Research Article

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Clinical and CT Analysis of Lumbar Spine Arthrodesis: β-Tricalcium Phosphate Versus Demineralized Bone Matrix

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Abstract

Background: Bone graft substitutes have been developed to circumvent donor site morbidity associated with iliac crest bone graft, but sparse literature compares the efficacy of various substitutes. Two commonly used bone graft substitutes used in lumbar fusion are β-tricalcium phosphate (BTP) and demineralized bone matrix (DBM).

Methods: A retrospective review of patients who underwent instrumented posterolateral lumbar fusion was conducted by a single surgeon from January 2013 to December 2016. Patients were divided into two groups based on whether DBM or BTP as graft in conjunction with local autograft. Clinical outcomes scores were collected at a minimum of 1-year follow-up. Postoperative CT scans were evaluated to assess fusion.

Results: Forty-one patients (DBM, 21 and BTP, 20) were reviewed. No significant differences were found in terms of age, sex, body mass index, smoking, diabetes, steroids, osteoporosis, American Society of Anesthesiologists classification, number of levels fused, estimated blood loss, length of stay, or surgical time between the DBM and BTP groups. A trend was found toward lower revision surgery (zero versus 15%), improved visual analog scale scores (postoperative change of 1.81 versus 3.25; $P = 0.09$), and higher rates of fusion (90% versus 70%; $P = 0.09$) in the DBM group compared with the BTP group.

Conclusions: No significant difference was found in clinical outcomes at 1 year, with a trend toward a higher fusion rate and lower revision surgery with DBM.

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Lumbar fusion is considered the benchmark for treating a number of degenerative lumbar conditions.[1] A major clinical challenge for lumbar arthrodesis is obtaining a solid union. A symptomatic nonunion can lead to poor patient outcomes and can sometimes necessitate revision surgery.[2-4]

In the recent literature, the reported radiographic incidence for pseudarthrosis ranges between 10% and 65%.[5] Although many factors can play a role in obtaining a fusion, the choice of graft material used is a surgeon-dependent and modifiable factor for improving fusion rates. Iliac crest bone autograft (ICBG) has long been considered the benchmark graft material used in spinal fusion, given its osteoinductive, osteoconductive, and osteogenic properties. ICBG has shown reliably high fusion rates and low disease transmission and immunogenicity risks.[6] However, the complications and morbidity associated with ICBG harvest have led to the development of bone graft substitutes, enhancers, or extenders, many of which possess only osteoinductive and osteoconductive properties.[7,8] Graft selection remains an ongoing challenge for spine surgeons.

The use of bone graft substitutes in combination with locally harvested bone (lamina, spinous process, facets) has shown equivalent fusion rates compared with ICBG,[5,9] but the amount of bone that can be locally harvested can be limited. Therefore, many surgeons use bone graft extenders. Few studies have directly compared two types of bone graft extenders. Two common extenders used in lumbar procedures are β--tricalcium phosphate (BTP) and a demineralized bone matrix (DBM) allograft. DBM is allograft bone that has been acid treated to have the mineralized portion removed while maintaining the organic matrix and growth factors. It is weakly osteoconductive and osteoinductive.[10] BTP is considered an osteoconductive synthetic bone substitute but can be combined with local bone graft and/or bone marrow aspirate (BMA) for osteoinductive and osteogenic potential.[11]

The purpose of this study was to compare the clinical and radiographic outcomes of DBM and BTP in the setting of lumbar arthrodesis.

Methods

Institutional review board approval was obtained, and a retrospective chart review of patients who underwent a lumbar spinal fusion by a single surgeon (D.K.P.) was performed within the last 3 years (ie, 2013 to 2016).

Inclusion and Exclusion Criteria

We included patients who underwent instrumented lumbar posterolateral fusion with the use of either DBM (Grafton; Medtronic) or BTP (Vitoss; Stryker) for a degenerative diagnosis; were between the ages 18 and 80 years at the time of surgery; and had a minimum follow-up of 1 year, follow-up clinical outcome questionnaires (ie, Oswestry Disability Index [ODI] and visual analog scale [VAS]) available, and a lumbar CT scan available at the final follow-up period. All patients had no more than one more level decompressed compared with fused.

Patients were excluded if neither bone graft substitutes was used; if they were undergoing treatment with immunosuppressant drugs; if they did not have sufficient follow-up, if they had two or more levels decompressed compared with fusion levels; or if there was no CT scan performed or available for review. Patients treated for lumbar fracture, tumor, or infection were also excluded.

Patient Population

Eighty-five consecutive cases of lumbar fusion were reviewed initially. A total of 41 patients met our criteria for this study. Demographic data included sex, age, BMI, ASA classification, and medical comorbidities. Surgical and hospitalization data were also collected. Patient-derived clinical outcome measurements were reported using available questionnaires obtained preoperatively and postoperatively at follow-up. The surgeon (D.K.P.) obtained ODI and/or VAS as standard practice.

The primary outcome evaluated was obtaining a solid posterolateral lumbar fusion. Radiographic studies in the form of postoperative CT scans were assessed for fusion quality. Imaging was obtained as standard of care by the surgeon. No patients were required to obtain any supplemental imaging. CT scans were ordered at approximately a year on all patients regardless of plain radiographic findings.

Fusion Assessment on CT Scans

All imaging studies obtained were blinded and reviewed by two board eligible orthopaedic surgeons (ie, P.H.R. and J.G.). Each CT scan was evaluated, and each spine level was given a fusion grade on both sides (ie, right and left) based on a previously reported scale.[5] Grades were based on three radiographic findings: (1) bridging trabecular bone on at least two sequential images, (2) cortication of the peripheral edges of the fusion mass, and (3) the presence of an identifiable cleft on sequential images.

Fusion assessment was given numbered grades from 1 to 5. "Grade 1" represented definitely not fused, with radiographic finding number 3 on imaging. "Grade 2" represented probably not fused, with the absence of radiographic finding 1 or 2 and the presence of radiographic cleft on a single image but not sequential imaging. "Grade 3" was considered indeterminate, with radiographic finding 1, or 2 and 3 on a single image. "Grade 4" represented probably fused, with radiographic finding 1 and partial radiographic finding 2, with the absence of radiographic finding 3. "Grade 5" represented definitely fused, and was considered so if the patient had both radiographic finding 1 and 2, with the definite absence of radiographic finding 3. For example, one patient undergoing an L2-4 posterolateral spine instrumented fusion would have a right L2-3 grade, a left L2-3 grade, and 2 more grades for the L4-5 level. On the basis of this grading, a spine motion segment was considered fused if at least the right or the left was graded >4. In contrast, a patient was considered "fused" if at least one side in each motion segment had a score >4.

Any score of "3" or disparity between the two reviewers, a third board-certified surgeon (blinded) served as a tiebreaker.

Surgical Technique

All patients underwent a standard open posterior approach for a posterolateral lumbar fusion with pedicle screws (Stryker or Medtronic). The posterolateral fusion bed was prepared by decorticating the transverse process, lateral pars, and facet joint surfaces, at each level and side, to bleeding bone with an electric burr.

In the DBM group, approximately one 2.5 × 5 cm Grafton DBM matrix was used in combination with local bone autograft (ie, spinous process and lamina). The amount was divided equally per side. In the BTP group, 25 × 100 × 4 mm (10 mL) strip was cut in half longitudinally and soaked in 10 mL of iliac crest BMA, obtained intraoperatively from the iliac crest. This was also combined with local bone graft.

Statistical Analysis

Statistical analyses were performed with SPSS software (v.20, IBM). To assess data normality, a Kolmogorov-Smirnov test was performed. Continuous demographic data (eg, age, BMI, number of patients) were compared between the DBM and BTP groups with a two-tailed Student *t*-test. Categoric demographic data (eg, diabetes, smoking status, osteoporosis, steroid use) were compared between the groups using a Spearman correlation, whereas a chi-square test was used to compare the distribution of ASA classification of patients in each group. A chi-square test was used to determine whether an association was found between the number of levels fused and treatment group, whereas continuous postoperative data (eg, EBL, length of stay, OR time, VAS, ODI score) were compared between the DBM and BTP groups using a two-tailed Student *t*-test. A Pearson correlation was calculated to determine whether a correlation was found between the treatment group and the necessity of revision surgery. A two-sided Pearson chi-square test was used to determine whether an association was found between the number of patients fused and the bone graft material used. Independent sample Mann-Whitney *U* tests were performed to compare the distribution of the percentage of successfully fused motion segments, as well as the distribution of the percentage of successfully fused sites ("site" refers to left or right sides of the spine). Finally, chi-square tests were used to compare the proportions of fused patients, motion segments, and sites in patients undergoing a 1-, 2-, or 3-level procedure with DBM versus BTP. Unless otherwise stated, significance was set at an $\alpha < 0.05$.

Results

Demographic, Surgical, and Hospitalization Data

A total of forty-one patients met the inclusion criteria. The average age was 59 years; 70% (n = 29) were women, with a mean BMI of 30 kg/m^2 and a mean follow-up period of 15 months.

In twenty-one patients, DBM was used as bone graft extender, and in twenty patients, BTP was used. In the DBM group, 17 patients (80%) were women, with an average age of 59 years and a mean BMI of 29.7 kg/m^2. In the BTP group, 12 patients (60%) were women, with an average age 58 years and a mean BMI of 30.5 kg/m^2. No significant differences were found between the groups with regard to age, sex, BMI, smoking, diabetes, steroids, osteoporosis, and ASA classification (Table 1).

The DBM group had an average follow-up of 14 months and a total of 34 motion segments, with 57% (12) being single-level posterolateral instrumented fusions. The mean EBL was 290 cc, the average OR time was 160 minutes, and the average length of hospital stay was 2.7 days. In comparison, the BTP group had an average follow-up of 16 months and a total of 37 motion segments, with 40% (8) being single-level posterolateral instrumented fusions. The mean EBL was 342 cc, the average OR time was 150 minutes, and the average length of hospital stay was 2.8 days (Table 2). No significant differences were found between the groups with regard to the number of levels fused, EBL, hospital stay, OR time, and follow-up (Table 2).

Clinical Outcomes and Fusion Rate

No patients required revision surgery at the final follow-up period for the DBM cohort, whereas three patients in the BTP cohort (15%) required revision surgery. All three patients required surgery for symptomatic nonunion, all occurring more than 6 months after index surgery. The VAS and ODI improved in both groups during the follow-up period, with no significant difference in the

Table 1

Study Demographics

Category	DBM	BTP	*P* Value
No. of patients	21	20	0.1
Male	4	8	—
Female	17	12	—
Age	59.3	58.7	0.8
BMI	29.7	30.5	0.6
Diabetes	4	5	0.6
Smoking status	4	4	0.2
Osteoporosis	1	5	0.7
Steroid use	1	1	0.9
ASA classification			0.5
Class 2	10	13	—
Class 3	10	6	—
Class 4	1	1	—

BTP = β-tricalcium phosphate, DBM = demineralized bone matrix

Table 2

Surgical and Clinical Data

Category	DBM	BTP	*P* Value
No. of levels fused	34	37	0.5
1	12	8	—
2	5	7	—
3	4	5	—
EBL	290.5	342.0	0.4
LoS	2.7	2.8	0.8
OR time	2:40:43	2:30:27	0.3
Revision surgery (nonunion)	0	3	0.7
Follow-up	14.2	16.1	—
VAS			
Pre	6.1	6.9	0.2
Post	4.3	3.6	0.4
Change	1.81	3.25	0.09
ODI			
Pre	51.4	41.6	0.09
Post	36.9	29.4	0.2
Change	17.38	12.82	0.5

BTP = β-tricalcium phosphate, DBM = demineralized bone matrix, LoS = length of stay, ODI = Oswestry Disability Index, VAS = visual analog scale

average preoperative and follow-up scores between the DBM and BTP groups (Table 2).

CT scan assessment demonstrated that 19 DBM patients (90%) versus 14 BTP patients (70%) were considered clinically fused, $P = 0.09$. When evaluating each spinal level as a separate motion segment, CT grading showed that 32 motion segments (94%) in the DBM group were considered fused compared with 29 (78%) in the BTP group, $P = 0.4$. No significant difference was found in the comparison done by attempted fusion sites, $P = 0.3$ (Table 3).

Discussion

Graft selection in lumbar arthrodesis remains a challenge for spine surgeons. A paucity of literature exists comparing different graft expanders in lumbar spine surgery, in particular DBM and BTP. Therefore, we conducted a retrospective review of lumbar fusions performed by a single surgeon using DBM and BTP and found that both DBM and BTP were effective in achieving fusion at 1-year follow-up. We found a trend toward a higher fusion rate in DBM compared with BTP, although this difference did not reach statistical difference. In addition, BTP trended toward a higher rate of revision, although this rate did not reach statistical significance in our series.

DBM is acid-treated allograft bone that offers osteoconductive properties by maintaining its organic properties (ie, collagen) and osteoinductive properties because of the small amount of bone morphogenic protein it retains.[10] Variable fusion rates have been reported in spine surgery, ranging from 52% to 98%.[9,10,12-14] Kang et al[9] conducted a prospective, randomized study comparing commercially available DBM graft with ICBG for lumbar fusion. They reported an 86% fusion rate in single-level fusions at 2 years in the DBM group, comparable to our 90% fusion rate, and found no significant difference between the DBM and ICBG groups in terms of the fusion rate.

BTP is a synthetic bone substitute that combines type 1 collagen and tricalcium phosphate with a highly porous scaffold that supports bone growth.[11,15,16] BTP is typically augmented by BMA to add osteogenic and osteoinductive qualities. Older patients may have a lower quality and quantity of BMA available to harvest, as well as a decreased number of mesenchymal stem cells available.[17] The average age in our study was 59 years. Should our study population have been older, our observed difference between the DBM and BTP groups may have been larger.

Table 3

Fusion Rates

Category	DBM	BTP	*P* Value
Patients fused (N_{DBM}, 21; N_{BTP}, 20)	19 (90%)	14 (70%)	0.09
Motion segments fused (N_{DBM}, 34; N_{BTP}, 37)	32 (94%)	29 (78%)	0.4
Attempted fusion sites (N_{DBM}, 68; N_{BTP}, 74)	58 (85%)	49 (66%)	0.3

BTP = β-tricalcium phosphate, DBM = demineralized bone matrix

Epstein[15] conducted an observational study of the use of the same BTP as a bone graft extender in posterolateral fusion. She reported a fusion rate of 94% for single-level fusion and 67% for multilevel fusion. Importantly, Epstein did not limit the number of decompressed levels relative to the number of fused levels, potentially adding a larger effect of local autograft in her study. Lee et al[18] reported that three levels of decompression are required to provide sufficient quantity of local autograft bone for a one-level fusion. In our study, we found a fusion rate of 70% in BTP patients after limiting our patients to only those with no more than 1 level decompressed than fused, a rate similar to Epstein's findings in multilevel fusion. Our study better controlled for the effect of local autograft on the fusion rate after BTP use.

Similar to our findings, Jenis and Banco[19] found a fusion rate of 76.5% in posterolateral fusion using silicate-substituted calcium phosphate ceramic. Although silicate-substituted calcium phosphate differs slightly from BTP, both biological products are ceramic in nature. Similarly, Yi et al[20] conducted a prospective randomized noninferiority trial comparing DBM and BTP in anterior cervical discectomy and fusion. They found a trend toward higher rates of fusion in DBM patients compared with BTP patients (87% versus 72%; *P* = 0.16) when assessing fusion on CT scans, although this difference did not reach statistical significance. Similarly, we also found a trend toward higher fusion rates in patients with DBM compared with BTP in the setting of lumbar posterolateral fusion.

In our study, a 15% (n = 3) surgical revision rate for symptomatic nonunion was found for the BTP group, whereas a 0% revision rate was found for DBM patients. Three patients who underwent revision surgery did so for symptomatic nonunion and reported improved outcomes compared with preoperative scores. These patients were all then revised for the symptomatic nonunion and improved clinically soon thereafter.

Strengths of our study include utilization of a series by a single surgeon. A single surgeon series controls for surgical and technical variations from surgeon to surgeon that may affect the fusion rate. In addition, we used CT scans obtained via standard of care to assess fusion, as well as stringent criteria to assess for fusion. Compared with plain radiographs, CT scans may allow for a more complete evaluation of fusion and have been shown to have a high agreement with surgical evaluation.[21] Limitations of our study include the retrospective nature of the data collected with the inherent bias it carries. In addition, our study observed trends from which some conclusions may be drawn, but a higher power study may more definitively delineate these relationships.

In conclusion, we conducted a retrospective review comparing DBM with BTP in the setting of posterolateral fusion and found a trend toward higher fusion rates and lower revision surgery for symptomatic nonunion in the DBM group, although these differences did not reach statistical significance. Future studies should focus on increasing power and improving study design comparing bone graft substitutes because differences in fusion rates may affect the long-term outcome.

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