Radiographic Study of Humeral Stem in Shoulder Arthroplasty After Lesser Tuberosity Osteotomy or Subscapularis Tenotomy

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Authors:
Robert Mason, MD Taylor Buckley, MD Richard Southgate, MD Gregg Nicandri, MD Richard Miller, MD Ilya Voloshin, MD

Author Affiliation | Disclosures

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Dr. Mason and Dr. Southgate are Orthopaedic Residents, and Dr. Nicandri and Dr. Miller are Associate Professors, Department of Orthopaedics and Rehabilitation, University of Rochester, Rochester, New York. Dr. Buckley is an Orthopedic Surgeon, Northern Rockies Orthopedics; and an Orthopedic Surgeon, Saint Patrick’s Hospital, Community Medical Center, Missoula, Montana. Dr. Voloshin is Professor of Orthopedics; Chief, Shoulder and Elbow Division; and Team Physician, Rochester Knighthawks NLL Lacrosse, Rochester Rattlers MLL Lacrosse Shoulder, Elbow, Knee Surgery-Sports Medicine, Department of Orthopaedics and Rehabilitation, University of Rochester, Rochester, New York.

Address correspondence to: Ilya Voloshin, MD, University of Rochester Medical Center, 601 Elmwood Avenue, Box 665, Rochester, NY 14625 (tel, 585-276-3106; fax, 585-276-2550; email, Ilya_Voloshin@urmc.rochester.edu).

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Take-Home Points

- LTO and ST remain viable options for takedown of the subscapularis.
- No difference exists in subsidence, lucent lines, and posterior subluxation on radiographic evaluation between LTO and ST.
- No clinically significant difference exists between outcome scores of patients with either technique.
- HAD was statistically significant but not clinically relevant between the 2 techniques.
- Results from the study do not apply to metaphyseal fitting stems, only diaphyseal fitting stems.

During the surgical approach for total shoulder arthroplasty (TSA), the subscapularis is taken down for adequate exposure to the glenohumeral joint. Various methods are available for taking down the subscapularis, including lesser tuberosity osteotomy (LTO) and a subscapularis tenotomy (ST). LTO offers the theoretical but unproven benefit of improved healing and function of the subscapularis secondary to bone-to-bone healing. One concern, however, is that humeral stem subsidence may be greater when an osteotomy is performed owing to compromise.
of metaphyseal cortical bone, which may compromise functional outcomes. The humeral stem design may also
influence subsidence when metaphyseal bone proximally is compromised. This is a concern in both metaphyseal
and diaphyseal fitting stems. Metaphyseal collars on diaphyseal fitting stems rely on adequate bone stock in the
metaphysis to provide the additional support needed. Also, posterior subluxation remains a challenge in shoulder
arthroplasty. The integrity of the subscapularis is important in prevention of posterior subluxation. To our
knowledge, no study to date has directly compared differences in humeral stem subsidence, loosening, or
posterior subluxation between LTO and ST techniques with any humeral stem design. Our hypothesis is that no
difference in proximal collar press-fit humeral stem subsidence or loosening exists, with no impairment of
functional outcomes using the LTO technique. We also hypothesize that no difference in posterior subluxation
exists between LTO and ST techniques.

Materials and Methods

Inclusion Criteria

Consecutive patients with a minimum of 12 months of radiographic follow-up were selected from 2007 to 2010
after TSA was performed by 1 of the senior authors (Dr. Miller and Dr. Voloshin). Study patients underwent
primary TSA for primary osteoarthritis or rheumatoid arthritis.

Exclusion Criteria

Patients were excluded if they underwent TSA for posttraumatic glenohumeral arthritis, hemiarthroplasty, or
osteonecrosis. Patients were also excluded if a rotator cuff tear was discovered intraoperatively or if they had a
history of a rotator cuff repair. Additional exclusion criteria included postoperative trauma to the operative
shoulder, postoperative infection, extensive documentation of chronic pain, and underlying neurologic disorder
(eg, Parkinson disease, dystonia). Patients with a history of diabetes mellitus were not excluded.

Surgical Technique

All patients underwent TSA via a deltopectoral approach in a modified beach chair position. Biceps tendons were
tenodesed at the level of the pectoralis major. All patients received the same proximal collar press-fit implant
(Bigliani-Flatow; Zimmer Biomet). These stems provide rotational stability in the metaphyseal segment via fins,
vertical stability with the proximal collar, and distal fixation via an interference fit. All parts of the procedure were
performed in similar fashion with the exception of ST vs LTO (Figures 1A-1D). All patients followed the same
postoperative rehabilitation protocol.

Lesser Tuberosity Osteotomy

LTO was performed as the primary or preferred technique of 1 surgeon. After completion of the biceps tenodesis,
the lesser tuberosity is reflected off with the subscapularis intact using an osteotome. After placement of the
press-fit humeral stem, the LTO is repaired using No. 5 Ethibond Excel sutures (Ethicon) passed through
previously created bone tunnels in the greater tuberosity. These sutures are tied over metal buttons over the
lateral cortex of the greater tuberosity. Last, the lateral corner of the rotator interval is repaired using a single
No. 2 FiberWire (Arthrex).
Subscapularis Tenotomy

ST is the preferred surgical technique of the second surgeon. After a biceps tenodesis, the subscapularis tendon is released from the lesser tuberosity at the margin of the bicipital groove. Through careful dissection, a single flap including the underlying capsule is created and reflected medially to the level of the coracoid. After placement of the press-fit humeral stem and humeral head, the subscapularis is repaired back in place through previous bone tunnels and with a No. 5 Ethibond Excel suture under the appropriate tension. Then, the lateral corner of the rotator interval is closed using a single No. 2 Ethibond Excel suture in a figure-of-eight fashion.2

Radiographic Analysis

The primary variables analyzed were subsidence and loosening. Additional variables, including humeral-acromial distance (HAD) and subluxation index, were also analyzed to assess for any additional impact caused by subsidence or loosening.3 All radiographic measurements were taken from the Grashey (true anteroposterior) view, except subluxation index, which was calculated using the axillary view. All radiographic measurements were completed by 3 independent reviewers. All radiographs were completed in a consistent manner according to postoperative protocols.

HAD was measured preoperatively, immediately postoperatively, and at final follow-up at a minimum of 1 year. The HAD was measured from the lowest point on the acromion to the humerus using a perpendicular line (Figure 2).

Subsidence of the prosthesis was calculated by determining the difference between immediate postoperative heights of the prosthesis in comparison to the value of the final follow-up films. To calculate the height, 2 lines were drawn, 1 line was drawn perpendicular to the top of the prosthetic head and 1 perpendicular to the top of the greater tuberosity (Figure 3). This distance was measured both immediately postoperatively and at final follow-up. The height difference between the 2 time points was used to calculate the subsidence.

Posterior subluxation is indicated by a value >65%, a centered head is between 35% and 65%, and anterior subluxation is indicated by a value <35% (Figure 4).3 The subluxation index was calculated using the method outlined by Gerber and colleagues3 using the axillary view radiograph (Figure 4). The midpoint of the glenoid was identified. Then, a perpendicular line (line z) was drawn projecting from the midpoint of the glenoid through the humeral head. Two lines were then drawn in an anterior-to-posterior direction on the humeral head. The first line (measurement A) was drawn from the posterior cortex to the previous perpendicular line (line z). The second line (measurement B) was drawn from the posterior to the anterior cortex. Measurements A and B should be calculated at the same height on the humeral head, roughly at the anatomic neck. The subluxation index is then calculated as A/B × 100. This was calculated both preoperatively and postoperatively.

The humeral stems were evaluated for loosening by assessing for lucency on final radiographic follow-up films. These were evaluated in a zonal fashion as demonstrated by Sanchez-Sotelo and colleagues and in Figure 5. The humeral stem-bone interface was evaluated in 8 radiographic zones. A lucency was not considered significant unless >2 mm. The zone of lucency was then determined for any significant lucencies. Zones 1 and 7 were at the level of the neck component, zones 2 and 6 were at the proximal half of the stem component, and zones 3 and 5 were at the distal half of the stem component. Zone 8 was noted directly inferior to the humeral head prosthesis.4
Functional Outcome Evaluation

Before clinical evaluation, each study patient completed the Western Ontario Osteoarthritis of the Shoulder (WOOS) index; the Disabilities of the Hand, Arm and Shoulder (DASH) questionnaire, and the pain and function sections of the Constant score. The functional outcomes scores were captured postoperatively from October to November 2011. The WOOS is a validated outcome measure specific to osteoarthritis of the shoulder and has been used in prior studies evaluating outcomes of TSA.\textsuperscript{5-7} Previous studies have determined that the minimal clinically important difference for the WOOS score is 15 on a normalized 0 to 100 scale (100 being the best). The DASH score is a validated outcome measure for disorders of the upper extremity but is not specific to osteoarthritis of the shoulder.\textsuperscript{8} The Constant score is a validated outcome measure for a number of shoulder disorders, including TSA.\textsuperscript{9,10}

Statistical Analysis

Statistical analyses were completed by a trained biostatistician. A power analysis was calculated using the noninferiority test to determine if adequate data had been obtained for this study. This was calculated by using previously accepted data demonstrating a statistically significant difference for subsidence and HAD. The data from these studies were used to make assumptions regarding accepted standard deviations and noninferiority margins, as calculated from the mean values of the 2 groups analyzed in each respective study.\textsuperscript{4,11} This analysis demonstrated power of 0.97 and 0.85 for the subsidence and HAD, respectively, given the current sample sizes. Intraclass coefficients were calculated to evaluate the measurements obtained during the radiographic analysis to determine the interrater agreement. Two samples’ $t$ tests were calculated for the variables analyzed, along with $P$ values and means.

Results

Demographics

A total of 51 consecutive patients were retrospectively selected for analysis. Of these, 16 patients were excluded from the study because they had <9 months of radiographic follow-up and were unavailable for further follow-up evaluation. Of the remaining 35 patients available for analysis, 4 patients had bilateral TSA, providing 39 shoulders for evaluation. Demographic characteristics of the study cohort are reported in Table 1. Fifteen patients underwent LTO, and 24 underwent ST. One patient underwent a tenotomy of the right shoulder and LTO of the left shoulder. Three LTOs were performed by the surgeon who primarily performed ST, owing to potential benefits of LTO. He eventually returned to his preferred technique of ST because of surgeon preference. Three ST procedures were completed by the surgeon who typically performed LTO at the start of the series prior to establishing LTO as his preferred technique. There was no significant difference between the study populations in terms of age, follow-up, male-to-female ratio, hand dominance, and primary diagnosis of osteoarthritis vs rheumatoid arthritis.

Radiographic Data

There was no significant difference in preoperative HAD between the LTO and ST groups ($9.5 \pm 2.4$ mm vs $10.9 \pm 2.7$ mm, $P = .11$). The immediate postoperative HAD was statistically significant between the LTO and ST groups ($11.9 \pm 3.7$ mm vs $15.9 \pm 4.5$ mm, $P = .005$). There was as statistically significant difference noted in the final
follow-up films between the LTO and ST groups (11.8 ± 3.2 mm vs 14.5 ± 3.9 mm, \(P = .025\)) (Table 2). There were no statistically significant differences found in subsidence between LTO and ST groups at final follow-up (2.8 mm ± 3.1 mm vs 2.5 mm ± 3.1 mm, \(P = .72\)) (Table 2). No statistically significant difference was noted in the subluxation index between the LTO and ST groups (0.55% ± 0.06% vs 0.54% ± 0.07%, \(P = .45\)), but there was a statistically significant difference noted postoperatively between the LTO and ST groups (0.55% ± 0.09% vs .48% ± 0.05%, \(P = .015\)) (Table 2).

Two stems were noted to have lucent lines >2 mm, both within the ST cohort. Each had 1 stem zone >2 mm, 1 in zone 7, and 1 in zone 4. No statistically significant difference was identified between the LTO and ST groups (0/15 vs 2/24, \(P = .51\)) (Table 2).

**Functional Outcomes**

Study patients were evaluated using functional outcome scores, including the Constant, WOOS, and DASH scores (Table 3). No statistically significant differences were noted in the DASH scores (8.4 ± 6.6 vs 13.8 ± 4.9, \(P = .13\)) or Constant scores (83.3 ± 9.1 vs 81.8 ± 10.1, \(P = .64\)) between the LTO and ST cohorts. There was a statistically significant difference between the WOOS scores (93.3 ± 5.3 vs 81.5 ± 20.8, \(P = .013\)). Because separate radiographic reviews were done by 3 independent personnel at 3 different times, it was important to ensure agreement among the reviewers. This was compared using the intraclass correlation coefficients. In the statistical analysis completed, the intraclass coefficients showed the 3 reviewers agreed with each other throughout the radiographic analysis (Table 4).

**Discussion**

At final follow-up, we identified no statistically significant difference between the LTO and ST patients in subsidence, lucent lines >2 mm, or functional outcomes (Constant and DASH scores) in patients who underwent TSA with the same proximal collar press-fit humeral stem. In regard to the functional outcome scores, although the WOOS score was statistically significant (\(P = .013\)) between the LTO and ST cohorts, we do not feel that this is clinically relevant because it does not reach the minimal clinically important difference threshold of 15 points.\(^8\)

A statistically significant difference was noted in postoperative subluxation index but was not clinically relevant, because the values between the LTO and ST groups (0.55 vs 0.48) still showed a centered humeral head. Gerber and colleagues\(^3\) discussed using a value of 0.65 as a measure of posterior humeral head subluxation, whereas Walch and colleagues\(^12\) defined posterior humeral head subluxation as a value >0.55. On the basis of these numbers, the values obtained in this study demonstrated that the postoperative values were still centered on the glenoid, and therefore were not clinically significant.\(^3,12\)

In regard to HAD, there was a statistically significant difference noted postoperatively (\(P = .005\)) and at final follow-up (\(P = .025\)) between the LTO and ST cohorts. Saupe and colleagues\(^13\) demonstrated that a HAD <7 mm was considered abnormal and reflected subacromial space narrowing. The values noted in the LTO and ST patients on postoperative and final follow-up radiographs were statistically significant (Table 2), but not clinically relevant because both were >7 mm. A potential source for the variation in HAD may be due to X-ray position and angle.

Studies have shown a concern regarding the integrity of the subscapularis after tenotomy or peel used in TSA with abnormal subscapularis function.\(^14,15\) Miller and colleagues\(^15\) reported 41 patients, nearly two-thirds, of whom described subscapularis dysfunction. Those authors’ response to the poor clinical outcomes was to remove a fleck
of bone with the tendon to achieve “bone-to-bone” healing.\textsuperscript{14} Gerber and colleagues\textsuperscript{16} reported on a series of patients using LTO and repair in TSA with 75\% and 89\% intact subscapularis function on clinical testing.\textsuperscript{16} Studies by Qureshi and colleagues\textsuperscript{17} and Scalise and colleagues\textsuperscript{18} showed similar results after LTO. Biomechanical studies have shown mixed results. Ponce and colleagues\textsuperscript{19} showed biomechanically superior results for LTO in comparison to the various repair techniques for ST. In another study, Giuseffi and colleagues\textsuperscript{20} showed no difference in LTO vs ST during biomechanical testing. In response to the increased concern regarding subscapularis integrity, Caplan and colleagues\textsuperscript{21} reported on 45 arthroplasties in 43 patients with improved postoperative testing with intact subscapularis testing in 90\% to 100\% of patients. A level 1 randomized control trial conducted by Lapner and colleagues\textsuperscript{22} did not demonstrate any clear clinical advantage of LTO vs ST. Controversy still exists regarding which is the preferred technique for TSA.

Sanchez-Sotelo and colleagues\textsuperscript{4} evaluated uncemented humeral components in 72 patients who underwent TSA. They found a humeral component was at risk for loosening if a radiolucent line ≥2 mm was present in at least 3 radiographic zones. They also evaluated tilt or subsidence by measurement and whether the components were observed to have changed. Their measured values correlated with their observed values. That study provided a benchmark for evaluation of loosening and subsidence used during this study.\textsuperscript{4} Although radiographic follow-up is limited in this study, we feel that any potential subsidence secondary to use of the LTO technique would be radiographically apparent at 1 year. There were 16 patients without adequate radiographic follow-up included in the study. However, we feel that this was not a large concern, because the study was adequately powered with the patients available to determine a difference based on subsidence.

**Conclusion**

We found no difference in subsidence, lucent lines >2 mm, posterior subluxation, and the Constant and DASH functional outcome scores when we compared TSA performed by a LTO with an ST technique with proximal collar press-fit humeral stem. These data cannot be extrapolated to metaphyseal fit stems, which may exhibit different settling characteristics in the setting of the LTO technique.

*This paper will be judged for the Resident Writer’s Award.*

**Key Info**

**Figures/Tables**

Figures / Tables:

* voloshin0518_f1.jpg
Figure 1. Lesser tuberosity osteotomy (LTO) vs subscapularis tenotomy (ST). (A) Anteroposterior and (B) lateral depictions of the technique used for LTO repair. (C) Anteroposterior and (D) lateral depictions of the ST repair, with the emphasis on sutures passing around the stem as the stem is inserted.

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Figure 2. Humeral-acromial distance.
Figure 3. Subsidence.
Figure 4. Subluxation index.

voloshin0518_f5.jpg
### Table 1. Demographic Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Tenotomy (n = 24)</th>
<th>Osteotomy (n = 15)</th>
<th>P-value</th>
</tr>
</thead>
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<tr>
<td><strong>Age</strong></td>
<td>68.2 [7.4]</td>
<td>70.2 [7.1]</td>
<td>0.46</td>
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<tr>
<td><strong>Follow-up</strong></td>
<td>20.6 [11.5]</td>
<td>18.5 [6.25]</td>
<td>0.94</td>
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<tr>
<td><strong>Females</strong></td>
<td>7 (29%)</td>
<td>6 (40%)</td>
<td>0.58</td>
</tr>
<tr>
<td><strong>Dominant shoulder</strong></td>
<td>14 (58%)</td>
<td>8 (53%)</td>
<td>0.81</td>
</tr>
<tr>
<td><strong>Primary Diagnosis</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Osteoarthritis</td>
<td>22 (92%)</td>
<td>15 (100%)</td>
<td></td>
</tr>
<tr>
<td>Rheumatoid arthritis</td>
<td>2 (8%)</td>
<td>0 (0%)</td>
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### Table 2. Radiographic Data

#### Humeral Acromial Distance

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<th>LTO</th>
<th>ST</th>
<th>P-Value</th>
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<tbody>
<tr>
<td>Preoperative, mm</td>
<td>9.5 [2.4]</td>
<td>10.9 [2.7]</td>
<td>0.11</td>
</tr>
<tr>
<td>Postoperative, mm</td>
<td>11.9 [3.7]</td>
<td>15.9 [4.5]</td>
<td><strong>0.005</strong></td>
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<td>Final follow-up, mm</td>
<td>11.8 [3.2]</td>
<td>14.5 [3.9]</td>
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#### Subsidence

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<th></th>
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<th>ST</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subsidence, mm</td>
<td>2.8 [3.1]</td>
<td>2.5 [3.1]</td>
<td>0.72</td>
</tr>
</tbody>
</table>

#### Subluxation Index

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**Figure 5.** Lucent lines.
<table>
<thead>
<tr>
<th></th>
<th>Preoperative, %</th>
<th>Postoperative, %</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTO</td>
<td>0.55 [0.06]</td>
<td>0.54 [0.07]</td>
<td>0.45</td>
</tr>
<tr>
<td>ST</td>
<td>0.54 [0.07]</td>
<td>0.48 [0.05]</td>
<td>0.015</td>
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**Lucent Lines**

<table>
<thead>
<tr>
<th></th>
<th>LTO</th>
<th>ST</th>
<th>P-Value</th>
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<tbody>
<tr>
<td>Lines &gt;2 mm, %</td>
<td>0.00</td>
<td>0.08</td>
<td>0.51</td>
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Abbreviations: LTO, lesser tuberosity osteotomy; ST, subscapularis tenotomy.

### Table 3. Functional Data

<table>
<thead>
<tr>
<th></th>
<th>LTO</th>
<th>ST</th>
<th>P-Value</th>
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<tbody>
<tr>
<td>WOOS index</td>
<td>93.3 [5.3]</td>
<td>81.5 [20.8]</td>
<td>0.013</td>
</tr>
<tr>
<td>DASH score</td>
<td>8.4 [6.6]</td>
<td>13.8 [4.9]</td>
<td>0.13</td>
</tr>
<tr>
<td>Constant score</td>
<td>83.3 [9.1]</td>
<td>81.8 [10.1]</td>
<td>0.64</td>
</tr>
</tbody>
</table>

Abbreviations: DASH, disabilities of the arm, shoulder and hand; WOOS, Western Ontario Osteoarthritis of the Shoulder.

### Table 4. Testing Agreement: ICC

<table>
<thead>
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<th>ICC</th>
<th>CI, 2.5%</th>
<th>CI, 97.5%</th>
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<tr>
<td><strong>HAD</strong></td>
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<td></td>
<td></td>
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<tr>
<td>Preoperative</td>
<td>0.4451</td>
<td>0.2202</td>
<td>0.6443</td>
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<tr>
<td>Postoperative</td>
<td>0.6997</td>
<td>0.4836</td>
<td>0.834</td>
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<tr>
<td>Final follow-up</td>
<td>0.5575</td>
<td>0.3592</td>
<td>0.7218</td>
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<tr>
<td><strong>Subsidence</strong></td>
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<td></td>
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<tr>
<td>Preoperative</td>
<td>0.6863</td>
<td>0.5349</td>
<td>0.807</td>
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<tr>
<td>Final follow-up</td>
<td>0.5364</td>
<td>0.299</td>
<td>0.7186</td>
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</table>

Abbreviations: CI, confidence interval; HAD, humeral acromial distance; ICC, intraclass correlation coefficient; SI, subluxation index.

### References


**Multimedia**

**Product Guide**

- BioComposite SwiveLock Anchor
- BioComposite SwiveLock C, with White/Black TigerTape™ Loop
- BioComposite SwiveLock Anchor, With Blue FiberTape Loop
- Knotless SutureTak® Anchor

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Citation

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Robert Mason, MD