REVIEW ARTICLE

Effects on Clinical Outcomes of Grafts and Spacers Used in Transforaminal Lumbar Interbody Fusion: a Critical Review

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Transforaminal lumbar interbody fusion (TLIF) is a relatively new and popular spinal fusion technique that has proven very useful since its introduction. To date, fusion rates for different combinations of modalities and materials have not been thoroughly compared and assessed. In this review of published reports, 29 papers met criteria for assessing fusion rates for three different interbody spacers and four different combinations of bone grafts and extenders. The spacers included Capstone, polyether ether ketones and Telamon cages, and the grafting materials reviewed were locally harvested bone, iliac crest bone with local, local bone plus recombinant human bone morphogenetic protein 2 and a mixture of local and allograft bone. Of these, it was found that only the Capstone cage and locally harvested bone achieved statistically significant higher fusion rates (96.46% ± 2.89% and 97.07% ± 1.94% respectively) than the other modalities and materials studied. Oswestry Disability Index scores and visual pain scales were also examined as indicators of overall improvement after using each spacer and graft; the Telamon cage and local bone mixed with rhBMP-2 stood out as conferring statistically significant greater improvements according to these two scales. Our findings are that Capstone and locally harvested bone alone are relatively superior in terms of fusion rates.

Key words: Clinical outcomes; Grafts; Spacers; Spinal fusion; Transforaminal lumbar interbody fusion

Introduction

Transforaminal lumbar interbody fusion (TLIF) is a relatively new technique that has proven useful since its introduction. One clear advantage it has over other approaches is that it provides a significantly better view of the surgical field. Another benefit is that, because it comes from a posterolateral direction, it is a better approach for decompression and placement of bone graft. For these reasons, it has gained significant popularity since its introduction as a spinal fusion alternative. Studies have shown TLIF to be superior to both anterior-posterior fusion and posterior lumbar internal fixation for treating symptomatic disc degeneration[1–4], as well as a suitable procedure for correcting both isthmic spondylolisthesis[5,6] and adult degenerative scoliosis[6]. The procedure has even evolved to having a minimally invasive option that has also proven to be effective and, for some indications, even more effective than traditional TLIF[7–9]. There have been numerous published reports assessing the efficacy of cage[10,11] and screw placement[12,13], use of recombinant human bone morphogenetic protein 2 (rhBMP-2)[14,15] and other factors thought to contribute to successful fusion. It would seem only fair to consider the possibility that one combination of implants, grafts, and extenders may prove more efficient and able to attain better outcomes than others. To date fusion rates for different combinations of modalities and materials have not been thoroughly addressed.

Materials and Methods

We conducted a systematic review of published reports of all studies that focused on the TLIF procedure and provided fusion rates and clinical outcomes. The inclusion criteria for the original PubMed search were articles in "English," published in the last five years (2006–2011) and mentioning either "TLIF" or "transforaminal lumbar interbody fusion." We

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TABLE 1 Type of interbody spacer used and related outcomes (mean ± SD)

Interbody device	Number of levels	Fusion (%)	VAS change	ODI change
Capstone (Medtronic)	64	96.46 ± 2.89	5.03 ± 0.42	24.82 ± 3.75
PEEK	485	92.11 ± 6.43	4.96 ± 1.02	32.74 ± 7.02
Telamon	85	94.12 ± 8.41	5.30 ± 0.00	41.00 ± 0.00

reviewed the resulting list of 256 articles and discarded the case reports. We mined the remaining articles for data regarding modalities and materials utilized, fusion rates and variables concerning clinical outcomes. We classified modalities and materials according to the type of interbody spacer used, whether they were cage or allograft implants, and the presence and type of bone graft and extenders. We excluded any papers not citing or ambiguously stating the materials used.

We recorded fusion rates as a percentage of the total number of levels at which fusion was attempted. Any paper without precise fusion rates, such as "near 100%" were excluded. Our definition of fusion was no motion on dynamic films with evidence of bony bridging and incorporation of the graft materials as a minimum standard. Many papers exceeded this with their own particular criteria.

The specific clinical measures of outcome we assessed were the Oswestry Disability Index (ODI) and Visual Analog Scale (VAS). We included only articles that provided pre and post-operative scores for these tools so that clinical improvement between groups could be compared.

To make the final analysis, papers provided at minimum: (i) precise information about the modalities and materials utilized in the fusion listed along with fusion rates; and (ii) preferably some measure of clinical or functional outcome. We performed statistical analysis of our findings with SPSS software to measure the means and standard deviations, as well as ANOVA and Dunnett's *t*-test for significance of the data set as a whole and to compare the different modalities and materials used for fusion.

Results

In all, we included 29 papers in our review[1,5,8,10,11,14–37]. We classified the modalities materials used for fusion according to cage or spacer type and source of graft and/or bone extender used and calculated data for each independently. The interbody devices used were interbody spacers (IBS), Capstone (Medtronic, Minneapolis, MN, USA), polyether ether ketones (PEEK), and Telamon (Fenton, MO, USA). However, IBS were only mentioned in one study so we discarded this data to prevent any bias. The grafts used were: locally harvested bone (LOCAL), LOCAL with rhBMP-2, a mix of allograft and LOCAL (ALLO), and a mix of both LOCAL and autograft from the iliac crest (AUTO).

Table 1 delineates the types of interbody spacer used and at how many levels fusion was attempted with each spacer. In addition, weighted averages for fusion rates and changes in VAS and ODI are shown. It is clear that PEEK cages were used more frequently than either Capstone or Telamon; however both Capstone (Medtronic) and Telamon cages had greater fusion rates and VAS changes. Telamon cages also had greater gains in ODI scores. ANOVA showed statistically significant differences in outcomes (VAS, ODI and fusion rate) for each of the treatment modalities and materials. In other words, the outcomes with PEEK, Capstone (Medtronic) and Telamon were significantly different from the one another as demonstrated by P values much less than 0.05.

Table 2 shows a similar analysis for the different graft materials utilized. Although the AUTO group is the clear standout in number of total levels at which fusion was attempted, the LOCAL group had much higher fusion rates. The rhBMP-2 group was superior in both pain reduction and improved functionality according to ODI score. As with spacers, ANOVA showed statistically significant differences between outcomes (VAS, ODI and fusion rate) of each treatment modality. In other words, the outcomes with LOCAL, rhBMP-2, AUTO and ALLO were different from one another as demonstrated by P values much less than 0.05.

Because fusion rate was the main focus of this study, we performed Dunnett's *t*-test for both spacer and graft groups using the variable with the highest recorded fusion rate as the control variable for comparison in all three recorded outcomes. We did this to further ensure the validity of our results.

TABLE 2 Type of graft material used and related outcomes (mean ± SD)

Graft material	Number of levels	Fusion (%)	VAS change	ODI change
LOCAL	156	97.07 ± 1.94	4.31 ± 4.61	27.94 ± 1.02
rhBMP-2	209	92.54 ± 9.78	5.70 ± 0.00	39.00 ± 0.00
ALLO	293	88.32 ± 8.41	5.31 ± 1.73	36.60 ± 0.95
AUTO	404	91.16 ± 9.28	4.96 ± 0.00	22.75 ± 0.60

TABLE 3 Multiple comparisons with "Capstone" as control

Dependent variable	(I) Treatment	(J) Treatment	Mean difference (I-J)†	SE	*P* value	95% Confidence interval	
Fusion rate	PEEK	Capstone	–4.3501	0.7595	0.000	–6.0144	–2.6858
	Telamon	Capstone	–2.3357	0.9783	0.031	–4.4795	–0.1919
ODI change	PEEK	Capstone	4.2690	1.7858	0.030	0.3531	8.1848
	Telamon	Capstone	–.0475	2.2828	0.542	–7.0531	2.9581
VAS change	PEEK	Capstone	–0.0689	0.1029	0.700	–0.2945	0.1567
	Telamon	Capstone	–0.5841	0.1315	0.000	–0.8724	–0.2957

†Dunnett *t* test (2-sided).

Table 3 focuses on the interbody spacers and shows that there is no significant difference between Telamon and Capstone (Medtronic) cages according to changes in ODI scores ($P = 0.542$). It also demonstrates no significant change in VAS between PEEK and Capstone (Medtronic) cages ($P = 0.700$). All other outcomes in each comparison were significant.

Table 4 shows the same analysis for graft materials using LOCAL as the control variable. Only one comparison was non-significant, namely the difference in fusion rate between ALLO and LOCAL groups ($P = 0.291$).

Discussion

The significant cost of performing spinal fusion and the need for patient satisfaction suggest that the best means would be the one used most often. Although there are a plethora of studies looking at efficacies of single modality treatments within the TLIF category, none have really compared the outcomes according to the different modalities and materials used[38]. Our critical review identified a statistically significant difference in fusion rates, functional outcomes according to ODI scores and pain scores between different groups of patients. Despite the PEEK cage's apparent availability, we found that the Capstone (Medtronic) produces a better overall fusion rate (92.11 ± 6.43 *vs.* 96.46 ± 2.89, $P = 0.000$). While this result is significant, a previous study has shown that radiographically solid fusion does not necessarily correlate well with functional outcome, at least when the minimally invasive approach is used[17]. This observation is corroborated by patients in the PEEK group gaining better improvements in ODI scores than those in the Capstone (Medtronic) group (32.74 ± 7.02 *vs.* 24.82 ± 3.75, $P = 0.030$). However, the clear winner in both pain and ODI improvement categories appears to be the Telamon cage. However, we question the validity of these results because these data come from a single study.

Our results also challenge the belief that rhBMP-2 improves fusion[15], because the group in whom only locally harvested bone (LOCAL) was used had a higher fusion rate than did rhBMP-2 and AUTO at statistically significant level (97.07 ± 1.94 *vs.* 92.54 ± 9.78 and 91.16 ± 9.28, respectively, $P = 0.00$). As mentioned before, there were no statistically significant differences in fusion rates between LOCAL and ALLO despite these groups being significantly different overall according to ANOVA. Staying with the counterintuitive trend, despite lower fusion rates the rhBMP-2 group had statistically significant higher gains in ODI and VAS scores than did the LOCAL group, though the accuracy of this is questionable because these date are from a single source and therefore bias cannot be ruled out.

Despite our best efforts to ensure a quality review of the methods used to perform the TLIF procedure, we had to deal

TABLE 4 Multiple comparisons with "LOCAL" as control variable

Dependent variable	(I) Treatment	(J) Treatment	Mean difference (I-J)†	SE	*P* value	95% Confidence interval	
Fusion rate	rhBMP-2	LOCAL	2.9074	0.5428	0.000	1.6161	4.1987
	AUTO	LOCAL	1.7084	0.4284	0.000	0.6893	2.7275
	ALLO	LOCAL	–0.7812	0.4932	0.291	–1.9546	0.3921
ODI change	rhBMP-2	LOCAL	–2.9200	0.6460	0.000	–4.45	–1.39
	AUTO	LOCAL	–9.0720	0.4900	0.000	–10.24	–7.91
	ALLO	LOCAL	–14.6920	0.4830	0.000	–15.84	–13.54
VAS change	rhBMP-2	LOCAL	0.8684	0.0767	0.000	0.6858	1.0509
	AUTO	LOCAL	0.2402	0.0557	0.000	0.1078	0.3726
	ALLO	LOCAL	0.5166	0.0539	0.000	0.3884	0.6449

†Dunnett *t* test (2-sided).

with quite a few sources of error. Many of the studies we looked at were not randomized and none were blind. The majority were retrospective, making selection bias a tangible problem in assessing their results. Also, there is no standard format for reporting key factors in spinal fusion such as materials used, location placed and smoking status. Nor is there a standard format for reporting outcomes, making for not only a rather small sample of papers that met our criteria, but also a rather limited focus. While all groups included in this review were large enough to achieve statistical power, there are large variations between groups in the numbers of spinal levels at which fusion was attempted. Given the lack of patient matching in areas such as severity of disease, surgeon experience, and placement of grafts and cages, along with the amount of variation between cohorts, our study cannot provide any hard-line recommendations. Rather, it provides insight into an area about which many surgeons feel very strongly and strongly suggests the need to take a closer look to ensure optimization, given that we found that the common choices of PEEK cages and rhBMP-2 are not the best at achieving fusion. We recommend a further study across multiple institutions to look at this issue more closely, one which at least randomizes for cage type and graft material as well as ensuring proper patient matching across multiple confounding factors such as was the case for our study. However, using a blinding or double blinding approach to this type of research may border on unethical, as prior knowledge of materials to be used in surgery is beneficial to at least the surgeon, if not the patient.

Our study looked at several different modalities, namely use of local bone, iliac crest bone, with or without bone extenders in addition to cages such as Capstone (Medtronic), PEEK and Telamon. All achieved acceptable rates of fusion and improvements in patient functionality and pain relief. According to our results, Capstone (Medtronic) and locally harvested bone alone are relatively superior in terms of fusion rates.

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