Comparison of the Reliability of Three Methods for the Assessment of the Lower Limb Length: EOS with New Micro–Dose Protocol vs. Long–Standing Radiograph vs. CT Scanogram

Burak Abay, Mehmet Fatih Erol, Metin Kucukkaya
Istanbul Bilim University
Dept. of Ortopedics and Traumatology,
Istanbul, TURKEY
25th Annual Scientific Meeting of Limb Lengthening and Reconstruction Society – Charleston, SC
22 July 2016
Disclosure

• No financial relationships interests to disclose.
Introduction

- New internal fixation devices
  (IM Lengthening nails, anatomic plates)
- Acute correction & precise preoperative planning
- Need for accurate radiological imaging methods
Problems in acute correction and internal fixation

1) Preoperative planning is made by long standing roentgenogram
   • Correction is performed
     • Under general anesthesia
     • In non-weight bearing supine position
     • With the Fluoroscopy images

2) Decision to end the distraction period of the lengthening nails
Methods used for measuring lower limb length

Clinical techniques

- Tape Measure
- Standing on blocks

Imaging Methods

- Long Standing roentgenogram
- Slit scanography
- Orthoroentgenogram
- Scanogram
- Computerized Tomography (CT) scanogram
- Ultrasound
- MRI Scanogram
- Biplanar digital roentgenogram
- EOS
Imaging methods for deformity and limb lengthening surgery

- Long standing roentgenogram
- Computerized Tomography (CT) scanogram
- EOS
- Slit scanography (supine position)
- Orthoroentgenogram
- Scanogram
- MRI Scanogram
Study method

1. **Inter-rater reliability:** agreement between the readers

2. **Intra-rater reliability:** agreement in the reader. *(test – retest or reproducibility)*

3. **Mean Absolute Differences (MAD):** between the three imaging modalities
• 14 lower limbs of 7 patients
  (7 men; mean age, 31 years; range, 25-46 years)
• Three methods of radiological imaging modalities
  • EOS (micro-dose protocol)
  • CT scanogram
  • Long standing roentgenogram
Assessment

• Lengths of bones (lower limb, femur, tibia)
  • Radiologic technician
  • Orthopedic surgeon
  • Senior resident

  *(2 separate occasions at a minimum of 4 weeks apart)*

• Statistics
  • Mean absolute difference (ANOVA)
  • Bland-Altman analyses

  *(Agreement between readers and modalities)*
EOS technique

- Biplanar radiography
- Scanner platform
- Whole lower limb
- Feet same coronal plane
- Micro-dose protocol
EOS with microdose protocol
Long Standing roentgenogram technique

- Single-exposure
- Standing full-length teleroentgenogram
- Patellas facing forward
- Beam to the knee joint
- Full extension
- 300 cm distance from tube
- 20 mm radioopaque sphere
Long Standing roentgenogram technique

- Single-exposure
- Standing full-length teleroentgenogram
- Patellas facing forward
- Beam to the knee joint
- Full extension
- 300 cm distance from tube
- 20 mm radioopaque sphere
Long Standing roentgenogram
CT scanogram technique

- feet entering the gantry first
- patellas oriented anteriorly
- a single posteroanterior scout image
- Non-weight bearing position
Length measurements and analysis

Long standing roentgenogram

CT Scanogram

EOS

Dror Paley, Principles of Deformity Correction
Results

- Mean absolute differences among three modalities

| Mean Absolute Differences between the measurements in Whole Lower Limb (in mm) |
|-----------------------------|-----------------------------|-----------------------------|
| Standing roentgenogram      | CT scanogram                | EOS                         |
| Mean (in mm)                | 863.7                       | 858.7                       | 857.4       |
| SD                          | 44.6                        | 41.2                        | 41.4        |
| Max. (in mm)                | 877.6                       | 871.6                       | 870.3       |
| Min. (in mm)                | 849.9                       | 845.9                       | 844.5       |

• The mean absolute differences for the standing roentgenogram and CT scanogram were all significantly different from that of EOS (p < 0.05).
• 6.3 mm / 863.7 mm (whole lower limb) = 0.7% difference between EOS and Long standing roentgenogram
Results Inter-rater reliability

Inter-rater reliability, quantified with Intra-class Correlation Coefficients, showed excellent (>0.90) agreement for standing roentgenogram, CT scanogram and EOS with microdose protocol.

- LSR=EOS=CT
Results Intra-rater reliability

Intra-rater reliability, quantified with Intraclass Correlation Coefficients, showed excellent (>0.90) agreement for standing roentgenogram, CT scanogram and EOS with microdose protocol.

- LSR=EOS=CT
# Methods for Assessing Leg Length Discrepancy

Sanjeev Sabharwal MD, Ajay Kumar MD

<table>
<thead>
<tr>
<th>Methods</th>
<th>Reliability</th>
<th>Accuracy</th>
<th>Magnification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supine tape measure—“Real”</td>
<td>+++</td>
<td>+</td>
<td>None</td>
</tr>
<tr>
<td>(ASAS to malleolus)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supine tape measure—“Apparent”</td>
<td>++</td>
<td>+</td>
<td>None</td>
</tr>
<tr>
<td>(umbilicus to malleolus)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standing blocks</td>
<td>++</td>
<td>+</td>
<td>None</td>
</tr>
<tr>
<td>Imaging</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teleoroentgenogram</td>
<td>+++</td>
<td>+++</td>
<td>~5%</td>
</tr>
<tr>
<td>Orthoroentgenogram</td>
<td>+++</td>
<td>+++</td>
<td>Minimal</td>
</tr>
<tr>
<td>Scanogram</td>
<td>+++</td>
<td>+++</td>
<td>Minimal</td>
</tr>
<tr>
<td>Computed radiography</td>
<td>+++</td>
<td>+++</td>
<td>Varies with technique</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(scanogram vs.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>teleoroentgenogram)</td>
</tr>
<tr>
<td>Microdose digital radiography</td>
<td>+++</td>
<td>+++</td>
<td>None</td>
</tr>
<tr>
<td>Ultrasound</td>
<td>+++</td>
<td>++</td>
<td>None</td>
</tr>
<tr>
<td>CT scan (digital localization</td>
<td>+++</td>
<td>+++</td>
<td>Minimal</td>
</tr>
<tr>
<td>image)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MRI</td>
<td>+++</td>
<td>+++</td>
<td>Minimal</td>
</tr>
</tbody>
</table>
Long Standing roentgenogram

- Magnification error depends on
  - Length of the lower limb
  - The distance to the tube
  - Divergence of the beam

Sabharwal et al, 2008
• Comparison of EOS with CT scanogram
• Interrater and intrarater reliability were excellent for both total length and intrabead distance on both EOS and CT scanogram
• \( r > 0.99 \) and \( P < 0.001 \)
Using Phantom limb (with sawbones)

EOS was the most accurate modality

The mean differences on both EOS settings were significantly different from those on CT scanograms, not clinically important.

No calibration method was used.
EOS with microdose protocol

Artifact in slow mode

16 y, F
Same patient
**EOS microdose protocol for the radiological follow-up of adolescent idiopathic scoliosis**

Brice Ilharreborde\(^1\) · Emmanuelle Ferrero\(^1\) · Marianne Alison\(^2\) · Keyvan Mazda\(^1\)

<table>
<thead>
<tr>
<th>Table 5: Radiation exposure (in mGy) of the most frequently used imaging techniques for spinal examination [16]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>----------------------------------------------------------</td>
</tr>
<tr>
<td>EOS microdose</td>
</tr>
<tr>
<td>EOS low-dose</td>
</tr>
<tr>
<td>Conventional radiograph</td>
</tr>
<tr>
<td>Full spine CT scan</td>
</tr>
<tr>
<td>Lumbar CT scan</td>
</tr>
<tr>
<td>Low-dose full spine CT scan</td>
</tr>
<tr>
<td>Low-dose lumbar CT scan</td>
</tr>
<tr>
<td>CT computed tomography</td>
</tr>
</tbody>
</table>
EOS = Biplanar radiography

23 y, F
Ideal method

1. Accurate
2. Excellent reliability and excellent reproducibility
3. Readily available in the physician’s office
4. Technically easy
5. Its cost and radiation dosage should be low
Conclusion

• The reliability of the LSR is similar to other two methods if appropriate calibration is done.
• *With the calibration* $1 \text{ mm} \approx 1 \text{ mm}$
• EOS might be helpful during the end of the distraction period
• Single–exposure LSR with the calibration might be good choice for the assessment and preoperative planning of the lower limb deformities.
Thank you