Complications and radiographic correction in adult scoliosis following combined transpsoas extreme lateral interbody fusion and posterior pedicle screw instrumentation

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Object. The authors recently used a combined approach of minimally invasive transpsoas extreme lateral interbody fusion (XLIF) and open posterior segmental pedicle screw instrumentation with transfominal lumbar interbody fusion (TLIF) for the correction of coronal deformity. The complications and radiographic outcomes were compared with a posterior-only approach for scoliosis correction.

Methods. The authors retrospectively reviewed all deformity cases that were surgically corrected at the University of Pittsburgh Medical Center Presbyterian Hospital between June 2007 and August 2009. Eight patients underwent combined transpsoas and posterior approaches for adult degenerative thoracolumbar scoliosis. The comparison group consisted of 4 adult patients who underwent a posterior-only scoliosis correction. Data on intra- and postoperative complications were collected. The pre- and postoperative posterior-anterior and lateral scoliosis series radiographic films were reviewed, and comparisons were made for coronal deformity, apical vertebral translation (AVT), and lumbar lordosis. Clinical outcomes were evaluated by comparing pre- and postoperative visual analog scale scores.

Results. The median preoperative coronal Cobb angle in the combined approach was 38.5° (range 18°–80°). Following surgery, the median Cobb angle was 10° (p < 0.0001). The mean preoperative AVT was 3.6 cm, improving to 1.8 cm postoperatively (p = 0.031). The mean preoperative lumbar lordosis in this group was 47.3°, and the mean postoperative lordosis was 40.4°. Compared with posterior-only deformity corrections, the mean values for curve correction were higher for the combined approach than for the posterior-only approach. Conversely, the mean AVT correction was higher in the posterior-only group. One patient who underwent the transpsoas XLIF approach suffered an intraoperative bowel injury necessitating laparotomy and segmental bowel resection; this patient later underwent an uneventful posterior-only correction of her scoliotic deformity. Two patients (25%) in the XLIF group sustained motor radiculopathies, and 6 of 8 patients (75%) experienced postoperative thigh paresthesias or dysesthesias. Motor radiculopathy resolved in 1 patient, but persisted 3 months postsurgery in the other. Sensory symptoms persisted in 5 of 6 patients at the most recent follow-up evaluation. The mean clinical follow-up time was 10.5 months for the XLIF group and 11.5 months for the posterior-only group. The mean visual analog scale score decreased from 8.8 to 3.5 in the XLIF group, and it decreased from 9.5 to 4 in the posterior-only group.

Conclusions. Radiographic outcomes such as the Cobb angle and AVT were significantly improved in patients who underwent a combined transpsoas and posterior approach. Lumbar lordosis was maintained in all patients undergoing the combined approach. The combination of XLIF and TLIF/posterior segmental instrumentation techniques may lead to less blood loss and to radiographic outcomes that are comparable to traditional posterior-only approaches. However, the surgical technique carries significant risks that require further evaluation and proper informed consent. (DOI: 10.3171/2010.1.Focus09263)

KEY WORDS • adult scoliosis • extreme lateral interbody fusion • spinal deformity • Cobb angle

T he benefits of anterior approaches for arthrodesis in deformity correction surgery are well known and include load sharing and increased fusion rates when compared with posterior-only fusion constructs. The application of anterior interbody fusion—initially developed for the treatment of spinal tuberculosis—to the treatment of spondylolisthesis was first reported by Burns in 1933.3 Lane and Moore13 first described its use in the treatment of intervertebral disc degeneration in 1948, and interbody arthrodesis has seen increasingly widespread use ever since.

Cloward4 introduced the technique of posterior interbody fusion in 1953, in his classic paper arguing for the
superiority of an approach that offered the spine surgeon the ability to accomplish decompression of the neural elements and circumferential arthrodesis, all from a single, posterior approach, and without the inherent risk to the abdominal viscera and retroperitoneal structures incurred by a transperitoneal approach.

In 2001, Pimenta introduced a novel approach to the anterior lumbar spine, using a lateral, transpsoas approach that was later popularized by Ozgur et al. in 2006 as “extreme lateral interbody fusion.” The extreme lateral approach offers several advantages over traditional interbody approaches. It obviates the need for mobilization of the great vessels—thereby avoiding the associated risk of sexual dysfunction—and does not require the assistance of a general surgeon. Similarly, it avoids transgression of the nerve roots and thecal sac and, therefore, places these structures at a lower theoretical risk. The extreme lateral approach has also been reported to decrease operating time when compared with other approaches to the anterior lumbar spine, including even mini-open and laparoscopic techniques. The lateral approach also offers the advantage of decreased blood loss, both through the avoidance of the epidural venous plexus, and through shorter operating times. For these reasons, transpsoas XLIF is a promising alternative to traditional interbody techniques in the treatment of adult degenerative scoliosis, because those affected by this condition are often more advanced in age and suffer from multiple medical comorbidities that make them less ideal candidates for traditional, “open” multi-level interbody fusions.

The application of transpsoas XLIF to adult lumbar degenerative scoliosis was first reported by Pimenta in 2001, and thus is still in its infancy, with a dearth of published results on the effectiveness of the technique for this indication. Over the past 18 months at our institution, we have applied the extreme lateral approach to the treatment of adult degenerative scoliosis, herein we report our initial radiographic results and perioperative complications, and compare them to those achieved using traditional interbody techniques for the same indication during the same time period.

### Methods

#### Study Design

We retrospectively reviewed all deformity corrections performed at the University of Pittsburgh Medical Center Presbyterian Hospital between June 2007 and August 2009. The purpose of the study was to evaluate radiographic deformity correction parameters and perioperative complications following posterior instrumented fusion supplemented with transpsoas interbody fusion, and to compare these results to those achieved following posterior-only correction in which TLIF or PLIF techniques were used. Eight patients underwent deformity correction via a combined A/P approach. Anterior interbody fusion was performed via an extreme lateral transpsoas approach, and 4 patients underwent deformity correction via a posterior-only approach. Laterally placed interbody spacers contained either Actifuse synthetic bone graft material (ApaTech, Inc.) or demineralized bone matrix (Table 1). All posterior instrumentation was placed via an open posterior approach. Posterior arthrodesis was performed at all instrumented levels by using a combination of decortication, local autograft, autologous iliac crest, and bone morphogenetic protein (Tables 1 and 2). In all patients, both pre- and postoperative standing PA and lateral long-cassette scoliosis series plain radiographs were available for review in our computerized radiographic archives. Medical records and patient interviews conducted at follow-up evaluations were used to document intra- and postoperative complications and to establish the VAS score in each treatment group.

#### Table 1: Patients undergoing combined XLIF and posterior instrumentation*

<table>
<thead>
<tr>
<th>Case No.</th>
<th>XLIF Levels</th>
<th>Posterior Interbody Levels</th>
<th>Instrumented Levels</th>
<th>XLIF Allograft</th>
<th>TLIF Graft</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>L2–4</td>
<td>L5–S1</td>
<td>T10–ilium</td>
<td>AF</td>
<td>IC, BMP</td>
</tr>
<tr>
<td>2</td>
<td>L1–4</td>
<td>L5–S1</td>
<td>T10–ilium</td>
<td>AF</td>
<td>IC, BMP</td>
</tr>
<tr>
<td>3</td>
<td>L2–5</td>
<td>L5–S1</td>
<td>T9–ilium</td>
<td>AF</td>
<td>IC</td>
</tr>
<tr>
<td>4</td>
<td>L1–4</td>
<td>L4–S1</td>
<td>T8–ilium</td>
<td>AF</td>
<td>BMP</td>
</tr>
<tr>
<td>5</td>
<td>L1–4</td>
<td>L5–S1</td>
<td>T11–ilium</td>
<td>AF</td>
<td>IC</td>
</tr>
<tr>
<td>6</td>
<td>L1–5</td>
<td>L5–S1</td>
<td>T10–ilium</td>
<td>DBM</td>
<td>IC, BMP</td>
</tr>
<tr>
<td>7</td>
<td>L1–3</td>
<td>L5–S1</td>
<td>T6–ilium</td>
<td>DBM</td>
<td>IC, BMP</td>
</tr>
<tr>
<td>8</td>
<td>L2–5</td>
<td>L5–S1</td>
<td>L1–S1</td>
<td>DBM</td>
<td>local bone only</td>
</tr>
</tbody>
</table>

* AF = Actifuse bone graft; BMP = bone morphogenetic protein; DBM = demineralized bone matrix; IC = autologous iliac crest.

#### Table 2: Patients undergoing posterior-only correction

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Posterior Interbody Levels</th>
<th>Instrumented Levels</th>
<th>Interbody Allograft</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>L2–5</td>
<td>L1–5</td>
<td>AF</td>
</tr>
<tr>
<td>2</td>
<td>L5–S1</td>
<td>T9–ilium</td>
<td>BMP</td>
</tr>
<tr>
<td>3</td>
<td>none</td>
<td>L1–S1</td>
<td>BMP</td>
</tr>
<tr>
<td>4</td>
<td>L3–4</td>
<td>T7–ilium</td>
<td>IC, BMP</td>
</tr>
</tbody>
</table>
Complications and outcomes for XLIF approach in scoliosis surgery

Radiographic Evaluation

All patients had pre- and postoperative standing PA and lateral scoliosis series radiographs available on our hospital's radiographic archival system. The software on this archival system provides measurement tools for the determination of distances and angles on the radiographs. Coronal Cobb angles, as well as the AVT, were measured. Preoperative and postoperative radiographs were compared to determine the degree of correction achieved following surgery.

The Cobb angle is used frequently to assess the severity of coronal and sagittal deformity. For coronal deformity, it is determined from the standing PA radiograph by drawing a line parallel to the superior endplate of the most superior VB, and a second line parallel to the inferior endplate of the most inferior VB of the scoliotic curve (Fig. 1). A second set of lines is drawn perpendicular to these first lines, and the angle subtended by these perpendiculars is the Cobb angle.

The AVT is the distance from the CSVL to the midpoint of the apical VB of the curve. The CSVL is a line that extends superiorly from the midpoint of the sacral promontory on a standing PA radiograph (Fig. 2).

Lumbar lordosis was measured using the Cobb method, with the superior endplate of L-1 and the inferior endplate of L-5. Hyperlordosis was defined as any Cobb angle > 60°, and hypolordosis as any angle < 20°. Return to normal lordosis after surgery was evaluated.

Statistical Analysis

Statistical analysis of correction of radiographically evaluated parameters was performed using SPSS software to evaluate statistical significance between pre- and postoperative radiographic measurements. Analysis was also performed to determine if there was any significant difference between the combined transpsoas and posterior and the posterior-only approach groups.

Results

Combined Lateral Transpsoas and Posterior Group

Eight patients underwent combined lateral transpsoas and posterior approaches for deformity correction. The average age of patients in this group was 60 years (range 48–69 years). Twenty-three interbody spacers were placed from a lateral approach (mean 2.8 spacers per patient), and in all patients an L5–S1 interbody spacer was placed from a posterior approach. The L5–S1 interbody space is not accessible from a lateral approach due to the iliac crest.
Posterior lateral arthrodesis was performed in all patients. This was accomplished with the combination of transpedicular instrumentation, along with local autograft and allograft placement. Two patients had the posterior procedure on the same day as the lateral procedure, whereas the other 6 had the second stage within 1 week of the lateral procedure.

In all patients, pre- and postoperative standing PA and lateral scoliosis series radiographs were available for assessment of deformity. Preoperative and postoperative coronal Cobb angles were compared (Table 3). The median preoperative Cobb angle was 38.5° (range 18–80°). Following surgery, the median Cobb angle was 10°. The mean percent of curve correction was 70.2%. According to paired t-test analysis, curve correction was statistically significant between pre- and postoperative Cobb angles (p < 0.0001).

The AVT is measured as the distance from the CSVL to the center of the apical VB in the curve. The mean preoperative AVT was 3.6 cm, and it was 1.8 cm postoperatively (p = 0.031).

The mean preoperative lumbar lordosis in this group was 47.3 ± 28.7° (mean ± SD, range 2–84°). Three patients had a hyperlordotic lumbar spine, defined as a Cobb angle > 60°, and 1 patient had a loss of lumbar lordosis, defined as a Cobb angle < 20°. The mean postoperative lordosis was 40.4 ± 2.8° (range 38–46°). Postoperatively, all patients either maintained lumbar lordosis or attained restoration of their previous hyper- or hypolordotic curvatures.

Posterior-Only Group

Four patients during the study time period underwent a posterior-only approach that combined TLIF and PLIF techniques with transpedicular instrumentation and posterolateral fusion. The average age in this group was 61 years (range 48–81 years). A total of 5 interbody grafts were placed via TLIF or PLIF approaches.

The mean preoperative coronal Cobb angle was 19° (range 17–25°), and postoperatively the mean coronal Cobb angle was 11° (Table 3). The mean percent curve correction was 44.7%, a statistically significantly different from preoperative values (p = 0.05). The mean preoperative AVT for the posterior-only group was 2.2 cm, and it changed to 1.1 cm postoperatively. This change was not significant (p = 0.114). The mean preoperative lumbar lordosis in this group was 30 ± 10.5° (range 19–44°). No patient had preoperative hyperlordosis, and 1 patient had a loss of lumbar lordosis. The mean postoperative lordosis was 37.7 ± 3.5° (range 35–43°). All patients had a normal lumbar lordosis postoperatively.

Comparison of Approaches

The percentage of curve correction and the AVT correction were used to compare efficacy of the 2 approaches. The mean values for curve correction were higher for the combined approach than for the posterior-only approach. Conversely, the mean AVT correction was higher in the posterior-only group. An independent-samples t-test revealed no significant difference between percentage of curve correction for either of the Cobb angles, or in AVT correction (Table 4).

Postoperative Complications

Of the 8 patients who underwent combined lateral transpsoas and posterior approaches for deformity correction, 2 (25%) sustained motor radiculopathies, and 6 (75%) experienced postoperative thigh paresthesias or dysesthesias. Motor radiculopathy resolved in 1 patient after 2 months, whereas the other patient had a persistent radiculopathy 3 months postoperatively. All but 1 of the sensory radiculopathies persisted at the most recent follow-up evaluation. One patient had resolution of the postoperative numbness approximately 2 months posturgery. One additional patient was originally scheduled for a combined lateral transpsoas and posterior instrumentation approach; however, during the transpsoas approach,

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Coronal Cobb Angle</th>
<th>AVT</th>
<th>Lumbar Lordosis</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Preop (°)</td>
<td>Postop (°)</td>
<td>Preop (cm)</td>
</tr>
<tr>
<td>combined approach</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>26</td>
<td>7</td>
<td>2.8</td>
</tr>
<tr>
<td>2</td>
<td>41</td>
<td>4</td>
<td>1.9</td>
</tr>
<tr>
<td>3</td>
<td>39</td>
<td>24</td>
<td>3.7</td>
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<tr>
<td>4</td>
<td>38</td>
<td>16</td>
<td>2.5</td>
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<tr>
<td>5</td>
<td>18</td>
<td>2</td>
<td>1.2</td>
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<tr>
<td>6</td>
<td>48</td>
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<td>5.7</td>
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<td>80</td>
<td>46</td>
<td>10.0</td>
</tr>
<tr>
<td>8</td>
<td>21</td>
<td>0</td>
<td>1.0</td>
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<tr>
<td>posterior-only approach</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>1</td>
<td>17</td>
<td>14</td>
<td>2.0</td>
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<td>0</td>
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<tr>
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<td>25</td>
<td>18</td>
<td>4.2</td>
</tr>
<tr>
<td>4</td>
<td>21</td>
<td>8</td>
<td>2.5</td>
</tr>
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</table>
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TABLE 4: Comparison of approaches

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Combined</th>
<th>Posterior-Only</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>no. of patients</td>
<td>8</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>% change, Cobb angle</td>
<td>70.2</td>
<td>44.7</td>
<td>0.08</td>
</tr>
<tr>
<td>% change, AVT</td>
<td>54.6</td>
<td>60.4</td>
<td>0.763</td>
</tr>
<tr>
<td>mean follow-up (mos)</td>
<td>10.5</td>
<td>11.5</td>
<td></td>
</tr>
</tbody>
</table>

A cecal perforation occurred, necessitating an emergency exploratory laparotomy and segmental bowel resection. This patient underwent a posterior-only approach for correc-
tion of her scoliotic deformity 6 months later, without incident. (This patient’s radiographic outcomes were excluded from the analysis.) There were no instances of hardware failure or pseudarthrosis at the most recent follow-up in the combined group.

Additional postoperative complications in the combined-approach group included incidental durotomy during posterior decompression, pleural effusions necessitating chest tube placement, pulmonary embolism, and postoperative ileus (Table 5). Also, one patient had a wound infection that progressed to meningitis and sepsis. This patient required wound debridement and application of a vacuum dressing, and he eventually underwent primary closure of his wound.

Complications in the posterior-only group included 1 patient who required a total colectomy for toxic megacolon secondary to *Clostridium difficile* colitis. This patient had undergone an uneventful scoliosis surgery without complication. One patient in this group also had an incidental durotomy that was closed primarily. At a mean of 11.5 months of follow-up, there have been no infections or evidence of hardware failure in this group. This patient in the posterior-only group developed a junctional kyphosis requiring superior extension of her instrumentation as well as pelvic instrumentation.

**Clinical Outcomes**

In the combined XLIF and posterior group, follow-up VAS scores were available in 6 patients, with a mean follow-up period of 10.5 months (range 3–16 months). The mean preoperative VAS score was 8.8, and the mean postoperative VAS score for the combined group was 3.5.

The mean follow-up duration for the 4 posterior-only patients was 11.5 months (range 10–12 months). The mean preoperative VAS score was 9.5, and the mean postoperative VAS score was 4 for the posterior-only group.

There was not a significant difference between preoperative ($p = 0.379$) or postoperative VAS scores ($p = 0.835$) between the two operative groups.

**Discussion**

Adult scoliosis may be defined as a coronal deformity with a Cobb angle $\geq 10^\circ$ in a skeletally mature patient. It arises from degeneration of adolescent scoliosis, or may occur de novo in a previously straight spine. Several authors have correlated radiographic parameters with clinical symptoms in adults. Restoration of sagittal and global spinal balance leads to improvements in quality of life measures. Loss of normal lumbar lordosis has also been associated with increases in pain and decreases in quality of life measures.

The use of interbody grafts in deformity correction surgery has gained popularity as a means of providing anterior column structural stability, increased fusion rates, and restoration and preservation of lumbar lordosis. Graft placement has traditionally been achieved through either an anterior (anterior lumbar interbody fusion) or posterior (PLIF or TLIF) approach. The introduction of the transpsoas interbody technique has offered the surgeon treating deformity a new approach to interbody placement, whose theoretical advantages of decreased blood loss, shorter operating time, and lower risk to the neural elements make it attractive for deformity correction in adults.

Restoration of balance and a return to near-normal anatomical alignment are associated with improved outcome and are the principal goals of most deformity correction surgeries. Traditional approaches to deformity correction include A/P approaches and posterior-only approaches, both of which have been shown to be effective. However, the anterior approach is associated with complications such as vascular injury, ileus, and retrograde ejaculation. Posterior approaches (PLIF and TLIF) place the nerve roots and thecal sac at greater risk because these structures must necessarily be exposed, and then protected, during graft insertion.

The transpsoas approach provides an alternative to these traditional interbody approaches. Although it is not entirely without risk—the most serious approach-related complication being injury to the bowel or other abdominal viscera—the technique uses a corridor that is designed to protect the vital structures both anterior and posterior to the VB.

Nevertheless, as our initial experience reported here demonstrates, these theoretical advantages of extreme lateral approaches have not translated without incident into practical application in our scoliosis practice. We had an 11% bowel perforation rate, and moreover, during a second procedure, at-risk bowel was clearly identified.
causing us to abort a level in that procedure. Subsequent review of these cases has revealed to us that the rotatory component of scoliotic spines significantly increases the risk of injury to intra- and retroperitoneal structures. (Of note, we have performed transpsoas XLIFs in more than 60 patients for indications other than scoliosis, and have not had a bowel perforation in that series.)

The choice of approach may also influence the biomechanical soundness of the final construct. In general, anteriorly placed grafts have been viewed as more biomechanically stable. This is due mostly to the destabilizing effect of the posterior facetectomy required for appropriate posterior graft placement, as well as to disruption of the tension band provided by the posterior longitudinal ligament. However, anterior graft placement involves disruption of the anterior longitudinal ligament, also a stabilizing structure. Placement of grafts via a lateral approach allows for preservation of the anterior longitudinal ligament, and has been shown in cadaver studies to be biomechanically equivalent to grafts placed via an anterior approach.

Pateder and colleagues, in a large series of patients, showed comparable outcomes in curve correction for those undergoing A/P or posterior-only correction. They achieved 54% correction in the posterior-only group and 46% correction in the A/P group. The mean correction rate in our combined posterior and transpsoas approach was higher (70%); however, we had a smaller number of patients, and thus, no definitive conclusions can be drawn, other than that adequate correction appears to be achievable with this approach. In comparison with our posterior-only group, there was no significant difference in correction, and thus, the 2 techniques appear to be at least equivalent in terms of radiographic outcome.

Apical vertebral translation is a measure of coronal balance, defined as the distance from the CSVL to the midpoint of the apical vertebra. The transpsoas group in this study showed a significant change in the AVT, suggesting a return to coronal balance (p = 0.031). Restoration of coronal balance has been shown to improve pain-related outcomes and may have an additional cosmetic benefit.

Degenerative changes in the lumbar spine may lead to changes in lumbar lordosis and contribute to global spinal imbalance in complex deformity. In their most extreme forms, these changes may result in hyperlordosis or, alternatively, in flat-back syndrome. Schwab and colleagues showed that patients with near-normal lordosis had lower VAS pain scores than patients with severe aberrations from the norm.

**Conclusions**

The purpose of the current study was to evaluate the efficacy of transpsoas interbody fusion, in combination with posterior release, transpedicular instrumentation, and posterior fusion, in achieving deformity correction in adults. It is readily apparent that the complication risk for extreme lateral approaches for scoliosis is higher than this approach for other spinal disorders. Although long-term radiographic outcomes, combined with validated clinical measures of pain and quality of life, are the gold standard by which this new technique will be judged, these data are not yet available because the transpsoas approach is still in its infancy. We hope, as our experience grows, to provide these data in the near future, and to correlate radiographic outcomes with validated clinical outcome measures and to further delineate the risk spectrum of the transpsoas extreme lateral approach in scoliosis surgery.

**Disclosure**

No authors received financial support for any of the work reported herein.

Author contributions to the study and manuscript preparation include the following. Conception and design: AS Kanter, MB Maserati. Acquisition of data: AS Kanter, MJ Tormenti, MB Maserati, CM Bonfield. Analysis and interpretation of data: MJ Tormenti, MB Maserati, CM Bonfield, DO Okonkwo. Drafting the article: MJ Tormenti, MB Maserati. Critically revising the article: AS Kanter, MJ Tormenti, MB Maserati, CM Bonfield, DO Okonkwo. Reviewed final version of the manuscript and approved it for submission: AS Kanter, MJ Tormenti, MB Maserati, CM Bonfield, DO Okonkwo. Statistical analysis: MJ Tormenti.

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