**Carpal Anatomy**

2 carpal rows:

1. **Distal**
   - Trapezium, trapezoid, capitate, hamate bound together by strong interosseous (intrinsic) ligaments to form distal row, which moves together as a single unit

2. **Proximal**
   - Scaphoid, lunate, triquetrum and pisoform form the proximal row. It has no muscle attachments and is inherently unstable in compression without its ligamentous attachments. Acts as a link between the relatively rigid distal row and the radioulnar articulations.
FLEXION-EXTENSION

Normal wrist range is:
- 85 to 90 degrees of flexion, and
- 75 to 80 degrees of extension
Total arc of radial-ulnar deviation is approximately 50 degrees: 15 to 20 degrees radially and 35 to 37 degrees ulnarly (Youm et al, 1978; Volz et al, 1980).
ARTHRITIC HAND/WRIST
WRIST ARTHRODESI

Plate Fixation
Themistocles Cluck performed the first total wrist arthroplasty is 1890, using an ivory prosthesis in a wrist joint affected by tuberculosis.
General Indications

• Disabling pain
• Combined radiocarpal / midcarpal arthritis
• Relatively low demand patient
• Preferably elderly
• Patient recognizes lifetime limitations
Specific to Rheumatoid

- Arthrodesis of opposite wrist
- Autofusion, severe stiffness
- Deformity that impairs function
- Multiple joints involved by arthritis
- Progressive deformity
Specific to Osteoarthritis

- SLAC wrist with capitate involvement
- An alternative for SLAC wrist in elderly
- Other global wrist degenerative patterns
Specific to Post-Traumatic Arthritis

- Low demand patient
- SNAC wrist
- Diffuse arthritic changes
General Contra-indications

- High demand patient
- Regular dependence on walking aids
- Previous wrist sepsis
- Absent motor control of wrist
- Poor bone stock
- Previous surgical fusion?
BIAX

<table>
<thead>
<tr>
<th>Year of Design</th>
<th>Normal Wrist</th>
<th>Swanson</th>
<th>Volz</th>
<th>Meuli</th>
<th>Trispherical</th>
<th>Biaxial</th>
<th>MWPIII</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of components</td>
<td>10*</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>2</td>
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<tr>
<td>F/E (degrees)</td>
<td>73/71</td>
<td>30/30</td>
<td>90</td>
<td>50/80</td>
<td>85</td>
<td>N/A</td>
<td>50/80</td>
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<tr>
<td>R/U (degrees)</td>
<td>19/33</td>
<td>10</td>
<td>50</td>
<td>70/70</td>
<td>10</td>
<td>N/A</td>
<td>70/70</td>
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<tr>
<td>Axial (degrees)</td>
<td>0</td>
<td>5**</td>
<td>0</td>
<td>&gt;10</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>Radial Component</td>
<td>Radius</td>
<td>1 stem</td>
<td>1 stem</td>
<td>2 stems</td>
<td>1 stem</td>
<td>1 stem</td>
<td>2 stems</td>
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<tr>
<td>Radial Component</td>
<td>3rd</td>
<td>3rd</td>
<td>2nd, 3rd</td>
<td>3rd short</td>
<td>2nd</td>
<td>3rd short</td>
<td>2nd, 3rd</td>
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<tr>
<td>MC components</td>
<td>Carpus</td>
<td>-</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Either</td>
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</tbody>
</table>

* Eight carpal bones and radius and ulna

** Estimate only: the design of the Swanson implies that there can be some axial rotation or torsional twist
**Summary of clinical results for all prostheses** *(Costi J, et al. *J Rheumatology* 25:3, 1998)*

<table>
<thead>
<tr>
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<th>MWPIII</th>
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<tbody>
<tr>
<td>No. studies</td>
<td>17</td>
<td>8</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>1</td>
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<td>Average FU range</td>
<td>12-96</td>
<td>18-103.2</td>
<td>2-24</td>
<td>60-108</td>
<td>31-72</td>
<td>54</td>
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<td>No. prosthesis</td>
<td>15-181</td>
<td>18-100</td>
<td>1-140</td>
<td>9-44</td>
<td>13-64</td>
<td>50</td>
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<td>Range of average F/E (degrees)</td>
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<td>45-67</td>
<td>59-81</td>
<td>38-79</td>
<td>55-70</td>
<td>70</td>
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<tr>
<td>Range of average R/U (degrees)</td>
<td>19-32</td>
<td>22-38</td>
<td>25</td>
<td>20</td>
<td>21-30</td>
<td>10</td>
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<td>Fracture (%)</td>
<td>3.8-65</td>
<td>0-3</td>
<td>0.7-2.4</td>
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<td>0</td>
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<tr>
<td>Revision (%)</td>
<td>3.8-41</td>
<td>0-33</td>
<td>0-36.6</td>
<td>0-5.7</td>
<td>0-17.2</td>
<td>22</td>
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</table>
UNIVERSAL TOTAL WRIST (UTW)
EXPERIMENTAL TESTING
Experimental Test Fixture

Neutral and offset positions permitted
The radial fixture resides on a x-y stage
UTW Medium Implant: 30N compression

Resisting Moment (Nmm) vs Rotation (degrees)

-60 -40 -20 0 20 40 60

Rotation (degrees)

-200 -150 -100 -50 0 50 100 150 200

Resisting Moment (Nmm)

30N (1) 30N (2) 30N (3) 30N (4) 30N (5) 30N (6)
THEORETICAL

FE Model
FE MODEL

~ 1 element/mm²
~ 215 elements/mm²
FE Model Definitions

• CAD (Pro E) models were imported into PATRAN (version 8.5)
• Each metallic component was modeled as a rigid body $E_{CoCr} \gg E_{PE}$.
  – Carpal Component: 6,710 quadrilateral elements
  – Radial Component: 1,366 triangular elements
• The polymeric component was modeled via 20,130 8-noded brick elements ($E_{PE} = 634.92$ MPa, $\nu = 0.45$).
• 3D FE non-linear contact analysis was performed with ABAQUS v5.8.
Point Contacts Arise within 1 degree of rotation
50 N Compressive load maintained

Von Mises (MPa)
CONTACT AREA: \textit{FE Predictions}
Von Mises Contour plot through 10 degrees of flexion
**Fatigue Testing:**
15-150 lb, 15Hz, 5,000,000 Cycles
FATIGUE TESTING:
Testing Configuration
**SINGLE-SNAP**

0.25 mm/s & 5 mm/s
COMPONENT-SNAP
0.25 mm/s & 5 mm/s
BENDING
Sagittal & Coronal
ROTATION