

CLINICAL REVIEW

Bone Grafts in Scoliosis Surgery: Does Allograft Work?

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ABSTRACT

Background: Spinal fusion can be performed to correct spinal curvature in adolescents with idiopathic and neuromuscular scoliosis. Autograft has traditionally been used to augment fusion however, it is commonly associated with morbidity and is limited in supply. For this reason, allograft has been explored as an alternative.

Objective: The purpose of this paper is to evaluate the current literature to determine the safety and efficacy of allograft in scoliosis surgery, and compare it to the standard autograft.

Methods: Literature searches using the Medline and PubMed databases were performed and references from each of these papers were examined. Outcome measures were extracted and the validity of the trials was determined. Given the lack of randomized trials, weighted means were calculated for the outcome measures. Weighting was conducted by sample size of the study. In addition, 95% confidence intervals around the estimates were calculated.

Results: Fourteen studies met eligibility criteria. The rate of pseudarthrosis was 2% (95% CI 2 to 6%) for allograft and 3% (95% CI -1 to 7) for autograft. Blood loss was 1464 milliliters (95% CI 886 to 2042) for allograft and 1613 milliliters (95% CI 686 to 2539) for autograft. Operative time was 244 minutes (95% CI 81 to 407) for allograft, and 248 minutes (95% CI 177 to 319) for autograft. Loss of correction was 4 degrees (95% CI 0 to 9) for allograft and 4 degrees (95% CI 1 to 8) for autograft. The rate of deep wound infections was 2% (95% CI -3 to 5) for allograft and 0.4% (95% CI -0.4 to 1.3) for autograft.

Conclusion: Allograft is a safe and efficacious alternative to autograft in spinal surgery for scoliosis.

Progression of scoliosis in adolescents with idiopathic and neuromuscular scoliosis is of clinical significance as it can cause severe spinal malformation and compromise cardiac and respiratory function. Without intervention, progressive scoliosis can thus increase mortality.¹ Since bracing is often ineffective in correcting scoliosis or impeding curve progression, early spinal fusion is advocated particularly in patients with neuromuscular scoliosis.¹ Spinal fusion commonly involves decortication of posterior elements, spinal instrumentation, application of bone graft to the fusion area, and sometimes facetectomy.² However, access to autograft may be limited in certain cases. Rib grafting may be precluded in children with respiratory disease since removing ribs from these children can further compromise pulmonary function especially in the early post-operative period. In addition, children with neuromuscular scoliosis may have an atrophic pelvis that is too small to provide a sufficient quantity of autograft to cover the area that requires fusion.

Following blood transfusion, bone is the second most commonly transplanted tissue.⁴ While instrumentation is used in spine surgery to achieve immediate alignment, bone grafts are incorporated for long-term biologic fusion.

Instrumentation typically refers to the insertion of two titanium rods which are attached to pedicle screws or hooks. This is intended to enhance incorporation of the bone graft into the new position of the spine. This technique is utilized to correct or reduce the degree of spinal curvature. Common donor sites in autologous bone grafts include the iliac crest, ribs and fibula.⁵ Benefits of autograft include biocompatibility, diminished risk of disease transmission and potential cosmetic appeal if harvested from deformed ribs.⁶ However, autograft is limited in supply and is associated with increased operating time and blood loss. In addition, the nerves, arteries and urethra may be damaged. Further, hematoma, infection, pelvic stress fractures or instability, peritoneal perforation or iliac hernia, and pneumothorax can occur during surgery. Long-term morbidity includes persistent pain at the donor site, dysesthesia, limb inequality, gait disturbance and an unsightly scar.⁷⁻¹⁰

Allograft is a commonly explored alternative to autograft. It is generally obtained from bone banks across the country. These facilities have specialized equipment to keep the bone frozen until needed. Depending on its harvesting and preparation, allograft is classified as fresh, fresh-frozen, fresh-dried, or demineralized. The process of allograft incorpora-

Table 1. Biologic Properties of Allograft Preparations

Graft	Preparation	Strength	Storage	Shelf Life
Autograft	From one site to another in same patient			
Fresh	Directly from donor to recipient			
Fresh-frozen	Washed in antibiotic solution; cooled to minus 70 degrees Celsius	Maintained	Minus 70 deg Cel	5 years
Fresh-dried	Washed in antibiotic solution; cooled to minus 70 degrees Celsius; dehydrated to reduce the water content to <5%		Decreased Room temp	5 years
Demineralized	Treated with acid; combined with another allograft	None	Room temp	Dependent on preparation

Graft	Osteogenic	Osteoinductive	Osteoconductive	BMP Presevered	Immunologic
Autograft	No	Yes	Yes		
Fresh	No		Yes		Not used in spinal surgery
Fresh-frozen	No		Yes	Partial	Less
Fresh-dried	No		Yes	No	Almost none
Demineralized	No		Yes	Partial	Almost none

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tion is similar to autograft bone, in that it proceeds through the five phases of inflammation, vascularization, osteoinduction, osteoconduction and remodeling.⁵ Each allograft type has a different propensity for biologic fusion depending on whether the bone is osteogenic, osteoinductive and osteoconductive. For bone to be osteogenic, it must contain precursor stem cells that can differentiate and lead to bone formation. For bone to be osteoinductive, it must include proteins that recruit precursor osteoblastic cells, promote neovascularization, and induce bone formation. For bone to be osteoconductive, it must provide a latticework onto which new bone can be established. Autograft is the only bone that is able to perform all of the above functions. Allograft is not osteogenic; however, depending on its preparation it may be osteoinductive and osteoconductive.⁵ See Table 1 for the biologic properties of the different allograft preparations.

Given the limitations of autograft in surgery for adolescents with idiopathic and neuromuscular scoliosis, we reviewed the evidence for allograft bone as a viable alternative to autograft bone, with the overall goal of informing surgical interventions. The efficacy of allograft was evaluated based on rate of pseudarthrosis, operating time and blood loss, pre-operative and post-operative curves, loss of correction at follow-up, and infection. These are the standard ways outcomes of scoliosis surgery are reported.

METHODS

Eligibility

Eligible studies met the following criteria:

- 1) Population: etiology included idiopathic and/or neuromuscular scoliosis.

- 2) Intervention: allograft augmentation included any one of fresh-frozen, freeze-dried, or composite. Studies were included regardless of the specific spinal instrumentation, including the Harrington, Luque, Leathermen Hook, Cotrel-Debousset, and Texas Southern Rite Hospital techniques.
- 3) Outcomes: the primary outcome was pseudarthrosis, and secondary outcomes included operating time and blood loss, pre-operative and post-operative curves, loss of correction at follow-up, and infections.
- 4) Methodology: all comparative studies examining allograft in scoliosis surgery were included. Case studies, review papers and publications in languages other than English were excluded.

Study Selection and Data Extraction

A literature search using the Ovid gateway of the Medline database (<http://gateway.ut.ovid.com>) and the Entrez gateway of the PubMed database (<http://www.ncbi.nlm.nih.gov/entrez/query.fcgi>) was performed. The following keywords were queried in combination with *allograft: scoliosis, idiopathic scoliosis, and neuromuscular scoliosis*. Restrictions on the database search were as follows: English was specified in the language category, and Human was specified in the study category. The papers were reviewed, categorized, and checked to see whether they met the inclusion criteria outlined above. References from each of these papers were then checked to ensure that all available studies were reviewed.

Cohort characteristics including mean age and gender were abstracted from each study. Other descriptive data

Table 2. Methodology of Individual Studies

Study	Year of Publication	Participants N, Mean Age	Etiology	Instrumentation	Allograft Type	Pseudarthrosis Suspicion	Fusion Mass	Follow-up Mean, Minimum
Aurori et al.	1985	208 23M, 185 F 14.5 years	Idiopathic	Harrington	Fresh-frozen	Persistent pain Tenderness to percussion of the fusion mass Significant loss of correction Failure of instrumentation Roentgenograph	Surgical exploration in patients with suspected pseudarthrosis	4.5 years Min. 2 years
McCarthy et al.	1986	32 19 M, 13F 14.6 years	Cerebral Palsy Myelomeningocele Duchenne Muscular Dystrophy Werdnig-Hoffmann spinal muscular dystrophy Miscellaneous	Harrington Luque	Fresh-frozen	Roentgenograph	Roentgenograph	3.7 years Min. 2 years
Dodd et al.	1988	40 14.9 years	Idiopathic	Harrington Leatherman hook	Fresh-frozen	Radiograph	Radiograph	0.5 years
Gersoff	1988	33 8M, 25F 17 years	Cerebral Palsy	Luque	Freeze-dried	Radiograph	Radiograph	3.3 years Min. 2 years
Montgomery et al.	1990	30 7M, 23F 15.5 years	Cerebral Palsy	Harrington Luque	Freeze-dried	Radiograph	Radiograph	3.5 years Min. 2 years
Fabry	1991	182 14 years	Idiopathic	Harrington	Fresh-frozen	Roentgenograph		1 year
Bridwell et al.	1994	40 26M, 14F 13.6 years	Duchenne's muscular dystrophy spinal muscular dystrophy Other flaccid neuromuscular disease Spastic cerebral palsy		Freeze-dried Fresh-frozen	Radiograph	Radiograph	3.9 years Min. 2 years
Blanco et al.	1997	25 4M, 21F 14.3 years	Idiopathic	CD	Freeze-dried	Persistent pain Tenderness along fusion mass Significant loss of correction Instrumentation failure	Radiograph	4.3 years Min. 3 years
Yazici et al.	1997	40 14.3 years	Cerebral Palsy Spina bifida cystica Duchenne muscular dystrophy Myopathy Neuropathy Spinal muscular dystrophy	Isola	Freeze-dried	Radiograph	Radiograph Min.2 years	3.3 years
Grogan et al.	1999	87 10 M, 77F 14.3 years	Idiopathic	CD, TSRH Wisconsin, Luque	Freeze-dried	Clinical Radiograph	Radiograph	3.4 years Min. 2 years
Sponseller et al.	2000	210 14.1 years	Cerebral Palsy Myelomeningocele					
Jones et al.	2002	55 16M, 39F 14.5 years	Idiopathic	CD, TSRH	Freeze-dried	Radiograph	Radiograph	3.25 years Min. 2 years
Price et al.	2003	88	Idiopathic		Freeze-dried Composite	Radiograph	Radiograph	3.6 years Min. 2 years
Knapp et al.	2005	111 14.1 years	Idiopathic	CD TSRH, Wisconsin	Freeze-dried			6 years Min. 5 years

CD= Cotrel-Dubousset

TSRH= Texas Scottish Rite Hospital

Composite= demineralized bone matrix and aspirated bone marrow (stem cells)

Table 3. Validity Assessment

Study	Randomized	Blinding	Similar Groups	Equal Treatment	Follow-Up	Intention to Treat
Aurori et al.	No Dependent on availability of bank bone		Yes	Yes	Yes	Yes
McCarthy et al.	No autograft control		Only allograft	Only allograft	Yes	Yes
* Dodd et al.	Yes	Yes	Yes	Yes	No Follow-up at 6 months	Yes
Gersoff	No autograft control		Only allograft	Only allograft	Yes	Yes
Montgomery et al.	No Surgeon's preference		Yes	Yes	Yes	Yes
Fabry	No		Yes	Yes	No Follow-up at 1 year	Yes
Bridwell et al.	Yes 2 allograft groups	Yes	Only allograft	Only allograft	Yes	Yes
Blanco et al.	No autograft control		Only allograft	Only allograft	Yes	Yes
Yazici et al.	No autograft control		Only allograft	Only allograft	Yes	Yes
Grogan et al.	No autograft control		Only allograft	Only allograft	Yes	Yes
Sponseller et al.	No		Yes	Yes		Yes
Jones et al.	No autograft control	Yes	Only allograft	Only allograft	Yes	Yes
Price et al.	No Dependent on time of operation		Yes	Yes	Yes	Yes
Knapp et al.	No autograft control		Only allograft	Only allograft	Yes	Yes

Randomized = randomized assignment of patients and concealment of randomization

Blinding = blinding of patients, outcome assessors, or data analysts to patient allocation

Similar groups = similarities across groups at the start of the trial

Equal treatment = equal treatment of participants in each group, except for the intervention being evaluated

Follow-up = completeness and sufficient length of follow up (Minimum of 2 years)

Intention to Treat = Intention to treat analysis

* Randomized Control Trial

Blank = Not reported

included etiology of scoliosis, allograft type, instrumentation type, and follow-up time period. If multiple studies reported data from the same cohort of patients, then the earlier paper was eliminated to prevent overrepresentation of a single population data set. Table 2 presents the methodology of individual studies.

Evaluation of Study Validity

The validity of studies was assessed by the following cri-

teria: 1) randomized assignment of patients and concealment of randomization, 2) blinding of patients, clinicians, outcome assessors, or data analysts to patient allocation 3) completeness and sufficient length of follow up, which was a minimum of 2 years, 4) equal treatment of participants in each group, except for the intervention being evaluated, 5) similarities across groups at the start of the trial, and 6) intention to treat analysis.²⁵

Table 4. Outcome Data

Allograft Outcomes

Study	Participants	Pseudarthrosis	Operative Time Minutes	Blood Loss Millilitres	Pre-Op Curve Degrees	Post-Op Curve Degrees	Reduction after Surgery Pre-Post %	Loss of Correction (from post-op to f/u)	Infection Superficial	Infection Deep	Infection Unspecified
Aurori et al.	94	5.30%	221.00	1485.00					0.00%	3.19%	0.00%
McCarthy et al.	32	0.00%		1528.00	61.00			3.00	3.13%	6.25%	0.00%
Dodd et al.	20	0.00%	140.60	1536.00	58.80	31.50	46%		5.00%	0.00%	0.00%
Gersoff et al.	33	0.00%	235.00	2125.00	65.00	30.00	54.00%	3.00	9.00%	6.00%	0.00%
Montgomery et al.	12	0.00%	281.00	1740.00	80.00	39.00	51.00%	15.00	0.00%	0.00%	17.00%
Fabry et al.	99	1.00%	203.10	938.90	58.70	37.80	36.00%	3.80	0.00%	0.00%	0.00%
Bridwell et al.	40	7.50%		62.00	33.00		48.00%		3.00%	0.00%	0.00%
Blanco et al.	25	0.00%		55.50	23.20		58.00%	3.70	0.00%	0.00%	0.00%
Yazici et al.	40	2.50%	445.00	1335.00	64.00	22.00	66.00%	3.00	5.00%	0.00%	0.00%
Grogan et al.	87	1.00%			59.00	28.00	52.00%	7.00	0.00%	1.00%	0.00%
Sponseller et al.	?/210			1591.00					Only patients with infection were reported		
Jones et al.	55	1.80%				35.00		3.40			
Price et al.	28	4.00%						6.96			
	(freeze-dried)										
Price et al.	43	0.00%						2.90			
	(demineralized)										
Knapp et al.	111	2.70%			59.00	29.00	51.00%	3.50	0.00%	1.00%	0.00%
Weighted Means		2.22%	243.69	1464.21	60.43	31.02	49.42%	4.37	1.38%	1.51%	0.34%
Pop. Std Dev.		2.12%	83.23	294.89	3.82	4.88	8.34%	2.15	2.50%	1.94%	2.39%
Upper Bound		6.37%	406.82	2042.18	67.91	40.57	65.78%	8.58	6.29%	5.32%	5.04%
Lower Bound		-1.93%	80.56	886.23	52.95	21.46	33.07%	0.15	-3.53%	-2.30%	-4.35%

Autograft Outcomes

Study	Participants	Pseudarthrosis	Operative Time Minutes	Blood Loss Millilitres	Pre-Op Curve Degrees	Post-Op Curve Degrees	Reduction after Surgery Pre-Post %	Loss of Correction (from post-op to f/u)	Infection Superficial	Infection Deep	Infection Unspecified
Aurori et al.	114	4.40%	259.00	1815.00					0.00%	0.88%	0
Dodd et al.	20	0.00%	176.00	1735.00	60.40	26.50	56.00%	3	0.00%	0.00%	0
Montgomery et al.	18	6.00%	344.00	2730.00	70.00	35.00	50.00%		5.50%	0.00%	0%
Fabry et al.	83	1.00%	230.70	1062.50	58.60	33.40	43.00%	5.40	0.00%	0.00%	0%
Sponseller	?/210			2367.00					Only patients with infection were reported		
Price et al.	17	6.25%						1.06			
Weighted Means		3.17%	248.45	1,612.50	60.59	32.50	46.19%	4.39	0.42%	0.43%	0.00%
Pop. Std Dev.		2.06%	36.21	472.93	3.99	2.73	5.00%	1.61	1.46%	0.44%	0.00%
Upper Bound		7.21%	319.43	2,539.43	68.41	37.84	56.00%	7.54	3.29%	1.29%	0.00%
Lower Bound		-0.87%	177.48	685.57	52.78	27.15	36.38%	1.23	-2.45%	-0.44%	0.00%

Blank values = Data was not reported

Data Synthesis

Given the rarity of randomized trials, we summarized data as proportions and means. We calculated weighted means (weighted by sample size) along with 95% confidence intervals for each of the outcome measures.

RESULTS**Literature Search**

The initial keyword search identified 43 results, with a final count of 26 once duplicate articles were eliminated. Another five studies were identified from reference list reviews. Of these 31 studies, five were eliminated because they were either case studies, were written in a language

other than English, examined bone substitutes other than allograft, or examined the perceptions of surgeons, leaving 26 potentially eligible studies for further review. Application of the other eligibility criteria to the full text papers excluded another 12 studies, leaving 14 for final inclusion. One study was a randomized controlled trial and thirteen were observational. Three of the studies were prospective.^{1-3,11-21}

Study Validity

The validity of all studies was assessed. Of the four prospective studies, only one clearly met the criteria for a randomized control trial in that patients were randomized, the study included an autograft gold standard group, and it

was explicitly stated that outcomes were assessed by two independent assessors who were blinded. See Table 3 for validity data on each study.

Outcome Measures

Pseudarthrosis

Pseudarthrosis information was available in 13 studies (N=971). Pseudarthrosis was suspected at follow-up if participants reported persistent pain, tenderness to percussion of the fusion mass, significant loss of correction, failure of instrumentation, or radiographic evidence. The range for pseudarthrosis was 0 to 8% for allograft and 1 to 6% for autograft. The weighted mean for pseudarthrosis was 2% (95% CI 2 to 6%) for allograft and 3% (95% CI -1 to 7) for autograft.^{1-3,11,21}

Blood Loss and Operative Time

The RCT found a decrease in blood loss for allograft, although not statistically significant ($p>0.07$). Intra-operative outcome measures including blood loss were available in seven studies (N=565) and operative time was available in six studies (N= 533 patients) including the RCT. The range of blood loss was 938 to 2125 milliliters for allograft and 1063 to 2730 milliliters for autograft. The weighted mean for blood loss was 1464 milliliters (95% CI 886 to 2042) for allograft and 1612 milliliters (95% CI 686 to 2539) for autograft. The range for operative time was 141 to 256 minutes for allograft and 176 to 259 minutes for autograft. The weighted mean for operative time was 244 minutes (95% CI 81 to 407) for allograft, and 248 minutes (95% CI 177 to 319) for autograft. Three of the fourteen studies found a statistically significant reduction in operative time or blood loss with allograft.^{3,11,14} The RCT found a mean operative time of 141 minutes for allograft and 176 minutes for autograft ($p<0.001$).^{1-3,11,21}

Radiographic Indices

Of the fourteen studies, preoperative curves were available in nine studies (N=620), postoperative curves were available in nine studies (N=643), post-operative reduction was available in seven studies (N=548), and follow-up curves were available in three studies (N=653). Curves were measured by the Cobb method from either sitting or supine radiographs of the thoracolumbar spine. The two groups were comparable at the outset of the studies. The range of preoperative curves was 56 to 80 degrees for allograft and 59 to 70 degrees for autograft. The weighted mean for preoperative curves was 60 degrees (95% CI 53 to 68) for allograft and 61 degrees (95% CI 53 to 68) for autograft. The two groups were also comparable post-surgery. The range for postoperative curves was 22 to 39 degrees for allograft and 26 to 35 degrees for autograft. The weighted mean for postoperative curves was 31 degrees (95% CI 21 to 41) for allograft and 33 degrees (95% CI 27 to 38) for autograft. The postoperative reduction was similar for the two groups.

The range for postoperative reduction was 36 to 66 degrees for allograft and 43 to 56 degrees for autograft. The weighted mean was 49% (95% CI 33 to 66) for allograft and 44% (95% CI 39 to 50) for autograft. The loss of correction at follow-up was also similar for the two groups. The range for loss of correction was 3 to 15 degrees for allograft and 1 to 8 degrees for autograft. The weighted mean for the loss of correction was 4 degrees (95% CI 0 to 9) for allograft and 4 degrees (95% CI 1 to 8) for autograft. The RCT did not find any statistically significant differences between the groups for the preoperative ($p>0.71$), postoperative ($p>0.15$), or follow-up ($p>0.34$) curves.^{1-3,11-21}

Infection Rates

Infection rates for deep and superficial wounds were reported in 11 studies (N=828). The range for deep wound infections was 0% to 6% for allograft and 0 to 1% for autograft. The weighted mean for deep wound infections was 2% (95% CI -2 to 5) for allograft and 0.4% (95% CI -0.4 to 1.3) for autograft. The range for superficial infections was 0 to 9% for allograft and 0 to 6% for autograft. The weighted mean for superficial infections was 1% (95% CI -4 to 6) for allograft and 0.4% (95% CI -2.5 to 3) for autograft. The RCT found only one case of infection in the allograft group. One study examined infection rates as the only outcome measure. Of the 10 risk factors tested, degree of cognitive impairment and use of allograft were found to be the only significant risk factors for infection.^{1-3,11,21,18}

DISCUSSION

The literature on the use of allograft suggests that similar outcomes can be achieved when comparing allograft to autograft for the treatment of scoliosis. The two groups emerged with comparable rates of pseudarthrosis, operating time and blood loss, preoperative and postoperative curves, and loss of correction at follow-up. The statistically significant advantages in the allograft group were decreased operating time and blood loss.^{3,11,14} The RCT concluded that even in the presence of adequate iliac crest bone graft, allograft is superior for grafting in idiopathic scoliosis surgery.

Several limitations have been identified in the reviewed studies. First, since the risk of autograft harvesting may be higher in neuromuscular or paralytic scoliosis, four of the six studies examining this population did not include the gold standard autograft comparison group. This is reasonable, however, given that the comparison group would likely present with better health, nutrition and pulmonary function.¹⁵ Second, researchers used different criteria for the diagnosis of pseudarthrosis across studies including loss of correction, instrumentation failure, and radiographic nonunion.²⁰ Third, varying spinal instrumentation techniques may have served as a confounding factor when assessing the efficacy of allograft across studies. Finally, a follow-up interval of two years or less may be inadequate to assess the long-term stability of allograft fusion, since instrumentation failure which is a radiographic suggestion that a nonunion has

occurred may require up to 3 to 4 years to manifest.¹⁹ Failure generally occurs when the rod or screws break due to an imposed load, because of incomplete or failed bone fusion.

The evolving strengths of allograft include safety, abundant supply, comparative incorporation process as autograft, and limited adverse effects. Sterile harvesting, storage techniques and peri-operative antibiotic prophylaxis are adopted to minimize the transmission of infection. HIV transmission has been documented in only four patients who received fresh-frozen allograft from two patients²² and in no patient receiving freeze-dried or demineralized allograft.²³ Overall, the risk of HIV transmission is less than 1 per 1 million.²⁴ Further, maintaining allograft supply is inexpensive and supply in donor banks can continually be replenished from common procedures including hip operations. Finally, the potential decrease in operative time and blood loss with allograft can decrease the morbidity and mortality associated with autograft harvesting during surgery for scoliosis.

Several explanations may account for the more optimistic results in the adolescent patients versus their adult counterparts. First, children and adolescents exhibit more robust osteogenic responses overall, particularly in fracture healing. This process is analogous to allograft incorporation in spine surgery. Second, idiopathic scoliosis predominantly affects the thoracic region, which is more rigid than the lumbar region and therefore, more predisposed to fusion. Idiopathic scoliosis refers to teenagers who do not have a pathologic cause like a congenital deformed vertebral body or neurological disorder. Third, radiographic visualization of the thoracic region is quite challenging and therefore, may underestimate the rate of pseudarthrosis in children.¹⁶

This review of the literature suggests that there is a potential advantage for allograft in scoliosis surgery. However, since only one randomized controlled trial was identified, more rigorous studies must be completed before definite recommendations can be made regarding allograft. Further, future studies are needed to make specific recommendations regarding the type of allograft that will serve as most efficacious.

In conclusion, allograft is a safe procedure, overcomes some of the limitations of autograft, and has comparable outcome results as autograft. Surgery involving allograft has demonstrated a low rate of disease transmission and several safety precautions are employed to minimize these risks. Also, allograft decreases morbidity and mortality associated with autograft and overcomes the limited supply. Finally, allograft achieves similar outcomes at follow-up including rates of pseudarthrosis, operating time and blood loss, loss of correction, rate of fusion and infection. Thus, allograft is

an efficacious alternative to autograft and will undoubtedly continue to play a pivotal role in surgery for scoliosis. †

REFERENCES

1. McCarthy RE, Peek RD, Morrissy RT, Hough AJ. Allograft bone in spinal fusion in paralytic scoliosis. *The Journal of Bone and Joint Surgery* 1986;370-375.
2. Grogan DP, Kalen V, Ross TI, Guidera KJ, Pugh LI. Use of Allograft Bone for Posterior Spinal Fusion in Idiopathic Scoliosis. *Clinical Orthopaedics and Related Research*. 1999;369:273-278.
3. Fabry G. Allograft Versus Autograft Bone in Idiopathic Scoliosis Surgery: A Multivariate Statistical Analysis. *Journal of Pediatric Orthopaedics* 1991;11:465-468.
4. Prolo DJ, Rodrigo JJ. Contemporary bone graft physiology and surgery. *Clinical Orthopaedics* 1985;200:322-345.
5. Grauer JN, Beiner JM, Kwon B, Vaccaro R. The Evolution of Allograft Bone for Spinal Applications. *Orthopedics* 2005; (28) 6: 573-579.
6. Steel HH. Rib resection and spine fusion in correction of convex deformity in scoliosis. *The Journal of Bone and Joint Surgery* 1983;65A:920-925.
7. Arrington ED, Smith WJ, Chambers HG, Bucknell AL, Davino NA. Complications of iliac crest bone graft harvesting. *Clinical Orthopaedics* 1996; 329: 300-309.
8. Banwart JC, Asher MA, Hassanein RS. Iliac crest bone graft harvest donor site morbidity: A Statistical Evolution. *Spine* 1995; 20: 1055-1060.
9. Gupta AR, Shah NR, Patel TC, Grauer JN. Perioperative and long-term complications of iliac crest bone graft harvesting for spinal surgery: a quantitative review of the literature. *International Medical Journal* 2001; 8:163-166.
10. Kurz LT, Garfin SR, Booth RE Jr. Harvesting autologous iliac bone grafts. A review of complications and techniques. *Spine*. 1989;14:1324-1331.
11. Aurori BF, Weierman J, Lowell HA, Nadel CI, Parsons JR. Pseudarthrosis After Spinal Fusion for Scoliosis. *Clinical Orthopaedics and Related Research* 1985;199:153-158.
12. Dodd CAF, Fergusson CM, Freedman L, Houghton GR, Thomas D. Allograft versus autograft bone in scoliosis surgery. *The Journal of Bone and Joint Surgery* 1988;70:431-435.
13. Gersoff WK, Renshaw TS. The treatment of scoliosis in cerebral palsy by posterior spinal fusion with luque-rod segmental instrumentation. *The Journal of Bone and Joint Surgery* 1988;70:41-45.
14. Montgomery DM, Aronson DD, Lee CL, LaMont RL. Posterior Spinal Fusion: Allograft Versus Autograft Bone. *Journal of Spinal Disorders* 1990;3(4):370-375.
15. Bridwell KH, O'Brien, Lenke L, Balduz B, Blanke K. Posterior spinal fusion supplemented with only allograft bone in paralytic scoliosis. Does it work? *Spine* 1994;19:2658-2666.
16. Blanco JS, Sears CJ. Allograft bone use during instrumentation and fusion in the treatment of adolescent idiopathic scoliosis. *Spine* 1997;22:1338-1342.
17. Yazici M, Asher M. Freeze-dried Allograft for Posterior Spinal Fusion in Patients with Neuromuscular Spinal Deformities. *Spine* 1997;22(13):1467-1471.
18. Sponseller PD, LaPorte DM, Hungerford MW, Eck K, Bridwell KH, Lenke LG. Deep Wound Infection After Neuromuscular Scoliosis Surgery: A Multicenter Study of Risk Factors and Treatment Outcomes. *Spine* 2000;25:2461-2466.
19. Jones KC, Andrich J, Kuivila T, Gurd A. Radiographic outcomes using freeze-dried cancellous allograft bone for posterior spinal fusion in pediatric idiopathic scoliosis. *Journal of Pediatric Orthopaedics* 2002;22:285-289.
20. Price CT, Connolly JF, Carantzas AC, Ilyas I. Comparison of Bone Grafts for Posterior Spinal Fusion in Adolescent Idiopathic Scoliosis. *Spine* 2003;28(8):793-798.
21. Knapp DR, Jones ET, Blanco JS, Flynn JC, Price CT. Allograft Bone in Spinal Fusion for Adolescent Idiopathic Scoliosis. *Journal of Spinal Disorders* 2005;18(1):S73-S76.
22. Asselmeier MA, Caspari RB, Bottenfield S. A review of allograft processing and sterilization techniques and their role in transmission of the human immunodeficiency virus. *American Journal of Sports Medicine* 1993;21:170-175.
23. Ehrler DM, Vaccaro AR. The use of allograft bone in lumbar spine surgery. *Clinical Orthopaedics* 2000;371:38-45.
24. Buck BE, Mainini TI, Brown MD. Bone transplantation and human immunodeficiency virus. An estimate of risk of acquired immunodeficiency syndrome (AIDS). *Clinical Orthopaedics* 1989;240:129-136.
25. David Moher, Deborah J Cook, Susan Eastwood, Ingram Olkin, Drummond Rennie, Donna F Stroup, for the QUOROM Group*. Improving the quality of reports of meta-analyses of randomised controlled trials: the QUOROM statement. *Lancet* 1999; 354: 1896-900.

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