Gap balancing in TKA: computer assisted balancing

Jacques Menetrey & Victoria B. Duthon

Centre de médecine de l’appareil locomoteur et du sport
Swiss Olympic medical Center
Unité d’Orthopédie et Traumatologie du Sport (UOTS)

Service de chirurgie orthopédique et traumatologie de l’appareil moteur

University Hospital of Geneva,
Geneva Switzerland
CAS as a quality control tool
Computer assisted surgery

- **Active system: robotics**
- **Passive system**
Principles

• Production of a digital image which serves as a map to guide the surgeon during the intervention

• Surgical instruments can be incorporated into the map and their position, attitude and progress can be controlled to an accuracy of a millimeter or degree
Principles

• Instrumented landing of an aircraft

• Driving a car using a ground-positioning satellite system (GPS)
Principles

- Image based systems:
  - Pre-operatively imaged: Ct-scan - MRI
  - Per-operatively imaged: fluoroscopy

- Image-free system:
  - Anatomical model embedded in the software
  - Direct registration of key anatomical landmarks
CAS (Computer assisted surgery)

- Real time navigation
- Three dimensions
- Precision
- Reliability
- Reproducibility
CAS (Computer assisted surgery)

- Quality control
- Teaching tool
- Research tool
- Expected improve function
- Expected reduce failure
- Expected facilitate rehabilitation
Objective

- The goal of total knee arthroplasty (TKA) is to achieve stable and well-aligned tibiofemoral and patello-femoral (PF) joints.

- To accomplish this successfully, accurate alignment of knee implants and balancing of soft tissues are essential.
Objective

Adequate ligament balancing avoids instability by preventing:

- **Gap inequality** or flexion/extension mismatch
- **Gap asymmetry** or collateral ligament imbalance
Hypothesis

- The management of soft tissue balancing remains difficult, and, without any objective guides, this portion of the procedure is often left to the surgeon's "feeling" and experience.

- Computer-assisted gap balancing may compensate this subjective part and be more accurate.
Questions:

- Is computer-assisted gap balancing technique more accurate than conventional measured resection technique?

- In computer-assisted gap balancing TKA, which technique is the best:
  - Ligament-balancing technique?
  - Measured resection technique?
Computer-assisted gap balancing

- Navigation systems now provide **femoral planning** based on initial flexion and extension gap measurements.

- Based on gap differences, distal femur cutting and posterior condylar cutting depth can be planned and **femoral component size and rotation adjustments** can be simulated to achieve flexion and extension gap balance.
Computer-assisted gap balancing

- Furthermore, final extension gaps can be adjusted during navigation-assisted TKA by modifying the distal femur cutting depth and flexion gap configuration.

- However, in cases with excessive ER of the femoral component, the specific portion of soft tissue responsible for the tight flexion gap must be released to avoid patellofemoral problem.
Navigation Dependent with simulation

One tibial cut

Balancing Cuts Simulation

2nd and 3rd Cuts

Femoral GAP

Tibial GAP

Flexion

Extension

Courtesy of Philippe Neyret
WORFLOW – Tibial Cut

Setup
Control
Tibia
Simulation/Balancing
Femur
Control

Level -5.0 mm
Level -9.0 mm

Varus 7.0°
POST Slope 15.0°

Courtesy of Philippe Neyret
Ligament Balance in Extension

Flexion 0.0°

Valgus Fémoral 5.0°

HKA 185.0°

PE (mm) 9

10.0 mm

20 mm

15 mm

Courtesy of Philippe Neyret
Ligament Balance in Flexion

Flexion 90.0°

Rot INT 2.0°

Entame -- mm

Taille

PE (mm)

Flexum (°)

19 mm

17 mm

10.0 mm

13.0 mm

9

3

3

 Courtesy of Philippe Neyret
Navigation may allow a better control of joint line

**Femoral Gap**

**Tibial Gap**

_Ligament Balance in Flexion_

- **Flexion**: 90.0°
- **Rot INT**: 2.0°
- **Entame**: -- mm
- **Taille**: 3 mm

Courtesy of Philippe Neyret
Computer-assisted gap balancing: proof-of-principle

- Amount of femoral bone cutting and external rotations of femoral components were found to depend on initial gaps.

- Patients with a final rectangular gap had greater knee flexion angles preoperatively and at 1 year after TKA.

- However, no differences were observed between the clinical and radiologic outcomes of knees with rectangular and nonrectangular gaps at 1 or 4 years after TKA.

→ The study shows that the navigation-assisted modified gap balancing technique provides an effective means of achieving rectangular flexion and extension gaps during TKA.

Seon J.K et al. J Arthop 2011
Computer-assisted balancing versus tensor

Tensor for TKA designed to facilitate soft tissue balance measurements with a reduced patello-femoral joint.

Joint gap and ligament balance measured in 30 osteoarthritic knees at 0° and 90° flexion, with the patella both everted and reduced.

Same measurements with a navigation system.

→ correlations between navigation system and the tensor.

Matsumoto T, et al. KSSTA 2007
Computer-assisted balancing versus tensor

Soft tissue measurements with the navigation system are well correlated with the direct measurements with the tensor, suggesting that the measurements with the navigation system are accurate and useful for assessment of soft tissue balancing.

Soft tissue balance measurements with the tensor and the navigation system are more accurate with a reduced PF joint than with an everted PF joint.


<p>| Table 1. Joint Component Gap and Ligament Balance With Patellar Eversion and Reduction |
|---------------------------------------------|---------------------------------------------|
| Flexion | Patellar eversion | PF joint reduction |                  | Patellar eversion | PF joint reduction |</p>
<table>
<thead>
<tr>
<th></th>
<th>TKA tensor</th>
<th>Navigation</th>
<th></th>
<th>TKA tensor</th>
<th>Navigation</th>
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</thead>
<tbody>
<tr>
<td>Joint component gap</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>0°</td>
<td>11.4 ± 0.6</td>
<td>11.5 ± 0.6</td>
<td>11.7 ± 0.6</td>
<td>11.8 ± 0.7</td>
<td></td>
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<tr>
<td>90°</td>
<td>20.2 ± 0.8*</td>
<td>18.1 ± 1.1*</td>
<td>17.1 ± 0.7*</td>
<td>15.8 ± 0.8*</td>
<td></td>
</tr>
<tr>
<td>Ligament balance</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>0°</td>
<td>3.2 ± 0.6</td>
<td>3.8 ± 0.6</td>
<td>3.1 ± 0.6</td>
<td>3.7 ± 0.6</td>
<td></td>
</tr>
<tr>
<td>90°</td>
<td>1.9 ± 1.1*</td>
<td>1.6 ± 1.2*</td>
<td>-1.1 ± 1.0*</td>
<td>-1.2 ± 1.1*</td>
<td></td>
</tr>
</tbody>
</table>

Values are shown as mean ± SE (mm). 
*Statistical difference between 0° and 90° (P < .01). 
†Statistical difference between patellar eversion and PF joint reduction (P < .01 vs patellar eversion).
Computer-assisted gap balancing versus conventional measured resection technique

- Unitt et al. measured flexion-extension gaps in 218 TKAs using the measured resection technique: balanced flexion and extension gaps during TKA were achieved using the measured resection technique in 175 knees (80.3%)

- Seon et al. obtained a final rectangular gap in 105 knees (94%) using the navigation-assisted gap balancing technique

omedical diagnosis

→ TKA using the navigation-assisted gap balancing technique produced better balanced flexion and extension gaps than TKA using the measured resection technique.

Seon et al. J Arthroplasty 2011
Between 2004 and 2006, 120 patients scheduled for unilateral TKA in a prospectively randomized clinical trial.
Computer-assisted gap balancing versus conventional measured resection technique

Navigation-assisted soft tissue balancing during TKA
- Reduced postoperative alignment outliers
- Reduced inadvertent medial soft tissue release
- Permitted the achievement of a more rectangular flexion and extension gap than offered by conventional TKA.

However, the clinical and radiological outcomes between two groups were similar.

Lee D.H. et al. *KSSTA* 2010
Lee H.J. et al. *KSSTA* 2011
Computer-assisted gap balancing versus conventional measured resection technique

140 patients randomized into two groups:

**Group 1:** Conventional measured resection technique without computer navigation

**Group 2:** Computer-assisted gap balancing
Computer-assisted gap balancing versus conventional measured resection technique

- **Group 1 (conventional measured resection technique):**
  - Significantly more patients (7%) with flexion contractures > 5°
  - Significantly more outliers (11%) with anterior tibial translation

- **Group 2 (computer-assisted gap balancing):**
  - Significantly better limb alignment with fewer outliers (> 3° varus/valgus)
  - Better outcome in the Total Oxford Score (0.030)

→ **Computer-assisted gap balancing technique was able to achieve more precise soft tissue balance and restoration of limb-alignment with better knee scores as compared to the conventional measured resection technique in TKA**

Pang H.N et al. *KSSTA* 2011
Conclusions

The navigation systems used for TKA provide

- Excellent restoration of the **mechanical axis** and precise component positioning
- More **objective and quantitative** measures of flexion and extension gaps: improves the accuracy of the balancing procedure
- No evidence of better clinical outcome

Clemens U. et al. *Orthopedics* 2005
Matsumoto T et al. *J Arthroplasty* 2009
Mark your calendar

16th ESSKA Congress
May 14-17, 2014

AMSTERDAM / THE NETHERLANDS
Thank you for listening