The Effect of Hindfoot Deformity on Mechanical Axis Alignment of the Lower Extremity

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My disclosure is in the Final AOFAS Program Book.

I have no potential conflicts with this presentation.
Introduction

- Mechanical axis deviation from anatomic axis is used in operative planning to improve alignment in treatment of ankle and knee deformity and associated osteoarthritis.
- Though no predictable relationship between ankle and knee malalignment has been found, a significant number of patients with knee malalignment will also have some degree of hindfoot deformity.
- Precise alignment is important for implant success following total knee arthroplasty (TKA), as even minor deviation can lead to increased loading, implant wear and early failure or subluxation.
Conventional mechanical axis deviation (MADC) is measured from the center of the femoral head to the center of the ankle, using femur length, tibia length and genu valgum angle.

A more accurate measurement of the actual weight bearing axis would account for hindfoot deformity distal to the subtalar joint.

Ground mechanical axis deviation (MADG) is measured from the center of the femoral head to the ground reaction point.

In order to account for hindfoot deformity, MADG uses MADC parameters in addition to foot height, foot-tibial angle, and the angle between the line joining the sole of the foot to the knee and femur (theta).
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Methods

• Free-body diagrams of single leg stance, double leg stance, toe off and heel strike were drawn in the coronal plane.
• Average adult male values of femur length (353.5mm), tibia length (286.5mm), and foot height (70.6mm) were used.
• Guichet et al.’s predicted trigonometry equation was coded in MATLAB (MathWorks, Inc., Natick, MA) and used to derive MADC and MADG for each stance over a range of foot-tibial and genu valgum angulations.
• Valgus deviation was considered positive while varus deviation was considered negative.

$$MADC = \frac{t \cdot f \cdot \sin(\gamma)}{\sqrt{t^2 + f^2 + 2 \cdot t \cdot f \cdot \cos(\gamma)}}$$

$$MADG = \frac{\sqrt{t^2 + h^2 + 2 \cdot t \cdot h \cdot \cos(\alpha) \cdot f \cdot \sin(\theta)}}{\sqrt{f^2 + f^2 + 2 \cdot t \cdot h \cdot \cos(\alpha) \cdot f \cdot \cos(\theta)}}$$

Where:
- $t =$ length of tibia
- $f =$ length of femur
- $\gamma =$ genu-valgum
- $\alpha =$ valgus angle of foot
- $h =$ height of foot

$$\theta = \text{angle between the line joining the sole of the foot to the knee and the femur:}$$

$$\theta = \gamma + \sin^{-1}\left(\frac{t \cdot h \cdot \sin(\alpha)}{(t^2 + h^2 + 2 \cdot t \cdot h \cdot \cos(\alpha))}\right)$$

-Guichet et al.
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Results

<table>
<thead>
<tr>
<th>Stance</th>
<th>Foot-Tibial Angle (degrees)</th>
<th>Genu Valgum (degrees)</th>
<th>MADC (degrees)</th>
<th>MADG (degrees)</th>
<th>MADG-MADC (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Leg Stance</td>
<td>Minimum</td>
<td>-20</td>
<td>-25</td>
<td>-68.48</td>
<td>-116.4</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>30</td>
<td>25</td>
<td>68.48</td>
<td>121.71</td>
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<tr>
<td>Double Leg Stance</td>
<td>Minimum</td>
<td>-18</td>
<td>-23</td>
<td>-63.08</td>
<td>-107.63</td>
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<tr>
<td></td>
<td>Maximum</td>
<td>28</td>
<td>23</td>
<td>63.08</td>
<td>113.14</td>
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<tr>
<td>Toe Off</td>
<td>Minimum</td>
<td>-15</td>
<td>-20</td>
<td>-54.95</td>
<td>-94.06</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>25</td>
<td>20</td>
<td>54.95</td>
<td>99.89</td>
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<tr>
<td>Heel Strike</td>
<td>Minimum</td>
<td>-16</td>
<td>-21</td>
<td>-57.67</td>
<td>-98.62</td>
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<tr>
<td></td>
<td>Maximum</td>
<td>26</td>
<td>21</td>
<td>57.67</td>
<td>104.35</td>
</tr>
</tbody>
</table>
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- Anatomical Axis
- MADC
- MADG

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AP | PA | AP + Calc1 | AP + Calc2 | AP + Calc3
Conclusions

• Using our computer model, we found that MADC underestimated true axis deviation, as predicted using MADG, by 46mm on average.
• Consideration of hindfoot alignment in determining the weight bearing axis of the limb provides for more accurate operative planning.
• Patients with concurrent hindfoot and knee deformity may benefit from hindfoot reconstruction prior to corrective knee surgery or arthroplasty to achieve optimal alignment.
• MADG used for operative planning in TKA may reduce the risk of postoperative malalignment and subsequently increase implant longevity.
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Limitations include:
- using only coronal plane to evaluate geometry
- using center of the heel to estimate the ground reaction force
- using femur, tibia and foot height estimates and assumed gait based on common measurements

Future studies using actual measurements and forces to compare MADC with MADG are warranted.
References