All tapers are not equal in design or function.

OPTIMIZING MODULAR TAPERS FOR TOTAL HIP ARTHROPLASTY

Timothy McTighe, Dr. H.S. (hc)
Executive Director,
Joint Implant Surgery & Research Foundation (JISRF)

Acknowledgement: Declan Brazil, PhD
John Keggi, MD, Louis Keppler, MD; Robert Kennon, MD, David Campbell, MD; Edward McPherson, MD
JISRF is a 501 c3 Non-Profit Foundation (1971) By Prof. Charles O. Bechtol, MD

JISRF is dependent on outside funding to support many of its activities.

Since 1971 JISRF has received funding from +30 commercial affiliations.

JISRF has stock investments in a number of commercial affiliations.

Executive Director: McTighe has vested interest in:
CDD, LLC; J&J; Signature Orthopaedics, Ltd; Omnilife; and has royalty interest in CDD, LLC

Note: JISRF Board Members and Advisors have multiple commercial relationships.

Intent

To make JISRF available as a resource to all within the orthopaedic community.

www.jisrf.org
ISSUES WITH SELF-LOCKING TAPERS

A self-locking taper (Morse) works by producing a frictional force that holds the components together and is greater than the forces pushing the components apart.

The frictional force resists torsional and axial forces created at the modular junction, while careful tolerancing provides optimal contact along the length of the taper. The success of a self-locking taper is influenced by the design of the taper, particularly the taper angle, the roughness, and the mating materials between the “male” and “female” components.

Types of self-locking tapers

- Head / Neck
- Head / Neck Sleeve
- Stem / Sleeve
- Neck/Stem
In the last two decades, manufacturers have been altering femoral stem trunnions from various tapers such as 14/16 to 12/14. The original 12/14 Ceramtec taper was at one time referred to as a Euro taper, meaning a 12/14 off-the-shelf Ceramtec Taper.

This term was not trademarked, and some companies began altering the manufacturing tolerance as originally produce from Ceramtec. The term Euro taper still is referred to by most in Europe as an off-the-shelf 12/14 Ceramtec taper.

A 12/14 taper can have slightly different manufacturing tolerances by different manufactures and should not be used as a generic term.

Demand for Head/Neck Adjustment

Tapers have been reduced in diameter and length compromising optimal stability of the taper interface.

Corrosion Growing Concern
Modular Heads came about during the 1960s

First C.C. head on a Titanium stem
11/13 taper (Preassembled in factory)

Mittelmeier Hip
Ceramic 14/16 taper

AML
Fixed Head
14/16
12/14
1970s
1980s
1990s

All 12/14 tapers are not equal!
(A Euro 12/14 taper is different than a ASTM 12/14 taper F1636)
Know what you are working with!
8% increase (torque) per 1 mm in true lateral ball-center offset.

6% increase (torque)
Per 1 mm increase in neck-length increase.

<table>
<thead>
<tr>
<th>Offset</th>
<th>Neck Length</th>
<th>Nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>35mm</td>
<td>49.50mm</td>
<td>84</td>
</tr>
<tr>
<td>40mm</td>
<td>56.58mm</td>
<td>96</td>
</tr>
<tr>
<td>45mm</td>
<td>63.65mm</td>
<td>108</td>
</tr>
<tr>
<td>50mm</td>
<td>70.72mm</td>
<td>120</td>
</tr>
<tr>
<td>55mm</td>
<td>77.79mm</td>
<td>132</td>
</tr>
</tbody>
</table>

TORSION IS OUR BIGGEST PROBLEM!
Large Head Diameter
High offsets
Metal on Metal
Reduced taper contact
Increases torsional loads

<table>
<thead>
<tr>
<th>11mm of 12/14</th>
<th>Contact length Offset (S)</th>
<th>Contact length Offset (M)</th>
<th>Contact length Offset (L)</th>
<th>Contact length Offset (XL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>28mm</td>
<td>10.5mm</td>
<td>10.5mm</td>
<td>10.3mm</td>
<td></td>
</tr>
<tr>
<td>32mm</td>
<td>10.5mm</td>
<td>10.5mm</td>
<td>10.5mm</td>
<td>8.8mm</td>
</tr>
<tr>
<td>36mm</td>
<td>10.5mm</td>
<td>10.5mm</td>
<td>10.5mm</td>
<td>9.2mm</td>
</tr>
<tr>
<td>40mm</td>
<td>10.5mm</td>
<td>10.5mm</td>
<td>10.5mm</td>
<td>9mm</td>
</tr>
</tbody>
</table>
### Range of Motion (Comparison Table)

<table>
<thead>
<tr>
<th>Stem Manufacturer</th>
<th>Head Diameter</th>
<th>Range of Motion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Versys</td>
<td>22mm</td>
<td>125deg</td>
</tr>
<tr>
<td></td>
<td>26mm</td>
<td>133deg</td>
</tr>
<tr>
<td></td>
<td>28mm</td>
<td>136deg</td>
</tr>
<tr>
<td>Aesculap</td>
<td>28mm</td>
<td>134deg</td>
</tr>
<tr>
<td></td>
<td>28mm</td>
<td>118deg</td>
</tr>
<tr>
<td>Definition</td>
<td>22mm</td>
<td>124deg</td>
</tr>
<tr>
<td></td>
<td>26mm</td>
<td>131deg</td>
</tr>
<tr>
<td>S-Rom 11/13 Taper</td>
<td>22mm</td>
<td>116deg</td>
</tr>
<tr>
<td></td>
<td>28mm</td>
<td>125deg</td>
</tr>
<tr>
<td>NEW S-Rom A 9/10 Tape</td>
<td>22mm</td>
<td>126deg</td>
</tr>
<tr>
<td></td>
<td>28mm</td>
<td>145deg</td>
</tr>
</tbody>
</table>

Marketing Pressure often overrides sound engineering principals.
S-ROM Slide from:

1984 Future Design Leader in Cementless THA

Less We Forget to Remember our History
250 lbs. patient with 50 mm femoral offset generates close to 80 ft-lbs of torque. Taper safety is 60 ft-lbs
Increased taper length from 11mm to 12.9mm (12/14 taper)
28% more surface contact area (36 mm Dia.)
22% Decrease in Torque Force
### Theoretical Downsides of Advanced Taper Design

<table>
<thead>
<tr>
<th>36mm Head Dia.</th>
<th>11mm 12/14 Taper</th>
<th>12.9mm 12/14 Taper</th>
<th>Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexion/Extension</td>
<td>199°</td>
<td>192°</td>
<td>7°</td>
</tr>
<tr>
<td>Abduction/Adduction</td>
<td>133°</td>
<td>130°</td>
<td>3°</td>
</tr>
<tr>
<td>Internal/External</td>
<td>210°</td>
<td>205°</td>
<td>5°</td>
</tr>
</tbody>
</table>
Market went from “Taper Mad” to “Taper Bad”

Fretting Corrosion

Retrieved Rejuvenate Stem (Stryker Orthopaedics) with Modular Neck Demonstrating Significant Fretting Corrosion. Revised for pseudo tumor

Courtesy of Dartmouth Biomedical Center

Overly Concerned with Fatigue Levels Ignored fretting issues (shot peened taper & reduced taper engagement)
PROBLEM
FATIGUE FAILURE OF FEMORAL NECKS OCCURS IN BOTH MODULAR AND MONOBLOCK DESIGNS

The maximum principal tensile stress in the neck retained stem was 35% less than that of the monoblock design.

Solution for fatigue failure of necks change material from titanium to Cobalt Chrome and change design to retain femoral neck.
Not all tapers are created equally.

- Shorter Bending Moment and Shorter Torsional Moment with Neck Retention results in less stress at modular implant interface.

<table>
<thead>
<tr>
<th>Taper Support</th>
<th>Taper Support</th>
<th>Femoral Offset</th>
<th>% Increase head center length</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSI™ / ARC™</td>
<td>17mm</td>
<td>27.5mm</td>
<td></td>
</tr>
<tr>
<td>Wright Medical</td>
<td>15mm</td>
<td>42mm</td>
<td>55%</td>
</tr>
<tr>
<td>Stryker</td>
<td>13mm</td>
<td>42mm</td>
<td>53%</td>
</tr>
</tbody>
</table>

Max. Principal Stress

ICJR Hawaii
July 7, 2014

Not all tapers are created equally.
ISO7206-6 SETUP
5340N - 10 MILLION CYCLES
MEASURED ABRASIVE WEAR

Fig. 1: Specimen tested-group 1.

Fig. 2: Specimen tested-group 2.

Beyond Compliance
The fretting wear for both types of systems is illustrated. Significant reduction in Tin coated.

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Mean initial weight [g]</th>
<th>Mean post-fatigue weight [g]</th>
<th>Weight loss [mg]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>37.6202</td>
<td>37.5408</td>
<td>79.4</td>
</tr>
<tr>
<td>1.2</td>
<td>37.5002</td>
<td>37.6172</td>
<td>-117.0</td>
</tr>
<tr>
<td>1.3</td>
<td>37.5419</td>
<td>37.4981</td>
<td>43.9</td>
</tr>
<tr>
<td>2.1</td>
<td>37.6659</td>
<td>37.6649</td>
<td>1.0</td>
</tr>
<tr>
<td>2.2</td>
<td>37.5203</td>
<td>37.5191</td>
<td>1.2</td>
</tr>
<tr>
<td>2.3</td>
<td>37.5404</td>
<td>37.5390</td>
<td>1.4</td>
</tr>
</tbody>
</table>

Specimen 1.

Specimen 2.
CONCLUSION: TIN COATING NECKS SIGNIFICANTLY REDUCES WEAR COMPARSED TO UNCOATED. THERE WAS NO SIGNIFICANT DIFFERENCE FOUND BETWEEN FULLY TIN COATED NECKS AND PARTIALLY COATED NECKS.

Significant advantage in reducing wear of C.C modular neck interfacing with titanium stem.
Increased taper engagement reduces stress thus reducing corrosion / debris generation.

Neck Retention design results in lower stress due to combined shorter offset with larger taper engagement. Tin coating of modular C.C. necks in a titanium stem reduces wear compared to uncoated necks.
CLINICAL EXPERIENCE

Positive bone remodeling increased calcar density
2,825 USA / ARC™ Stems implanted since April 2010
98.6% survival
2 reported pseudo tumors both w / MoM bearings (1 AU & 1 USA)

Short Curved Neck Preserving Stem
Modular Junctions

Not all taper junctions are designed or function equally
Know your design
Know required technique
Know design & material limits
Demand beyond compliance testing
Sound engineering principals work
Incremental advancement in technology works
Modularity can be designed and fabricated safely