Is inclusion of the occiput necessary in fusion for C1–2 instability in rheumatoid arthritis?

Clinical article

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Object. The atlantoaxial joint is the location most and earliest affected in patients with rheumatoid arthritis (RA). In longstanding disease, ligamentous and osseous destruction can progress and involve all cervical segments. If surgical intervention is necessary, some prefer, to be safe, undertaking fusion to the occiput, whereas others advocate 1-level fusion of C1–2. Sparing the occiput (Oc–C1) segment would allow retention of a considerable amount of physiological range of motion and seems beneficial against subaxial overload. Previous clinical studies on this topic have provided only nonspecific data after short-term follow-up, rendering a segment-sparing approach questionable.

The purpose of the present investigation was to assess long-term progression of inflammatory or degenerative destruction in the Oc–C1 segment after isolated C1–2 fusion for RA.

Methods. In a series of 113 consecutive patients with RA-related destruction restricted to the cranio cervical junction, 14 individuals underwent Oc–C2 fusion and 99 underwent surgery exclusively at the C1–2 level. After a mean follow-up period of 9.4 years (range 4.9–14.7 years), 46 patients were available for clinical and radiographic examination, including CT imaging.

Results. None of the 46 patients needed additional surgery to extend the fusion to the occiput. Despite marked deterioration in the subaxial cervical spine, in general there were little or no changes in the atlantooccipital region. All but one patient presented with bony fusion of the fixed C1–2 level at follow-up.

Conclusions. The results of this investigation suggest that if the Oc–C1 joint is free of osseous destructions on conventional radiographs and free of abnormalities on MRI scans at the time of surgery (for transarticular fixation and fusion of C1–2), there is a very low risk for relevant destruction in the following 5–14 years. Thus, no prophylactic oligosegmental approach, but rather a segment-sparing monosegmental approach, is preferred, even in patients with high inflammatory levels. (http://thejns.org/doi/abs/10.3171/2012.10.SPINE12710)

KEY WORDS • atlantoaxial instability • C1–2 fixation • atlantoaxial fusion • adjacent-segment degeneration • atlantooccipital joint • craniocervical fusion • rheumatoid arthritis • surgical technique

ATLANTOOCIPITAL and atlantoaxial instability caused by destructive inflammation of synovial joint compartments represent the most characteristic manifestations of cervical spine involvement in RA. Atlantoaxial instability in this population (prevalence range 10%–25%), occurring at a mean of 3.9 years after diagnosis of RA, raises mortality rate up to eightfold due to compression of the spinal cord or brainstem, with an estimated 1-year mortality rate of 50% in patients with myelopathy. Age, late presentation, and rheumatoid factor seropositivity are poor prognostic factors. Surgical treatment has proved to increase survival time (from 4.2 years to 59.8 years in conservatively treated patients) while there is common acceptance for early surgical intervention, the extent of initial stabilization is still debated.

Some authors prefer fusions to the occiput, whereas others opt for monosegmental C1–2 fusion to spare atlantooccipital motion whenever this can be attempted. The main purpose of the present retrospective follow-up study was to quantify adjacent-level instability and degeneration mainly at Oc–C1 in the long term after a restrictive approach to atlantoaxial fixation in patients with C1–2 instability due to RA. The second purpose was to evaluate the outcome of the fixed level.

Methods

This study was based on a retrospective review. A follow-up evaluation including CT and conventional radiography in an outpatient setting was done with each patient’s written consent. Operatively treated patients with atlantoaxial instability of various etiologies were systematically charted in our department dating back to January 1994. This study

Abbreviations used in this paper: Oc = occiput; RA = rheumatoid arthritis.
focuses on 113 consecutive cases of short-length fusions in patients with an established diagnosis of RA surgically treated between 1994 and 2003. Of these patients, 14 underwent Oc–C2 fusion and 99 underwent fusion that did not include the occiput. In 2010, 43 patients responded and agreed to be reexamined in an outpatient visit. Three severely handicapped patients were available for telephone inquiry and up-to-date imaging evaluation. Fifty-three individuals were lost to follow-up for the following reasons: 37 could not be contacted, 10 had died, 6 were not able to travel to our hospital and did not have recent images.

A careful clinical examination and interview, we performed plain radiography (anteroposterior, lateral neutral, flexion and extension) of the cervical spine with the patients sitting down. Preoperatively and at follow-up, these studies were supplemented with 2-mm slice axial CT scans with coronal and sagittal reconstructions. Patients underwent MRI in every case and MR angiography of the cervical vessels in 27 cases preoperatively.

The problem of evaluating static images to quantify dynamic instability was addressed by analyzing the images representing the highest degree of subluxation on lateral flexion radiographs in each case. Conventional radiographs were digitized and calibrated using the follow-up digital images as reference.

The goal of follow-up radiography and CT scanning was to identify direct signs of fusion (individually for the lateral masses and posterior arch–graft interfaces) and indirect signs of nonunion (loosening of screws), screw malpositioning/breakage, and adjacent-level instability/degeneration. Because we could not find a classification system for evaluating adjacent-level degeneration in RA-affected cervical spines, we modified the classifications of Thabe and Gore and separately grouped the atlantooccipital joint and the subaxial region (Table 1). Evaluation of the radiographs by one neuroradiologist and one spine surgeon independently, both blinded to clinical data, was done to define the degree of degeneration according to the criteria listed in Table 1. Evaluation of adjacent-segment degeneration in this study was based on morphology. Scores for clinical outcome assessment were not used, because, at the time of initial treatment, no tool for evaluating this phenomenon in an RA population was available.

**Perioperative Management and Surgical Technique**

Antirheumatic medication was modified in the following way: 1) no reduction of the methotrexate dose and 2) limitation of steroid dose to a minimum. Biologicals were not on the market then. The operative approach throughout the series was stage oriented with maximum emphasis on reduction. Isolated C1–2 fixation was restricted to cases of reducible atlantoaxial (sub)luxations with moderate deviation from physiological atlantoaxial kyphotic angle, the absence of relevant cranial settling, and the absence of severe atlantooccipital joint destruction.

With these preconditions, our standard concept of surgical treatment for atlantoaxial instability was transarticular fixation of C1–2 modified after the Magerl technique. A graft from the iliac crest was fixed to the laminae according to Gallie, using a thread. Surgical setup, patient positioning, and surgical technique followed the descriptions of ElSaghir et al., using 2.7-mm-diameter screws. Applying the aforementioned criteria of patient selection for 1-level fusion did not lead to deviation from the technique of unilateral C1–2 transarticular fixation due to segmental morphology in this group of RA patients. The reason for including the occiput mainly was lateral mass collapse of C-2 on one or both sides leading to segmental deformity and cranial settling. Throughout the procedure somatosensory evoked potentials were monitored. Postoperative immobilization was achieved using a Philadelphia collar.

**Statistical Analysis**

Statistical analysis was performed using SPSS version 17.0 computer software (IBM). The results are reported as the means ± SD. Paired-sample t-tests were used to define measured differences at the different imaging evaluations.

<table>
<thead>
<tr>
<th>Spinal Segment</th>
<th>Instability</th>
<th>Destruction/Deformation</th>
</tr>
</thead>
<tbody>
<tr>
<td>atlantooccipital</td>
<td>progressive cranial settling</td>
<td>+ joint space narrowing &amp;/or cysts, no joint line deformation, no joint incongruity</td>
</tr>
<tr>
<td>subaxial†</td>
<td>ant-pst or lat listhesis, segmental kyphosis/lordosis</td>
<td>+ 25% disc space narrowing, barely visible endplate sclerosis, barely visible osteophyte formation</td>
</tr>
</tbody>
</table>

* Modified from the works of Thabe and Gore. Abbreviations: ant = anterior; mod = moderate; pst = posterior.
† Subaxial indicates C-2 and below.
**Results**

*Sample Characteristics*

For the 5 male and 41 female patients (mean age 53.3 years [range 26–79 years]) who agreed to participate in the current study, the mean follow-up duration was 9.4 years (range 4.9–14.7 years). All patients fulfilled the 1987 revised criteria for the classification of RA. Symptoms indicating cervical myelopathy were present in 7 patients at the time of surgery.

Radiographic, MRI, and CT measurement data presented in Table 2 mirror the morphological characteristics of the study group. The mean preoperative osseous posterior atlantoaxial distance was 13.5 mm (range 8.2–19.8 mm) whereas that at follow-up increased to a mean 15.8 mm (11.2–21.9 mm), with no significant difference between postoperative and follow-up values. Measurement of the anterior osseous atlantoaxial distance revealed a reverse relationship (that is, the mean anterior atlantodental distance decreased from preoperative to follow-up).

Preoperatively in 2 patients, occipitoatlantoaxial disintegration forced the odontoid to exceed the level of the foramen magnum, with protrusion of 0.9 and 2.4 mm, respectively. Measurement of the basion-dens interval to quantify vertical atlantoaxial instability (with negative values characterizing dental protrusion into the occipital foramen) showed a mean of 2.3 mm (range −2.4 to 6.4 mm). An average gain of +0.3 mm indicated only irrelevant progression at the time of the follow-up analysis. Rotational atlantoaxial subluxation averaged 4.7° (range 0°–20°) before surgery and this value decreased to a mean of 3.3° (range 0°–13.3°) at follow-up.

The mean atlantoaxial kyphosis angle of 27.1° (range 6°–54°) measured before surgery significantly (p = 0.002) decreased to 25.8° (range 4°–50°) at follow-up. Of the 27 patients who underwent MR angiography, 4 harbored a unilateral hypoplastic vertebral artery.

Surgery was performed by 2 different surgeons in 28.2% of the cases and by 3 other surgeons in the remaining 71.8%. The only deviation from the previously described operative technique was the use of 3.5-mm screws and a sublaminar wire loop/fixated graft in 2 of the patients treated early in the series. Both of these patients presented to follow-up with osseous fusion after postoperative course that involved no complications. Persisting symptomatic medullary compression by retrodental pannus tissue necessitated transoral odontoid resection in 1 of the patients 9 days after the initial surgery.

*Complications, Fusion, and Adjacent-Level Degeneration*

In 2 patients one of the screws pointed too high, crossing the atlantooccipital joint line; 1 of these patients had presented preoperatively with C1–2 subluxation. Unilateral screw removal eliminated local pain in 2 other patients. One of these screws was angled too cranially and too medially; the other surpassed the anterior C-1 border. There was no damage due to malpositioning, and screw revision after bony fusion at 8 and 19 months resulted in uneventful postrevision courses in both cases. The other major complications were superficial wound infection in 1 patient and hematoma of the iliac crest graft donor site in 1 patient. No episodes of greater occipital nerve injury, dural leakage, deep wound infection, or donor-site infection occurred.

Unilateral screw breakage was identified in 2 cases, and bilateral screw breakage was demonstrated in 2 other cases at follow-up. All 4 patients presented with a solid fusion. In a female patient with severe RA, surgical revision was required for a C1–2 pseudarthrosis; this involved bilateral removal of the broken screws and transarticular repeat fixation 5 months after initial surgical treatment. At follow-up this patient presented with a C1–2 solid fusion; however, subaxial degeneration of her cervical spine had been treated by C-5 corpectomy at another institution.

Osseous fusion, defined as the continuity of bone trabeculae and absence of movement between C-1 and C-2 could be proven in all but one patient. Criteria for fusion were bony bridges either between the lateral masses or the bone graft and the posterior arches of C-1 and C-2. According to those criteria, radiological and CT imaging revealed fusion of at least 3 osseous interfaces of the construct in 89.9% of the patients, with discontinuity of trabeculae between the graft and C-1 arch in 6 cases and the graft and C-2 arch in 2 cases. Signs of osseous bridg-

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** TABLE 2: Morphological characteristics of the craniocervical region in the present series**

<table>
<thead>
<tr>
<th>Variable</th>
<th>No. of Cases</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>isthmic height (mm)†</td>
<td>46</td>
<td>3.7</td>
<td>10.2</td>
<td>6.77</td>
<td>1.26</td>
</tr>
<tr>
<td>isthmic width (mm)†</td>
<td>46</td>
<td>3.9</td>
<td>9.2</td>
<td>6.04</td>
<td>1.15</td>
</tr>
<tr>
<td>preop pst ADD (mm)</td>
<td>38</td>
<td>8.2</td>
<td>19.8</td>
<td>13.51</td>
<td>3.36</td>
</tr>
<tr>
<td>FU pst ADD (mm)</td>
<td>46</td>
<td>11.2</td>
<td>21.9</td>
<td>15.8</td>
<td>2.56</td>
</tr>
<tr>
<td>preop &amp; FU difference of pst ADD (mm)</td>
<td>35</td>
<td>−3.5</td>
<td>8.4</td>
<td>2.3</td>
<td>3.12</td>
</tr>
<tr>
<td>atlantoaxial kyphosis angle at FU (°)</td>
<td>45</td>
<td>4</td>
<td>50</td>
<td>25.74</td>
<td>9.37</td>
</tr>
<tr>
<td>atlantoaxial rotation at FU (°)</td>
<td>46</td>
<td>0</td>
<td>13.3</td>
<td>3.3</td>
<td>2.67</td>
</tr>
<tr>
<td>preop basion-dens interval (mm)</td>
<td>39</td>
<td>−2.4</td>
<td>6.4</td>
<td>2.26</td>
<td>1.88</td>
</tr>
<tr>
<td>FU basion-dens interval (mm)</td>
<td>46</td>
<td>−2.5</td>
<td>7.6</td>
<td>2.18</td>
<td>2.07</td>
</tr>
</tbody>
</table>

*ADD = atlantodental distance; FU = follow-up.
† Measured at level of foramen transversarium.
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ing between the occiput and the graft were documented in 7 cases, which were excluded from the analysis of both atlantooccipital and subaxial degeneration.

The extent of degeneration of the levels above or below the fusion site is depicted in Table 3. Subaxial degeneration was noted for the level with the most severe degenerative changes, independent of the number of levels involved. Among the different raters, the intraclass correlation coefficients for radiographic analysis of degeneration at the Oc–C1 segment and subaxial segment were 0.97 and 0.95, respectively (p = 0.01). Severe subaxial degeneration necessitated additional surgery at subaxial levels at the time of the index surgery in 2 patients and later in 4 additional patients. The extent and distribution of the degeneration were similar for the segments above and below C1–2. However, none of the patients needed surgery to extend the fixation to the occiput during the follow-up period (Fig. 1). Four of the 7 patients with spontaneous Oc–C1 fusion after C1–2 fusion, who had moderate degeneration (second degree according to the Gore19 and Thabe55 criteria [Table 1]) of the subaxial levels even at time of index surgery, had further deterioration (third degree according [Table 1]) of these segments at the time of follow-up.

**Discussion**

In RA the atlantoaxial segment is a main target for instability caused by soft-tissue destruction due to inflammation. Morphological conditions that involve the absence of a stabilizing intervertebral disc, horizontally positioned facet joints, and predominant ligamentous stability contribute to the spinal level’s vulnerability. In any attempt to achieve stabilization one has to consider the characteristics of the RA patient with poor structural bone and skin quality after years of immune-modulating drug therapy, as well as potential anesthesia-related difficulties. As a three-point fixation construct, transarticular C1–2 fixation in combination with an autologous bone graft has proven superiority over both two- and one-point fixations for creating rigid primary stability.8,9,21,22,25,27,30,35,42

Transoral odontoidectomy was eventual necessary in only 1 patient whose symptoms indicated persistent medullary compression. Because of the proven potential for spontaneous regression of the retrodental pannus tissue,23,24 odontoidectomy is necessary only in rare cases. In contrast to some authors’ recommendations,13,35,47 we believe odontoidectomy should be performed after C1–2 stabilization whenever possible. According to biomechanical studies,10,41 this avoids additional destabilization prior to the stabilizing procedure. Ultimately the decision depends on the feasibility of atlantoaxial reduction, which can be limited by the peridental pannus tissue. The technique of transoral odontoid resection, described by Böhm and Meshtawy,4 leaves

**TABLE 3: Atlantooccipital and subaxial degeneration at follow-up (current study data) modified after Thabe and Gore**

<table>
<thead>
<tr>
<th>Spinal Segment</th>
<th>Variable</th>
<th>Cases at Surgery</th>
<th>Cases at FU</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>Cumulative %</td>
</tr>
<tr>
<td>atlantooccipital</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>no degeneration/cranial settling</td>
<td>8</td>
<td>21.6</td>
<td>21.6</td>
</tr>
<tr>
<td>+ degeneration</td>
<td>20</td>
<td>54.1</td>
<td>75.7</td>
</tr>
<tr>
<td>++ degeneration</td>
<td>8</td>
<td>21.6</td>
<td>97.3</td>
</tr>
<tr>
<td>+++ degeneration</td>
<td>1</td>
<td>2.7</td>
<td>100</td>
</tr>
<tr>
<td>subaxial</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>no degeneration/instability</td>
<td>4</td>
<td>10.8</td>
<td>10.8</td>
</tr>
<tr>
<td>+ degeneration*</td>
<td>3</td>
<td>8.1</td>
<td>18.9</td>
</tr>
<tr>
<td>++ degeneration*</td>
<td>12</td>
<td>32.4</td>
<td>51.4</td>
</tr>
<tr>
<td>+++ degeneration*</td>
<td>16</td>
<td>43.2</td>
<td>94.6</td>
</tr>
<tr>
<td>operation because of degeneration/instability</td>
<td>2</td>
<td>5.4</td>
<td>100</td>
</tr>
</tbody>
</table>

* Degeneration with or without segmental instability of the subaxial spine.
the anterior arch of C-1 intact, thus restoring the stability of the C1–2 construct after atlantoaxial fixation and avoiding the necessity for inclusion of the occiput.

Screw breakage occurred in 5 patients; the 7 broken screws in these 5 patients represented 7.6% of the overall 92 screws placed. This incidence of screw breakage falls into the same range as that of earlier studies (range 0%–10.6%35,53,58) of patients with RA. However, with a mean follow-up period of 21.6 months in the aforementioned studies, the follow-up was relatively short compared with ours (mean 112.8 months). This could possibly explain the breakage rate in our series. In fact, breakage tended to occur in the late postoperative course. One revision for unilateral breakage was necessary 5 months after the initial surgery. In the remaining 4 patients the time of breakage cannot be given. One patient presented with unilateral breakage as early as 1 month postoperatively. The mean period from operation to last radiological proof of intact screws in the remaining 3 individuals was 24 months. However, the presence of solid fusion did not depend on intact screws at follow-up.

Our fusion rate of 97.8% mirrors the results of other studies (range 95%–100%) in which the same technique was used.11,13,15,17,22,25,37,53 The present pseudarthrosis rate differs considerably only from that (18.9%) reported by Madawi et al.35 To some extent this probably reflects the use of different diagnostic tools to detect fusion failure.14

**Atlantoaxial and Subaxial Degeneration**

While the C1–2 segment allows for 50% of axial cervical spine rotation,36 physiological Oc–C1 function provides for a considerable range of motion of the cervical spine in extension-flexion.1 Any attempt at a motion-restoring approach requires definition of criteria that justify extending the fusion to the occiput. Primary inclusion of the occiput should be limited to patients with advanced atlantooccipital joint destruction and brainstem compression due to cranial settling of the odontoid. Following this rule, we found it necessary to perform primary Oc–C2 surgery only in 8.2% of our RA patients.

There is a large body of evidence in the literature on the problem of adjacent-level degeneration after fusion for degenerative diseases or trauma of the cervical spine. The rates of degeneration (range 12.5%–50%) depend on the duration of follow-up (range 2–10 years) and classification of degeneration.18,28,31,32,48,57 Yue et al.59 reported a revision rate related to degeneration of 16.9% in a mean follow-up of 41.8 months. In contrast, only a few studies have provided data for patients with RA after undergoing upper cervical fusion.29,34,38,41,51 (Table 4). Clarke et al.7 noted an incidence of progressive instability/subluxation in subaxial segments in 39% of their patients, and no case of progression to cranial settling after C1–2 fusion. Kraus et al.34 reported a 5.5% reoperation rate due to subaxial subluxation and no case of Oc–C1 degeneration that required surgery after an average of 9 years following atlantoaxial fusion. To our knowledge, no other data exist that describe the problem of Oc–C1 degeneration following atlantoaxial fusion.

Only 4 of 44 patients required further subaxial surgical interventions during the follow-up period (initially subaxially treated individuals excluded). In previous studies, the incidence of subaxial instability in populations of RA patients who had not been treated surgically at time of evaluation was 15%–19%.3,44,45 By contrast, we found severe degeneration of subaxial and occipitoatlantal levels even at time of operation in 75.6% and 24.3%, respectively, of our patients (second- and third-degree degeneration). The main reason for this finding is that our study group represents a preselected population of RA patients with an indication for surgical treatment. Progression of degenerative changes at levels below C-2 eventually required surgical intervention in 4 patients. Despite ongoing Oc–C1 degeneration after C1–2 fusion in 24.3% and 40.5% of patients with second- and third-degree changes, respectively, extending the fixation to the occiput was not necessary in our study group. The reason for the higher reoperation rate due to subaxial degeneration in our patients is that severe changes at the cervical spine below C-2 in most cases lead to spinal canal stenosis, which rarely occurs with Oc–C1 joint degeneration. In our study the number of patients initially treated with Oc–C2 fu-

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>Initial Extent of Fusion</th>
<th>Fixation Technique</th>
<th>No. of Cases</th>
<th>FU (mos)</th>
<th>Oc–C1 Degeneration Rate (%)</th>
<th>C2–CX Degeneration Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clarke et al., 2006</td>
<td>C1–2</td>
<td>pst interlaminar wiring</td>
<td>31</td>
<td>99.6</td>
<td>0</td>
<td>39</td>
</tr>
<tr>
<td>Matsunaga et al., 2000</td>
<td>Oc–CX</td>
<td>pst rectangular rod fixation</td>
<td>16</td>
<td>87.3</td>
<td>NS</td>
<td>31</td>
</tr>
<tr>
<td>Kraus et al., 1991</td>
<td>Oc–C2</td>
<td>NS</td>
<td>24</td>
<td>72.6</td>
<td>NS</td>
<td>36</td>
</tr>
<tr>
<td>Grob et al., 1991</td>
<td>C1–2</td>
<td>NS</td>
<td>55</td>
<td>65.4</td>
<td>0</td>
<td>5.5</td>
</tr>
<tr>
<td>Ito et al., 2009</td>
<td>C1–2</td>
<td>occipitocervical Y-plate</td>
<td>22</td>
<td>41.5</td>
<td>NS</td>
<td>18.2</td>
</tr>
<tr>
<td>Mukai et al., 2007</td>
<td>C1–2</td>
<td>transarticular screws at C1–2, pst interlaminar wiring</td>
<td>28</td>
<td>72</td>
<td>NS</td>
<td>18</td>
</tr>
<tr>
<td>present study</td>
<td>C1–2</td>
<td>transarticular screws at C1–2, pst interlaminar wiring</td>
<td>46</td>
<td>97.8</td>
<td>23.1 (n = 39)</td>
<td>13.3 (n = 44)</td>
</tr>
</tbody>
</table>

*CX = subaxial; NS = not stated.*
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sion (n = 14) is too small to sufficiently discuss subaxial degeneration after atlantoaxial fusion. However, our data suggest a preserving effect of segment-sparing C1–2 fixation also on the subaxial levels (Fig. 1).

Several investigators have emphasized the importance of the atlantoaxial kyphosis angle (AAKA) in the development of subaxial changes after upper cervical fixation procedures. Contrary to these results, Mukai et al. found no significant correlation between changes in the AAKA and subaxial alignment. They suspected a multifactorial influence on development of subaxial changes and concluded that prediction is difficult.

At follow-up, deviance from physiological values of the AAKA was only on average (range –25° to 21°). The mean values in healthy adults are 26.5° in men and 28.9° in women. A statistical correlation between angle deviation and subaxial changes could not be shown.

A limitation in this study and possible source of bias is the rate of patients lost to long-term follow-up. The crippling character of RA with multivisceral destruction may have been a main reason for changes in addresses or inability to travel long distance to attend control visits. Survival analysis of adjacent-segment problems, for that reason, would not be valuable. However, the differences in the mean age of the patients at the time of surgery among those who could be retrieved (53.3 years), those lost to follow-up (61.4 years), and those who died (64.7 years), suggests a rather natural course of the RA as a systemic disease.

Conclusions

Data from the present investigation suggest that, in the absence of severe destruction of the Oc–C1 joint and cranial settling at time of surgery for C1–2 instability in patients with RA, there is a very low risk for relevant destruction in the following 5–14 years. Thus, a segment-sparing monosegmental C1–2 fusion should be the preferred treatment choice.

Subaxial degenerative changes, commonly marked in the rheumatic cervical spine, rarely require further operative intervention, even years after surgical treatment of the C1–2 segment.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Boehm. Acquisition of data: Werle, Ezzati, ElSaghir. Analysis and interpretation of data: Werle, Ezzati, Boehm. Drafting the article: Werle. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Werle. Administrative/technical/material support: Boehm. Study supervision: Boehm.

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References
