SPINE Volume 30, Number 19, pp 2138–2144
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Long-Term Results After Anterior Cervical Discectomy and Fusion With Allograft and Plating

A 5- to 11-Year Radiologic and Clinical Follow-up Study

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Study Design. A retrospective review.

Objectives. To determine the clinical and radiologic outcomes beyond 5 years after anterior cervical discectomy and fusion with allograft and plating.

Summary of Background Data. Anterior cervical discectomy and fusion is commonly performed for cervical disc disease. The routine use of allografts and plating, though increasing in popularity, has not been well studied for long-term results and complications.

Methods. Seventy-one patients who had anterior cervical discectomy and fusion with allograft and plating an average of 7.2 years prior responded to an invitation to return for a follow-up clinical and radiographic review.

Results. At final review, symptom resolution remained greater than 82% and fusion occurred in 92.6% of the disc spaces operated on. No graft extrusion or migration occurred. Based on our strict criteria, the rates of collapse and subsidence were high, at 47.9% (34 patients) overall. However, in only 6 patients (8.5%) did segmental kyphosis result, none of whom required any revision surgery in the follow-up period. Implant complications occurred in 7 patients (9.9%), none of whom required revision surgeries. Adjacent level degeneration occurred in 52 patients (73.2%). Further cervical spine surgeries were required in 14 patients (19.7%), 2 for inadequate decompression, and 12 for adjacent level disease. Segmental and global cervical lordosis was restored and maintained by the surgery over the study period.

Conclusions. The use of allografts and plate fixation in combination for anterior cervical discectomy and fusion does not compromise the radiologic and clinical outcomes while providing the advantages of donor site morbidity elimination, restoration of cervical segmental lordosis, and not requiring postoperative immobilization.

Key words: anterior cervical discectomy and fusion, adjacent level disease, implant complications, cervical alignment. **Spine 2005;30:2138–2144**

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Acknowledgment date: December 16, 2003. First revision date: June 11, 2004. Second revision date: September 13, 2004. Acceptance date: November 1, 2004.

The device(s)/drug(s) is/are FDA-approved or approved by corresponding national agency for this indication.

No funds were received in support of this work. No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.

Study performed at the Columbia Spine Centre, Columbia, MO, USA.

Presented as a poster at the 31st Cervical Spine Research Society Annual Meeting, Scottsdale, AZ, 11–14 December 2003.

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Anterior cervical discectomy and fusion (ACDF) is the standard of care for cervical radiculopathy and myelopathy secondary to anterior compression due to osteophytes or soft disc prolapses.[1–17] The combined use of allograft[3,5,17–27] and plating[24–26,28–46] for fusion after decompression is an attractive option that has gained increasing popularity among orthopedic and neurosurgeons.[47] The use of internal fixation with plates attempts to increase the fusion rate and preserve or restore segmental lordosis in the diseased cervical spine segments while reducing the period and extent of immobilization demanded of patients after ACDF. Donor site morbidity, which ranges from 0.6% to 36% in the literature,[12,13,23,27,48,49] is eliminated by the use of allografts. However, the long-term outcome and complications of the use of allografts and plate fixation in combination for ACDF have not been previously not well reported.

This study was undertaken to assess the long-term radiologic and clinical outcomes in patients who have undergone ACDF with allografts and plate fixation. Specific areas that were studied include: 1) clinical improvement, 2) graft complications and fusion rates, 3) implant complications, 4) adjacent level degeneration and revision surgery, and 5) cervical and segmental sagittal alignment.

Materials and Methods

Between January 1, 1992 and December 31, 1997, 176 patients underwent ACDF with freeze-dried fibular allografts and plating by the senior author (T.R.H.). The charts and radiographs were reviewed to confirm the preoperative complaints and clinical findings, intraoperative findings, levels operated, duration of surgery, the plating system used, and prior surgeries in the neck region. Seventy-one (38 females, 33 males, 134 disc spaces) responded to an invitation to return for a follow-up examination by two independent orthopedic surgeon reviewers (W.-M.Y. and W.B.). Six patients had died of unrelated causes, 1 patient was too ill with cancer to return, 22 patients had no forwarding address, and 76 patients did not wish to return because of the traveling required and also felt that they did not have any significant problems that required a follow-up visit despite being offered a free examination. The index surgery for each patient was taken as their first by the senior author during the period. During the interview, the current status of symptoms was graded by questionnaire and clinical examination. Specific symptoms that were assessed were axial neck pain, radicular pain in the upper extremities, radicular weakness and numbness in the upper extremities, and gait abnormalities. Each were graded as completely resolved, substantially improved, no change or worse, compared with preoperative levels.

Lateral, flexion, and extension radiographs of their cervical spines were obtained to determine the fusion status and the presence of any late implant or graft complications. Absence of radiolucent lines at the interface between the allograft and the adjacent vertebral endplates, presence of bridging trabeculae across the entire interface, absence of motion of the adjacent vertebral bodies in flexion-extension radiographs, and presence of bridging bone in the intervertebral space beyond the limits of the allograft were assessed to determine fusion. This was graded as definitely fused, probably fused, probably not fused, and definitely not fused for each level. Graft incorporation was detected by comparing the radiodensity of the graft vis-à-vis adjacent vertebral bodies. This was graded as totally incorporated (uniform radiodensity throughout graft and adjacent vertebral bodies), partially incorporated, and not incorporated (graft is totally distinct compared with adjacent vertebral bodies). Graft collapse was defined as any loss of graft height and graft subsidence was defined as any migration of the graft into the adjacent vertebral bodies.[17] Segmental alignment was determined by measuring the angle formed by the superior and inferior planes of the fused segment.[50] Global cervical spine alignment was determined by measuring the angle formed by the lines parallel to the posterior border of C2 and C7, respectively[50] (Figure 1). Adjacent level degeneration was determined by the presence of any disc space narrowing, anterior or posterior osteophytes.

The index surgery consisted of a standard Smith-Robinson approach to the cervical spine[2,6] under general anesthesia, with endotracheal intubation. No traction was used, and lordosis of the cervical spine was maintained with a contoured foam pillow beneath the neck. The approach was *via* the left side preferentially, as well as through any previous surgical scar, if present. Deep retraction of the soft tissue was achieved with self-retaining retractors, the tips of the blades of which were placed deep to the longus colli muscles on either side. Thorough discectomy and removal of any offending osteophytes as identified on the preoperative studies was performed under loupe magnification and headlight illumination. The cartilaginous endplates of the adjacent vertebral bodies were removed, but the bony endplates were retained. Distraction of the disc space was achieved *via* Caspar pin retractors screwed into the adjacent vertebral bodies. A segment of freeze-dried fibular allograft (Musculoskeletal Transplant Foundation, Holmdel, NJ), manually cut according to the postdiscectomy defect and shaped to provide a lordotic contour, was then inserted and impacted till the anterior surface of the graft is recessed 1 to 2 mm posterior to the anterior surface of the adjacent vertebral bodies. A plate was then applied across the disc spaces and secured to adjacent vertebral bodies with unicortical screws. The plating systems used were Cervical Spine Locking Plate (CSLP; Synthes Spine, Paoli, PA) in 60 patients (84.5%), Aline system plate (Surgical Dynamics, Norwalk, CT) in 10 patients (14.1%), and Orion plate (Sofamor-Danek, Memphis, TN) in 1 patient (1.4%).

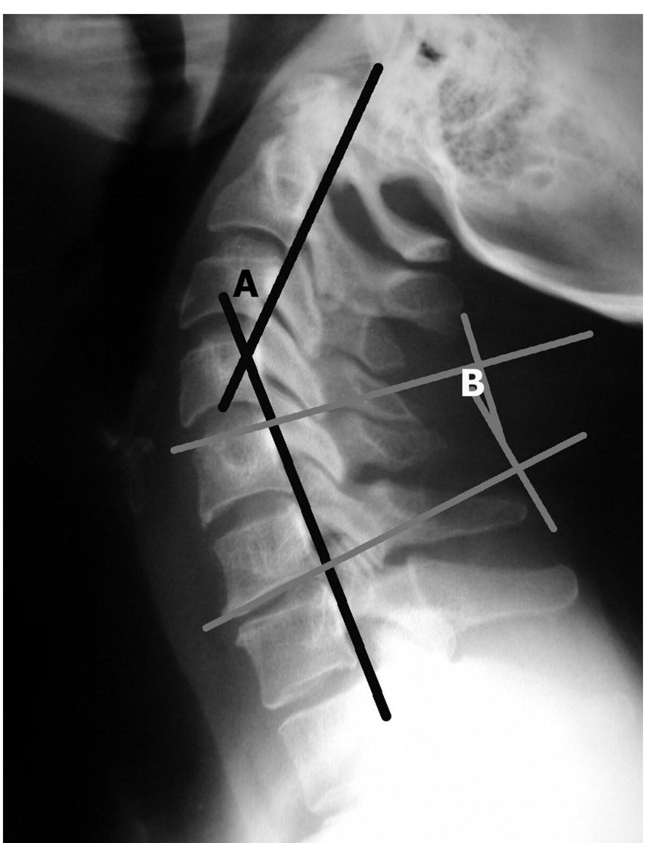

Figure 1. Global cervical lordosis (A) and segmental lordosis (B).

Statistical Analysis. Analysis was done using the SPSS program version 9.05. The *t* test for independent samples was used to compare symptom resolution with continuous variables such as age, and duration of symptoms before surgery. The paired *t* test was used to compare changes in segmental and global cervical lordosis before surgery, in the early postoperative period and at final review. The χ^2 test was used to compare symptom resolution with nominal variables, such as sex, fusion status, smoking status, presence of graft collapse, and implant complications. When the expected count was less than 5 in any cell, the Fisher's exact test was used. Statistical significance was deemed when the *P* value was less than 0.05. When the order of significance was higher, it was indicated as so.

Results

The average age of the patients at surgery was 52.7 years (range, 32–78 years) and the average duration of symptoms before surgery was 27.2 months (range, 0.5–120 months). They were followed up for an average of 7.2 years (range, 5.4–11.1 year). The mean duration of initial follow-up after the index surgery was 34.6 months (range, 3–112 months) before the commencement of this study. Surgery was performed on one level in 28 (39.5%), two levels in 26 (36.6%), three levels in 14 (19.7%), and four levels in 3 (4.2%) patients. The levels to be operated on were determined by clinical findings, plain radiographs, and magnetic resonance imaging or computed tomography after myelogram. Neural compression was secondary to spondylosis in 42 patients (59.2%), herniated nucleus pulposus ("soft discs") in 13 patients (18.3%), and both spondylosis and herniated nucleus pulposus in 16 patients (22.5%). In 65 patients (91.5%), the index surgeries were primary surgeries on their cervical spines. The average duration of surgery per level was 43.5 minutes, and the patients were hospital-

Table 1. Symptoms at Final Follow-up

	Neck Pain	Radicular Arm Pain	Upper Limb Weakness	Upper Limb Numbness	Gait Problems
Total with symptoms preoperatively (n)	67	65	52	47	4
None [no. (%)]	35 (52.2)	47 (72.3)	32 (61.5)	35 (74.5)	2 (50)
Better [no. (%)]	29 (43.3)	15 (23.1)	11 (21.2)	5 (10.6)	2 (50)
Same [no. (%)]	1 (1.5)	2 (3.1)	6 (11.5)	5 (10.6)	0
Worse [no. (%)]	2 (3.0)	1 (1.5)	3 (5.8)	2 (4.3)	0

ized for an average of 2.1 days (range, 1–6 days). Twenty-one (29.6%) patients were known smokers at the time of surgery. No external immobilization was used except for the intermittent use of soft collars in the first 12 patients (16.9%).

Clinical Results

Before surgery, 67 patients (94.4%) had axial neck pain, 65 patients (91.5%) had radicular arm pain, 52 patients (73.2%) had weakness in the upper extremities, and 4 patients (5.6%) had gait problems. At the final follow-up, the progress of each symptom is shown in Table 1. After an average of 7.2 years (Figure 2), the proportion of patients who retained significant improvement in axial neck pain, radicular arm pain, upper extremity weakness, upper extremity numbness, and gait problems were 95.5%, 95.4%, 82.7%, 85.1%, and 100%, respectively. Improvements were not related to whether union occurred, the smoking status, duration of symptoms before surgery, duration of surgery, the number of levels operated on, the collapse, or subsidence of the grafts. Sixty-four patients (90.1%) would definitely opt for the same surgery, given the same symptoms and clinical course they have experienced.

Fusion Results and Graft Complications

There was no incidence of graft extrusion or migration. Partial subsidence of a least one graft occurred in 13 patients (18.3%), leading to segmental kyphosis in 3 patients (range, 3°–6°). Partial collapse of at least one graft occurred in 21 patients (29.6%), leading to segmental kyphosis in another 3 patients (range, 2°–4°). Those with graft collapse are more likely to have more levels operated on (2.5 *vs.* 1.6, $P = 0.001$). Graft incorporation was complete in 27 spaces (20.1%), partial in 95 spaces (70.9%), and absent in 12 spaces (9%). Fusion was definite in 105 disc spaces (78.4%), probable in 19 spaces (14.2%), probably not in 6 spaces (4.5%), and definitely not in 4 spaces (2.9%). All 9 patients who were discovered to have pseudarthrosis at long-term follow-up were initially thought to have fused and discharged an average of 3.4 years after the initial surgery. The greater the number of levels operated on, the more likely that at least one level will have probable or definite pseudarthrosis (Table 2; $P = 0.01$). Those whose index surgery were revision surgeries had a greater chance of having at least one level with probable or definite pseudarthrosis (4 of 6) compared with those whose index surgery were primary (5 of 65; $P = 0.002$). Fusion status was not related to the smoking status, type of implant used, presence of subsidence or collapse, and the age of the patient. No patient with a probable or definite pseudarthrosis was symptomatic enough to require surgery for the purpose of nonunion repair.

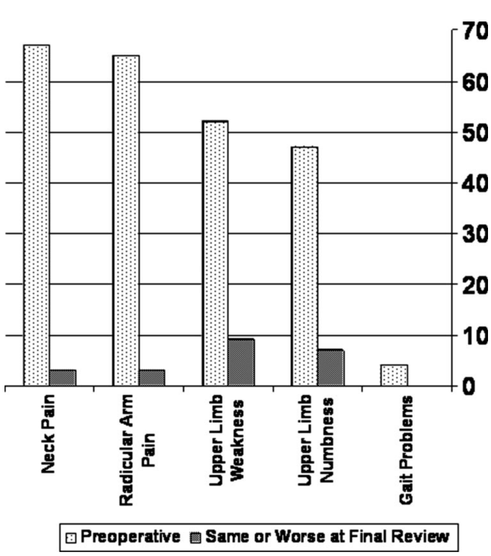

Figure 2. Symptoms at same or worse level at final follow-up *versus* before surgery.

Implant Complications

Sixty-six patients (89.2%) had no implant complications. There was only one true implant failure with a broken plate (1.4%). This was a 33-year-old woman who was a smoker and had 3-level surgery at C3–C4, C4–C5, and C5–C6 interspaces for radiculopathy secondary to spondylosis. After surgery, her neck pain improved substantially and the weakness, numbness, and pain in her upper extremity were completely resolved. At 6 months post-surgery, her fusion was deemed complete and she was discharged from follow-up. Five years after the index injury, she was evaluated after her neck symptoms worsened and she experienced a sudden increase in the range of motion of her neck. Flexion and extension

Table 2. Fusion Rates by Operated on Level

Level	Fused [no. (%)]	Nonunion of at Least 1 Level [no. (%)]
1	27 (96.4)	1 (3.6)
2	23 (88.5)	3 (11.5)
3	10 (71.4)	4 (28.6)
4	2 (66.7)	1 (33.3)

Table 3. Implant Complications by No. of Levels Operated

No. of Levels Operated	Implant Complications No.	Total	%
1	0	28	0*
2	4	26	15.4
3	1	13	7.7
4	2	3	66.7

*$P = 0.002$.

lateral radiographs demonstrated nonunion at C3–C4 and C5–C6. In addition, the plate (CSLP) was broken at C5–C6 and the proximal screws in C3 were loose and had backed out slightly. The locking screws of the distal screws in C6 were also loosened. She is still considering revision surgery as she is still clinically better than before her index surgery. Six other screws backed out slightly (8.1%) in 6 other patients. These were all discovered in the early postoperative radiographs and had not progressed at final review. None was associated with any change in position of the plate. Four of the six involved one of the inferior most screws, which were either in the C7 or T1 vertebral body. None has required revision surgery to specifically deal with the prominent screws. Implant complications were related to the number of levels operated on (Table 3). All the implant problems occurred in patients who had surgery to more than one level while those who had single-level surgery had no implant complications ($P = 0.002$).

Adjacent Level Disease and Revision Surgeries

New onset or worsening of preexisting degeneration of disc spaces adjacent to the operated levels occurred in 52 patients (73.2%). The breakdown of the level(s) of involvement relative to the index fusion is listed in Table 4. Half had no evidence of adjacent level degeneration before surgery, while the other half had evidence of mild degeneration in the adjacent levels before surgery. It was the senior surgeon's practice to include any severely degenerated adjacent levels in the index surgery. Two patients had revision surgeries of the same levels in the early postoperative period to deal with problems of inadequate decompression. Revision anterior cervical surgeries to address symptomatic adjacent level disease were required in 12 patients (16.9%) at an average of 41.8 months (range, 7–73 months) after the index surgery. Of these, 5 had preexisting degeneration while 7 did not. Neither the occurrence of adjacent level disease nor the need for revision surgery was related to the number of levels operated on or eventual fusion status.

Cervical and Segmental Alignment

Segmental lordosis of the operated segments (Table 5) was increased from a mean 0.6° before surgery to 10.9° in the early postoperative period. Although some of the lordosis restored was lost by final review (mean, 8.7°), this was still significantly better than before surgery ($P = 0.001$). Global cervical lordosis (Table 5) from C2–C7 was also increased and maintained in the early postoperative period and at final review compared with before surgery. This increase was not statistically significant though.

Limitations

The chief limitation of this study is that this is a retrospective review, subject to the patients' recall lapses. A number of patients also have had subsequent procedures performed through the anterior neck region. Validated outcome measures could not be meaningfully used as preoperative and early postoperative measurements could not be made.

Patients Who Did Not Return for the Study

A brief mention is made here regarding those patients who did not return for evaluation for this study but nonetheless had significant information obtainable from their charts. Fourteen patients were observed up for at least 1 year and 42 patients were observed up for 2 years or more, based on the entries in the patients' charts. Of the former group, all the patients were noted to have improvement in their symptoms in terms of axial neck pain, radicular arm pain, upper extremity weakness, upper extremity numbness,and gait problems. The results in the latter group was similar except for 1 patient who was recorded to have no improvement in the radicular arm pain and 1 patient who was recorded to have no improvement in gait function. All the patients were recorded to have achieved bony union in the follow-up radiographs. There were no implant complications except for one asymptomatic broken screw. Ten patients were also recorded to have subsequent anterior cervical spine surgery, 2 of the same level as the index surgery, 3 of the level above, 3 of the level below,and 2 of the levels above and below the index surgery.

Table 4. Adjacent Level Degeneration and Subsequent Revision Cervical Spine Surgery

	Adjacent Level Degeneration [no. (%)]	Revision Cervical Spine Surgery [no. (%)]
None	19 (26.8)	57 (80.3)
Level above	22 (31.0)	8 (11.3)
Level below	19 (26.8)	4 (5.6)
Level above and below	11 (15.4)	—

Table 5. Segmental and Global Cervical Lordosis

Lordosis	Measurement (°)
Preoperative segmental lordosis	0.6 ± 6.0*
Postoperative segmental lordosis	10.9 ± 8.2*
Segmental lordosis at review	8.7 ± 8.0*
Preoperative cervical lordosis	17.1 ± 10.8
Postoperative cervical lordosis	23.1 ± 10.3
Cervical lordosis at review	24.2 ± 12.2

*Significant increase of postoperative and latest segmental lordosis over preoperative values ($P < 0.05$).

Discussion

The anterior approach to treatment of cervical disc disease was first described by Robinson and Smith[1] and popularized by Cloward[3,5] in the 1950s. Short- and long-term clinical success in the range of 67% to 100% has been extensively reported in the literature.[2,3,5,11–17] The aims of the surgery remain 1) the adequate decompression of neural structures, whether directly or *via* distraction and fusion, 2) a solid arthrodesis, 3) maintaining or restoring normal cervical alignment; and 4) minimization of complications. The gold standard to which all other modifications are compared is the use of autograft, in various configurations[1,3,4,10] from either the iliac crest or fibula, with the use of external immobilization rather than internal fixation. Problems with donor site morbidity,[12,13,23,27,48,49] nonunion in multilevel fusions,[13,15,51,52] and collapse and subsidence leading to kyphotic deformities[23,51] are still concerns. In addition, most surgeons will have patients be in at least a semirigid collar for at least 6 weeks in the postoperative period, hampering the rehabilitation process.

It is generally recognized that the use of allografts will lead to elimination of donor site morbidity and shortening of operating time. However, their use comes with potential problems, including risk of infections and graft rejection,[27] higher rates of collapse and nonunion,[11,17,18,20,23,27] especially in multilevel fusions, and prolonged period required for graft incorporation.[20,27,53,54] The fear of adverse outcomes due to infections and graft rejection has largely been proven to be unfounded.[55] Based on our strict criteria, the rates of collapse and subsidence were high, at 47.9% (34 patients) overall. However, in only 6 patients (8.5%) did segmental kyphosis result, none of whom required any revision surgery in the follow-up period. Slight degrees of collapse and subsidence may be part of the graft incorporation and remodeling processes.

Fusion criteria for the current study were also intentionally strict as the authors thought that the fusions should have matured over the extended period since the index surgery. Based on these, 6 spaces (4.5%) were probably not fused and 4 spaces (2.9%) were definitely not fused. It is also interesting that these were originally deemed to have fused, with the patients subsequently discharged from follow-up; and none of these was symptomatic enough to require revision surgery. It is possible that these were fibrous unions with sufficient stability either inherently or from the presence of the plate to prevent clinical failure. The only exception occurred in 1 patient, whose plate broke, apparently 5 years after surgery. It has been noted in animal studies as well as inferred from studies on fracture healing that allografts, especially cortical allografts, take a long time to incorporate.[53,54] In the case of massive cortical allografts, they may not incorporate fully at all.[53] Even with autografts, apparent unions after 3 or 4 months could eventually manifest as nonunions with longer follow-up.[15] A longer follow-up period may be required in cases where cortical allografts, such as fibular rings, are used in anterior cervical fusions, to ensure that fusion is complete.

The aims of rigid internal fixation in anterior cervical fusions are to 1) increase rates of solid fusion, 2) prevent graft complications such as collapse, subsidence, extrusion, 3) maintain cervical spine sagittal alignment, and 4) decrease the need for cumbersome bracing.[34,37,56] All these aims seemed to have been achieved in a sustained manner according to the findings of this study. Fusion rates for one- and two-level surgeries (50 of 54, or 92.5%) were comparable to the fusion rate with use of autograft and plating in the literature (94%–100%).[28,30–32,35,37,40,41] While fusion rates were lower in the multilevel cases (12 of 17, or 70.6% in those involving three or four levels), they were better than those reported in the literature without internal fixation[15,52] and comparable to those with internal fixation (54%–82%).[44,50,57] Graft extrusion was totally prevented. Significant collapse and subsidence were also minimized. Certainly segmental alignment was restored and maintained, in keeping with the findings of two studies specifically on the subject in the literature.[50,58] External immobilization was minimized, with the majority of patients not even needing to wear a soft collar after surgery.

The concerns with use of internal fixation include 1) injury to surrounding soft tissue during the insertion process or due to implant migration,[28,32,34,35,37,38,57,59,60] 2) presence of a plate as an impediment to fusion,[61] 3) implant failure,[31,32,34,35,37,56] and 4) accelerated adjacent level disease due to the increased rigidity.[34] The first three were not significant problems encountered, even with prolonged follow-up. The rate for revision surgery for adjacent level disease of 16.9% is comparable to the most widely quoted rate of 2.9% per year of symptomatic adjacent level disease after anterior cervical fusion with autograft, without internal fixation.[62] This, as well as the high rate of adjacent level degeneration, may not even represent an acceleration of the degenerative process. Rather, this may just be a reflection of "normal" degeneration with age.[62,63]

■ Conclusion

This study demonstrates that the use of allografts and plate fixation in combination for ACDF does not compromise the radiologic and clinical outcomes while providing the advantages of donor site morbidity elimination, restoration of cervical segmental lordosis, and not requiring postoperative immobilization. Serious implant complications were minimal. Fusion occurred in 92.6% of the disc spaces operated on. Prolonged follow-up may be needed to confirm ultimate fusion with allografts and the development of late implant failure. While more than 70% of patients developed adjacent level degeneration over 7.2 years, only 17% required further anterior cervical spine surgeries.

Key Points

- Symptom resolution remained greater than 82% and fusion occurred in 92.6% of the disc spaces operated on.
- Significant implant complications occur in only 1 patient (1.4%).
- Segmental and global sagittal cervical lordosis is restored and maintained with allografts and plating.
- Prolonged follow-up may be needed to confirm ultimate fusion with allografts and the development of late implant failure.
- Although more than 70% of patients developed adjacent level degeneration over 7.2 years, only 17% required further anterior cervical spine surgeries.

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