Biomechanics of RTSA – 101 – Lateral Humeral Design – Hybrid?

Thomas W. Wright MD
University of Florida
Department of Orthopaedics and Rehabilitation
Gainesville, Fl.

Conflict!!

- Design surgeon for Exactech
  - Royalties
  - Institutional research support

Introduction

- Biomechanics - relationship to current implant designs
- Pros and Cons of each design
- What does all this mean?

Reverse Understanding

- Limited to theory of Grammont as explained by Boileau in JSES

Grammont reverse prosthesis: Design, rationale, and biomechanics

Pascal Boileau, MD, Duncan J. Watkinson, FRCS, Armodios M. Hatzidakis, MD, and Frederic Balg, MD, FRCSC, *Nice, France*

- Limited head to head comparison of effect of design on mechanics of Reverse

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Do You Understand Lever/Moment Arm?

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Do You Understand Lever/Moment Arm?

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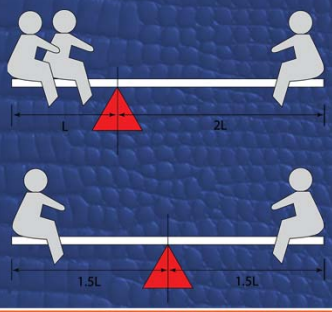
Moment Arm Basics

The key point is a longer lever arm means it requires less force to balance the weight. In this case, the weight of the arm



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Lever Arm

- The longer distance between the COR and location of applied force - force is magnified by that distance.
- P= force X distance

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Design Philosophy

- Four major designs available at this time
  - Medialized Glenoid Design / Medialized Humerus Design - Grammont
  - Lateralized Glenoid Design / Medialized Humerus Design – Encore
  - Medialized Glenoid Design / Lateralized Humerus Design – Exactech
  - Lateral Glenoid Design/ Lateralized humerus design – FH/Tornier bioRSA contemp humerus – Exactech lateral glenosphere
- Design diff bound-mechanical implications

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Four Classes of RTSA

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Types of Humeral Implants

Sit on Top lateral humerus (low neck angle), medial glenosphere

Sit inside medial humerus (low neck angle), lateral glenosphere

Sit inside medial humerus (high neck angle), medial glenosphere

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Types of Humeral Implants

Sit on Top lateral humerus (low neck angle), medial glenosphere

Sit inside medial humerus (low neck angle), lateral glenosphere

Sit inside medial humerus (high neck angle), medial glenosphere

Maximizes Deltoid Wrapping angle

Decreased Deltoid moment arm

Minimal Deltoid wrapping angle

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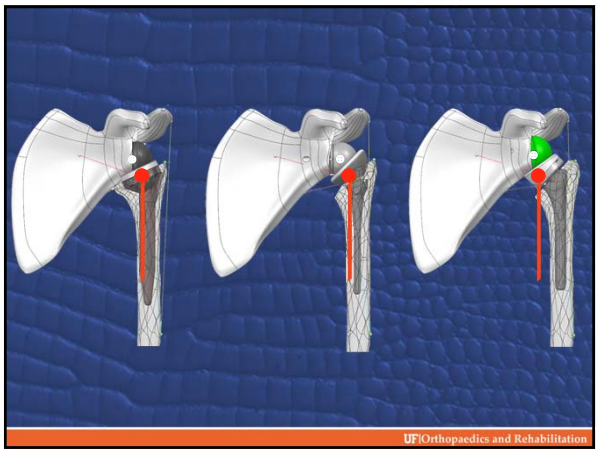

Design Changes are not Free

- Design change improving one parameter will cost elsewhere
- There is no perfect implant

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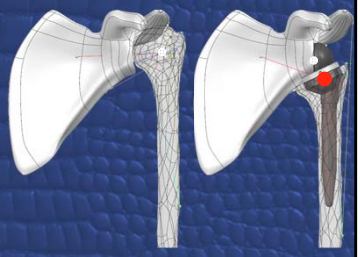
Grammont Design Philosophy

- MGD / MHD
- Medialized COR
- Increasing resting length of deltoid
- High neck angle
- Inset humerus



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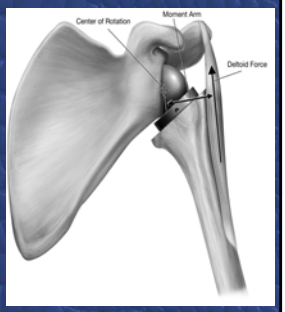
Grammont Design Philosophy

- Improved deltoid efficiency
- Higher risk of scapular notching
- Performs well high abduction angle
- Performs poor in adduction



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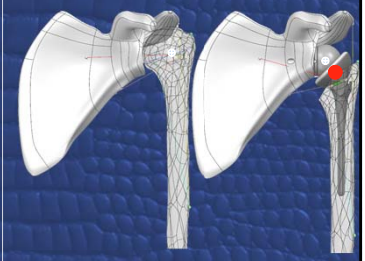
Lateral COR Design Philosophy

- LGD/ MHD
- Move COR away from glenoid face
- Lateralizes humerus
- Humeral component inset



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Lateral COR Design Philosophy

- Reduced scapular notching
- Potentially improved range of motion
- Decreased deltoid efficiency – shorter moment arm
- Potentially higher risk of baseplate loosening
- Less humeral distalization

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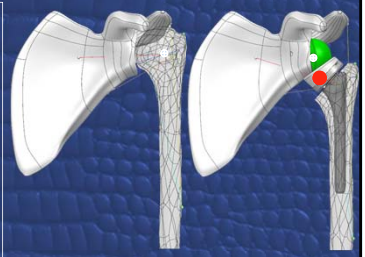
Lateral Humerus Design Philosophy

- MGD / LHD
- Keep COR on face of glenoid
- Lower neck angle than Grammont
- Humeral component sits above cut
- Lateralizes humerus



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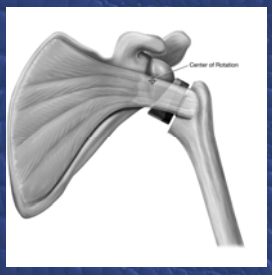
Lateral Humerus Design Philosophy

- Reduced risk of scapular notching
- Excellent deltoid efficiency
- Restore more anatomic Cuff tensioning (Roche)
- Minimize risk of baseplate loosening
- Distalizes Humerus



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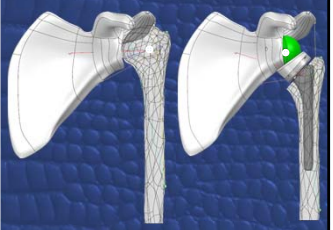
Lateral COR + Lateral Humerus

- Global lateralization LGD/LHD
- Humeral sit on top – low neck angle
- Lateralizes and distalizes humerus



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Lateral COR + Lateral Humerus

- Deltoid efficiency
- Cuff tensioning
- Low notching rate
- Good stability
- Maximally tensions deltoid

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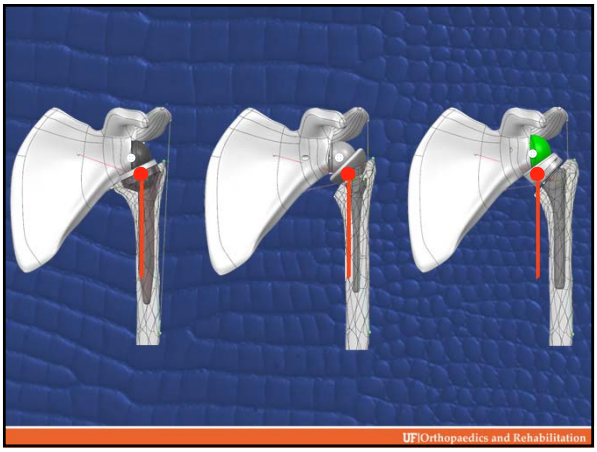

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Aim of Study

- Compare these three designs with focus on impact on muscular moment arms around the Reverse shoulder
- Understand efficiencies
- Explain potential problems

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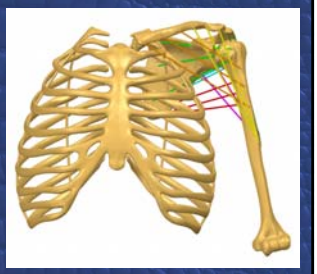
Methodology for Analyzing Moment Arms

- As described previously by Roche et al
- Key difference incorporation of scapular rhythm
- Muscles analyzed
- Deltoid (anterior, middle posterior)
- Pec Major
- Teres Major and Minor
- Subscapularis
- Infraspinatus



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Deltoid

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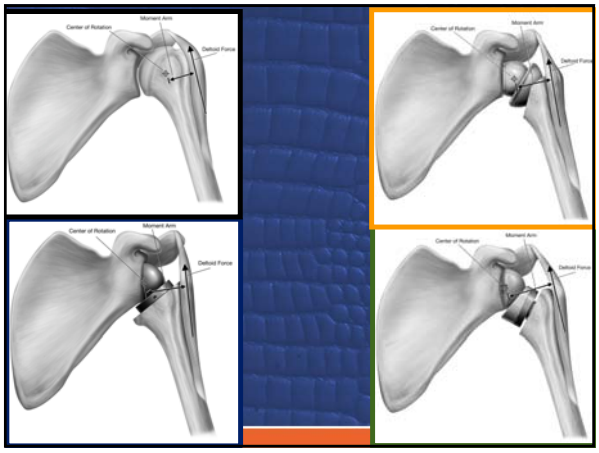
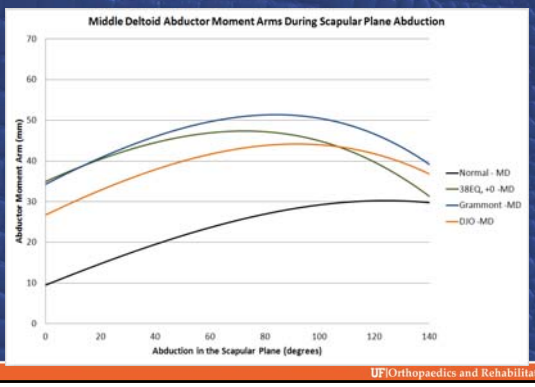
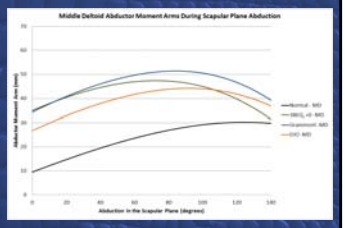


Comparison of Deltoid Moment Arms



Comparison of Deltoid Moment Arms

- Deltoid Efficiency at Low Abduction Angles
  - Exactech: 350%
  - Grammont: 350%
  - Encore: 270%
  - Normal: 100%



Clinical Relevance: Deltoid

- Larger Moment Arm = Less work for the Deltoid to initiate abduction
  - Deltoid Fights other Muscles to Abduct
  - Acromial Stress Fx?
  - Long Term Deltoid Fatigue?

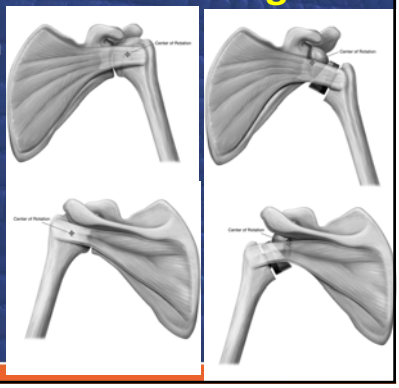
Rotator Cuff

Constants and Variables

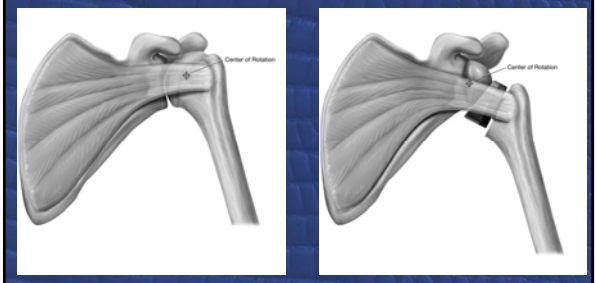
- Muscle Origin and Insertion - Constant
- New Center of Rotation - Variable
- How does NEW Center of Rotation impact function of Cuff post-RSA
  - How do different designs compare?
  - Evaluating adduction/abduction moment arms only this model

Cuff Functional Change

- Distalization of Humerus
- COR changes
- Adductor Effect Increased!



Rotator Cuff Muscles



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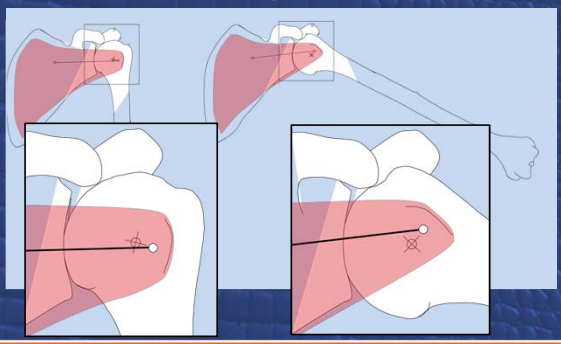
Biphasic Nature of the Subscapularis / Infraspinatus



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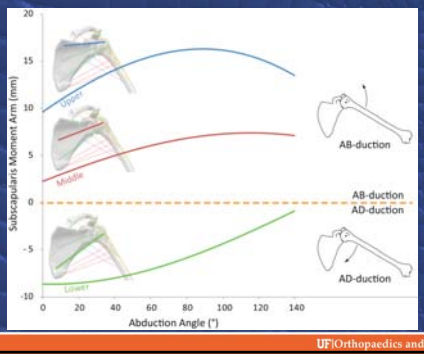
Subscapularis Breakdown



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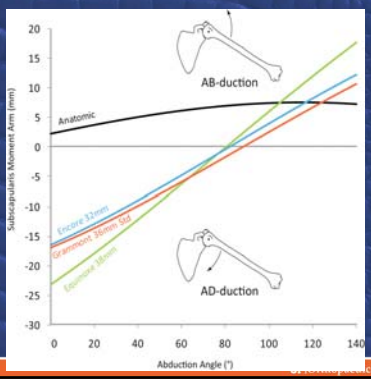
Crossover is Later

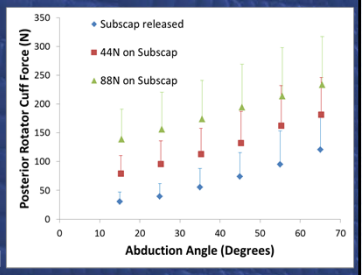


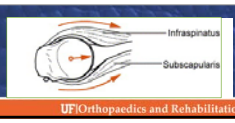
Clinical Relevance: Subscapularis

- Intact Subscapularis will force Deltoid to work harder to achieve abduction
  - At least first 80 degrees.
- Intact Subscapularis forces posterior cuff to work harder to avoid Horn Blower Sign
  - Concept supported by Hansen's Data
- Not repairing Subscapularis is associated with instability in some designs
  - Obligatory Subscap repair has a consequence

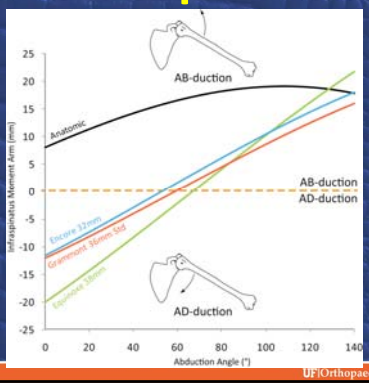
Hansen, et al ORS 2012

- Hansen et al published study on effect of subscapularis on loading of posterior cuff
- Up to 460% increase in Posterior cuff load
- Up to 130% deltoid load





Infraspinatus



Relevance - Infraspinatus

- Unique functional role (along w Teres Minor) as ER producing cuff muscle
- Critical to function of shoulder – eliminates Horn Blower Sign

Biomechanics of Implant Design

- Effect of lateralized design on muscle and joint reaction forces for reverse shoulder arthroplasty
  - William Liou, PhDa , Yang Yang, PhDa , Graysen R. Petersen-Fitts, MDb , Daniel J. Lombardo, MDb , Sasha Stine, BSb , Vani J. Sabesan, MDb, *
  - JSES
- Four implant designs all had decreased joint reactive forces compared to normal
- Deltoid efficiency is enhanced with lateral humeral designs relative to lateral glenosphere designs
- Shear forces greater in lateral glenoid designs

Medial Glenosphere/Medial Humerus

- Pro
  - Easy to fix subscap and tuberosities
  - Longest track record
  - Performs well in full abduction
- Con
  - High notching rate
  - Higher instability rate without subscap repair
  - Performs poor in full adduction

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Lateral Glenosphere/Medial Humerus

- Pros
  - Stable
  - Low notching rate
  - Fair posterior cuff tension
  - Less distalization of humerus
- Cons
  - Decreased deltoid moment arm – deltoid must work harder
  - Increased joint reactive force

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Medial Glenosphere/Lateral Humerus

- Pros
  - Excellent deltoid moment arm
  - Excellent posterior cuff moment arm
  - Very stable – deltoid wrap
  - Low notching
- Cons
  - Difficult to repair subscap/lesser tuberosity
  - Distalizes humerus – more tension on acromion

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Lateral Glenosphere/Lateral Humerus

- Pros
  - Low notching rate
  - Low instability rate
  - Excellent deltoid wrap
- Cons
  - Tough to repair tuberosities and subscap
  - Slightly decreased deltoid moment arm

Pick Ur Poison

- Efficient Deltoid
  - Medial Glenosphere Design advantage
  - Medial Glenosphere lateral humerus advantage
- Posterior Cuff efficiency – Good active ER
  - Lateral Humeral Design advantage
- Minimize notching
  - Lateral Glenosphere and/or Lateral Humeral
- Minimize resting tension Deltoid
  - Inset medial humeral design

Conclusions

- Post RTSA - muscles do not function anatomically and vary by design
- MGD/LHD improves Deltoid Moment Arm - easier Deltoid to elevate arm
- Repair of noncompliant Subscap may create iatrogenic Horn Blowers Sign
  - However if needed stability should get priority over function – MGD/MHD