Humeral Implant Stress Shielding Issues

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Disclosure

• Wright Medical—consulting, royalties

Stress shielding. Stress shielding is characterized by adaptation of the bone to the altered stress distribution following Wolff’s law, resulting in the bone’s becoming either thinner (external remodeling) or more porous (internal remodeling).
Proximal stress shielding is decreased with a short stem compared with a traditional-length stem in total shoulder arthroplasty.

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- Traditional length stems demonstrated 74% cortical thinning and 31% partial calcar resorption compared to 50% thinning and 23% resorption for shorter stem of same design.
- No functional difference between long and short stems.
- Not just length but Diaphyseal Design

• Stress shielding: Stress shielding is characterized by adaptation of the bone to the altered stress distribution following Wolff's law, resulting in the bone's becoming either thinner (external remodeling) or more porous (internal remodeling).
• Hip: AML whether clinically apparent depends on starting bone mass.
• Long diaphyseal: arthrex study but not in promos.
• Short stems too: Walch ascend Filling ratio useful to compare size effect.
• Filling ratio not the whole story.
• Collar might help.
• Longitudinal loading or bending/torsion?
• Technique could be important: smaller size, bone grafting?
Diaphyseal design
Diaphyseal design Promos design


Radiologic bone adaptations on a cementless short-stem shoulder prosthesis

- No Loosening
- High Bone adaptations 51.9%
- Cortical Thinning Osteopenia 82.7%
- Spot Weld Lateral Cortex 78.6%
- High Filling ratios in metaphysis and diaphysis associated with high bone adaptations
Collared rectangle versus oval stem

- 28%
- 71%

Excellent Results, 106 patients
- No loosening
- No lucencies
- No stress shielding


Multiple manufacturers
- 85% partial bone resorption
- 18% full thickness cortical resorption

Greater tuberosity, lateral diaphysis, medial calcar

Risk Factors:
- female, HHR with cuff reconstruction, large filling ration, on growth stem coating

Reverse shoulder arthroplasty with a cementless short metaphyseal humeral implant without a stem: clinical and radiologic outcomes in prospective 2- to 7-year follow-up study

- Excellent Results, 106 patients
- No loosening
- No lucencies
- No stress shielding

Humeral bone resorption after anatomic shoulder arthroplasty using an uncemented stem

Multiple manufacturers
- 85% partial bone resorption
- 18% full thickness cortical resorption

Greater tuberosity, lateral diaphysis, medial calcar

Risk Factors:
- female, HHR with cuff reconstruction, large filling ration, on growth stem coating
Study Population

• Evaluate the short to medium term radiographic outcomes of a press-fit short stem primary TSA
• 72 Shoulders
• 2 Surgeons
• F/U 24-50 Months
Aseptic Humeral Loosening 5.5%

- Overall Revision Rate: 7/137 (5.1%)
- Humeral Loosening: 6/137 (4.4%)
- Stem Revision for Loosening: 4/72 (5.6%)
- Aseptic Humeral Loosening: 4/72 (5.6%)

Reverse Total Shoulder Arthroplasty: A Review of Results According to Etiology

- Cemented Grammont Stems
  - 117 (.7%) Loosening

Stem Radiolucency Results

- Stem Radiolucency (based on 69 TSAs in final radiographic follow-up group)
  - Y=69 (91.3%)
  - N=6 (8.7%)
- Stems at Risk (based on 69 TSAs in final radiographic follow-up group)
  - Y=9 (13.6%)
  - N=59 (85.5%)
Radiolucency Zone Results

Calcar Osteolysis

- Based on 69 TSAs in final radiographic follow-up group
- Complete—3 (4.3%)
- Partial—16 (23.2%)
- None—50 (72.5%)

Diaphyseal v Metaphyseal

- Stress Shielding can be seen in both diaphyseal and metaphyseal designs
- Filling ratio can be a significant factor but design again is important
Effect of Short Stem Size on Humerus Stress-Shielding

Finite Element Model

Axial loading = 40% Body Weight (150 lbs)
Volume of Elements with Risk for Stress-Shielding

Medium Stem  Large Stem

Strain Energy Distribution

Medium Stem  Large Stem

Shoulder Elevation

Bending Moment = Weight of upper arm

Finite Element Model

Coronal Cross-Section
Volume of Elements with Risk for Stress-Shielding

Medium Stem  Large Stem

Cylindrical Short Stem No Collar

Finite Element Model

Medium Stem  10% Larger Stem

Shoulder Elevation

Finite Element Model

Bending Moment = Weight of upper arm
Net Compressive Strain

Medium Stem 10% Larger Stem

Volume of Elements with No Compressive Strain

Medium Stem 10% Larger Stem

50% increase in area of no compressive strain with 10% larger stem

What about loading in torsion?

Long-term results of uncemented humeral components in shoulder arthroplasty

- 37 Neer II Components
- 9.2 Years
- 14% Tilted
- 19% At risk for loosening
- No Revisions
- Prevalence of at risk components not associated with pain or decreased function.

Journal of Shoulder and Elbow Surgery, 2016
Total Shoulder Arthroplasty Utilizing Mini-Stem Humeral Component: Technique and Short-Term Results

- 49 Mini Stems
- No Loosening reported
- 11/49 < 1mm lucent lines
- Good to excellent clinical results

SHOULDER AND ELBOW

Short-stem uncemented primary reverse shoulder arthroplasty

- 44 patients
- No Loosening
- 29.5% proximal humeral remodeling
  - One patient subtotal tuberosity resorption
- Diaphyseal Fixation
- Metaphyseal Fixation

Proximally Coated Porous Stem

122 Shoulders

- Similar Reproducible Excellent Results
- Loosening: 2/122 (1.6%) [5.4%]
- Radiolucent Lines: 9/122 (7.4%) [91%]
- Stem at Risk: 2/122 (1.6%) [14.5%]
- Calcar Osteolysis: 35/122 (28.7) [27.5%]
- Severe Lateral Cortical thinning 13/122 (10.6%)
  - < 1mm remaining lateral cortex
Osteolysis is not always due to stress shielding.
How can we prevent stress shielding especially in osteoporotic patients with large canal?

- Know the potential for the implant design being used
- Minimize oversizing
  - Consider cement augmentation
  - Consider bone grafting to rebuild bone and use a smaller size implant?
Implants Today

- Smaller filling ratio
- Bone grafting technique can affect stem size

Improve the accuracy of evaluating bone density through the use of Phantoms for calibrating CT scans.
Summary

• Bone adaptations occur in all stems even if not visible on xray
• Filling ratio can be a significant factor but design is important
• Collar might have an effect
• Bending moments might be more important than longitudinal loading
• Technique might play a role in the potential for bone adaptations
• Bone mass available at the time of implantation is important