The use of beta-tricalcium phosphate and bone marrow aspirate as a bone graft substitute in posterior lumbar interbody fusion

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Abstract

Purpose Due to the disadvantages of iliac crest bone and the poor bone quality of autograft gained from decompression surgery, alternative filling materials for posterior lumbar interbody fusion cages have been developed. β -Tricalcium phosphate is widely used in cages. However, data regarding the fusion rate of β -TCP assessed by computer tomography are currently not available.

Materials A prospective clinical trial involving 34 patients (56.7 years) was performed: 26 patients were treated with single-level, five patients double-level and three patients triple-level PLIF filled with β -TCP and bone marrow aspirate perfusion, and additional posterior pedicle screw fixation. Fusion was assessed by CT and X-rays 1 year after surgery using a validated fusion scale published previously. Functional status was evaluated with the visual analogue scale and the Oswestry Disability Index before and 1 year after surgery.

Results Forty-five levels in 34 patients were evaluated by CT and X-ray with a follow-up period of at least 1 year. Clinically, the average ODI and VAS for leg and back

scores improved significantly ($P < 0.001$). CT assessment revealed solid fusion in 12 levels (26.67 %) and indeterminate fusion in 15 levels (34.09 %). Inadequate fusion (non-union) was detected in 17 levels (38.63 %).

Conclusion The technique of PLIF using β -TCP yielded a good clinical outcome 1 year after surgery, however, a high rate of pseudoarthrosis was found in this series therefore, we do not recommend β -TCP as a bone graft substitute using the PLIF technique.

Keywords Posterior lumbar interbody fusion · Alternative graft materials · β -Tricalcium phosphate · Fusion rate · Computer tomography

Introduction

Over the last decades, the number of lumbar fusion surgeries has steadily increased [1]. For many years the iliac bone crest autograft has been the gold standard for achieving lumbar fusion [1]. It provides both the osteogenic factors and the scaffold required for fusion. However, iliac bone harvesting is associated with donor site pain, haematoma, infection, fracture of the ileum, sensory disturbance, and cosmetic impairment [2]. These complications, ranging from 1 to 39 % [2] caused by bone graft harvesting can result in disability and thus increase the recovery time and patient care costs. These facts of iliac crest graft harvesting led to the development of alternative bone graft options, such as allograft, ceramics, demineralized bone matrix, osteoinductive factors, autogenous platelet concentrate, mesenchymal stem cells, bone morphogenetic proteins and gene therapy.

The ideal bone graft substitute for spinal fusion should be osteoinductive, osteoconductive and have strong

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mechanical properties. Ceramic descendants were developed to be osteoconductive and biodegradable and sup-
pliable in unlimited quantities without donor site morbidity or risk of infection. They are non-toxic, non-immunogenic and easy to sterilize. However, their disadvantages are that they are brittle and have low shear strength. Therefore, ceramics scaffolds are used with rigid fixation, which protects them from loading forces. The most commonly used ceramic products in spinal fusion procedures are calcium phosphates such as hydroxyapatite, tricalcium phosphate, and a combination of these materials [3].

Porous β -tricalcium phosphate (β -TCP) is biocompatible and osteoconductive but has poor osteoinductivity. Therefore, biologically active tissues, like bone marrow aspirate are required when using β -TCP [3]. Bone marrow aspirate has osteopromotive potential due to the presence of osteo-progenitor cells and osteoinductive growth factors, and therefore a combination with calcium phosphates is recommended [4]. The fusion rates for β -TCP have proven to be excellent as graft expander or alone for posterolateral fusion [5, 6] and in anterior cervical fusion [7]. However, no study has investigated the use of β -TCP as filling material for posterior lumbar interbody fusion (PLIF) cages.

The purpose of the current study was to assess the effect of β -TCP as a bone graft substitute in PLIF cages. The study was performed as a prospective controlled clinical trial to determine clinical and radiological outcome using thin slice CT scans at a minimum of 1 year follow-up.

Materials

Patients with lower back pain and degenerative disc disease (DDD) and degenerative spondylolisthesis with neuronal compression between L3 and S1 were included. Patients were included only if symptoms persisted for more than 6 months despite conservative treatment. Inclusion criteria were patient age between 18 and 80 years, objective radiographic significant evidence of significant disc degeneration and neuronal compression at lumbar level involving L3/L4, L4/L5 and L5/S1 as confirmed by plain films and magnetic resonance imaging (MRI) or computer tomography (CT). Exclusion criteria were presence of infection of the spine, past or present, tumor, metabolic bone disease, spondylolisthesis greater than Grade I according to Meyerding or significant bony defect in the lumbar spine. Physical therapy was started on postoperative day two for all patients. The patients were instructed to avoid bending, lifting, stooping, and twisting for the first 3 months and heavy lifting for the first 6 months.

The study was approved by the local ethics committee and all patients gave informed consent prior to participation.

PLIF-cage design

The Plivios-Chronos cage (Synthes, Switzerland, Oberdorf) is a Polyether ether ketone (PEEK) cage prefilled with β -TCP (Chronos, Synthes, Switzerland, Oberdorf). Its surfaces are designed to match vertebral anatomy and restore lordosis to reliably restore normal spinal alignment, stability and provide optimal conditions for fusion. Primary stability is achieved by means of sharp teeth on the superior and inferior surfaces of the cage. The Plivios-Chronos cage was implanted in all patients. This cage is prefilled with a β -TCP bloc which was vacuum-impregnated with bone marrow aspirate gained from the iliac crest before implantation. A trocar was placed in the iliac crest after skin incision and 20 ml of bone marrow were aspirated by a syringe and applied into the vacuum perfusion device provided. Chronos is a 100 % synthetic product with macropores of a defined size (100–500 μ m) in order to facilitate bony ingrowth. The β -TCP (Chronos) used in the current study has a porosity of 60 % for the granules and 70 % for the preformed shapes. The macropores range from mainly 100–500 μ m. It is a fully synthetic and resorbable bone graft substitute with a compressive strength similar to that of cancellous bone. The interconnected porous structure of Chronos acts as an osteoconductive matrix for the ingrowth of bone cells and blood vessels.

Surgical approach

All PLIF procedures were performed by the same surgeon (CMB). The PLIF technique was performed in a standardized technique. First the pedicle screws (ClickX, Synthes, Switzerland, Oberdorf) are placed under fluoroscopic control. The extent of dorsal decompression was adapted to the clinical and anatomic necessities based on preoperative imaging. A medial facetectomy was performed and the nerve root was mobilized medially to get access to the disc space. A window was cut into the disc, large enough to place the appropriate cage avoiding excessive traction on the root. The higher the disc space, the greater was the extent of bony resection in the area of the facet joints. After removal of the disc, the endplates of the vertebrae were denuded, without weakening the subchondral bone plates to avoid implant subsidence.

Cage implantation was carried out in all cases according to a standardized operative procedure. The opposite side was distracted with the test cage of the same size. Additional distraction was achieved on the ipsilateral side by using a spreader attached to the pedicle screws.

In the current study we focused on the intervertebral space to assess fusion. The PLIF cages are prefilled with β -TCP bone bloc. We additionally filled the space medially, anteriorly and laterally to the cage with Chronos

granules. All Chronos material was perfused with bone marrow aspirate from the iliac crest. For intertransverse fusion however, local autograft was used because β -TCP granules are not appropriate for this area and the Chronos strip was not available at that time. The assessment of fusion and non-union, however, as described in the current study was only performed for the intervertebral area and not for the interspinous region.

Clinical and radiological assessments

The Oswestry Disability Index (ODI) and the visual analogue scale (VAS) were used to assess patients preoperatively and 1 year after surgery. The ODI was also assessed at 3 months follow-up. Postoperative clinical and radiological evaluations were done at discharge, 3, 6 and 12 months after surgery. Clinical and radiological evaluations were performed by an independent observer (MT). All subsequent surgeries in the lumbar spine of any type were documented. All intraoperative and postoperative complications such as infection (superficial and deep), vascular injury, dura leakage, haematoma and adjacent disc disease were documented. Intraoperative data, like blood loss, duration of hospital stay and cut-suture time were recorded.

Anteroposterior and lateral radiographs were taken at discharge and at 3, 6 and 12 months. CT scans were obtained 12 months after surgery. Bony fusion in the plane X-rays was assessed according to an established method described by Hackenberg. Criteria for fusion were bony bridging, bony continuity between endplates, trabecular structure in anterior bone bridge and lack of radiolucent lines around implants. Fusion rate was classified as “fused 3” (3 criteria positive), “probably fused 2” (2 criteria positive), “probably not fused 1” (1 criterion positive) and “pseudarthrosis” (0 criteria positive and evidence of radiolucent lines) [8].

For the CT scans a General Electric Lightspeed 16© (GE Healthcare, Wisconsin, USA) was used with 100 kV, 100 mA source, rotation 0.8 s, DFOV 15, noise index 20 and a slice thickness of 0.625 mm.

As shown in Table 1 qualitative criteria were used for assessment of fusion in the CT scan. The classification as described by Faundez et al. [9] was used to assess anterior fusion in CT scan. Approximately, 30 % of endplate to endplate bridging bone surface was required to consider the interbody fusion to be radiologically fused (A-1). A level was probably fused when bony bridging of less than 30 % was seen (A-2). The interbody fusion was indeterminate when indeterminate bony bridges were detected (A-3). No bony bridges between the two endplates as well as marginal lucencies revealed in the CT scan were classified as probably not fused (A-4). If the CT scan showed cystic lucencies, graft fragmentation and marginal lucencies on screws the level was classified as pseudoarthrosis (A-5).

For posterolateral fusion, a modification of Christensen’s classification was used [10] (Table 1). Continuous intersegmental bridging in the posterior column was classified as fused (P-1). If the CT scan revealed doubtful intersegmental bridging bone between the posterior elements the classification was fragmented (P-2). The lack of intersegmental bridging bone was defined as pseudoarthrosis (P-3) [10].

Both classification systems were further classified to a final radiological outcome scale which is mainly based on anterior fusion status [10].

1. Solid radiological fusion: anterior column: fused (A-1 >30 % bony bridges) with any fusion status of posterior column.
2. Partial radiological fusion: anterior column: probably fused (A-2 bony bridges <30 %) with any fusion status of posterior column.
3. Indeterminate fusion: anterior column: indeterminate (A-3) with any fusion status of posterior column.

Table 1 CT scan assessment scale for anterior and posterior fusion mass

Grade			Criteria/CT scan	N	%
Anterior					
A-1	Fused		Bridging bone (BB) ≥ 30 %	4	9.09
A-2	Probably fused		BB <30 %	8	18.18
A-3	Indeterminate		Indeterminate BB	15	34.09
A-4	Probably not fused		No BB + marginal lucencies	8	18.18
A-5	Pseudarthrosis		Cystic lucencies, graft fragmentation, marginal lucencies on screws	9	20.45
Posterior					
P-1	Fused		Continuous intersegmental bridging bone	6	13.64
P-2	Fragmented		Doubtful intersegmental bridging bone	18	40.91
P-3	Pseudarthrosis		No intersegmental bridging bone	20	45.45

CT evaluation of fusion at 1 year follow-up

A anterior, P posterior

4. Inadequate fusion: anterior column: probably not fused (A-4 no bony bridges, marginal lucencies) or not fused (A-5 cystic lucencies, graft fragmentation, lucencies on screws) with any fusion status of posterior column.

Fusion was also compared between patients with single level PLIF and patients with multilevel PLIF. Additionally, we investigated whether any of the patient characteristics available (age, gender, occupational status, smoker) had any impact on the outcome. As outcome we defined fusion A-3 or better evaluated by anterior CT scans at 12 months follow-up.

Statistical analysis

Data were processed using Stata (Stata Statistical Software: Release 11, StataCorp LP, College Station, TX, USA). In most cases the data were not normally distributed. Therefore, we report medians together with first and third quartile [median (Q_1 , Q_3)], if not stated otherwise. For inferential statistics, the Friedman test was used to test for longitudinal differences of more than two measures. For comparisons of two measures we used the Wilcoxon test. P values <0.05 were considered statistically significant. In the case of significant results, Wilcoxon tests were performed for post hoc analysis without correction for multiple testing.

The influence of patient characteristics on the outcome (fusion) was assessed using logistic regression (logit).

Results

The primary diagnosis for all patients was DDD or degenerative spondylolisthesis. 34 patients were enrolled in the study. In all patients PLIF and additional posterior pedicle screw fixation was performed. 26 patients underwent single-level, five double-level and three triple-level PLIF. In total 45 levels were treated, 8 levels (17.8 %) at L3/L4, 16 levels (35.6 %) at L4/L5 and 21 levels (46.6 %) at L5/S1. Mean patient age at surgery was 56.1 years (SD 12.5). 19 (44.1 %) female patients and 11 (32.4 %) smoker were included. Eight patients (23.5 %) had prior lumbar surgery. On average patients stayed 11.9 (3.9) days in hospital, while the average skin to skin duration was 217.5 (SD 69.0) min. The average blood loss was 365.9 (SD 231.4) ml per patient. 5 (14.5 %) patients encountered complications. Intervertebral cages ranging from 9 to 15 mm were used. Patient demographics and surgical parameters are shown in Table 2.

Pain assessment and ODI

ODI scores were assessed before surgery, at 3 months follow-up and at 12 months follow-up. ODI scores were

Table 2 Patient demographics and surgical parameters

Patients	
Total	34
Female	19 (44.1 %)
Male	15 (65.8 %)
Smoker	11 (32.4 %)
Skin-to-skin duration (min)	217.5 (69.0)*
Blood loss (ml)	365.9 (231.4)*
Number of treated levels	
Total	45
L3/L4	8 (17.78 %)
L4/L5	16 (35.56 %)
L5/S1	21 (46.67 %)
Prior lumbar surgeries	
DDD adjacent to a fused segment	8 (23.5 %)
Complications	
Transient paresis L5	1 (2.94 %)
Dura leakage	1 (2.94 %)
Migration of cage	1 (2.94 %)
Seroma	2 (5.88 %)
Fusion level	
Total	45
L3/L4	8 (17.78 %)
L4/L5	16 (35.56 %)
L5/S1	21 (46.67 %)
Duration of hospital stay	11.91 (3.86)*
Cage height implanted (mm)	
9	6 (13.3 %)
11	11 (24.4 %)
13	16 (35.6 %)
15	16 (35.6 %)

* Mean (SD)

available for 32 of 34 patients preoperatively and at 12 months follow-up. Of 34 ODI scores 27 were available at 3 months follow-up. Complete data from all measures was available for 27 patients.

Preoperatively, median ODI score was 62 (48, 70), which decreased to median 16 [6, 26] after 3 months and to median 14 (2, 38) at 12 months follow-up. The ODI scores at 3 and 12 months follow-up showed significant improvement as compared to preoperatively (Fig. 1) ($P = 0.0414$; Table 3).

Post hoc comparisons between the values assessed before surgery and 3 months follow-up and 12 months follow-up, respectively, were also significant ($P < 0.001$). However, the changes between 3 and 12 months follow-up were not significant ($P = 0.6130$; Table 3).

Back and leg pain assessments with VAS were performed preoperatively and at 12 months follow-up. VAS scores were available for all patients preoperatively and at 12 months follow-up. Back pain (VAS) was reduced from

Fig. 1 Box plot showing the ODI scores preoperatively and at 3 and 12 months follow-up

Table 3 Clinical outcome parameters

	Preoperative	3 months	12 months	
VAS back	8 (3)		3 (1)	$P < 0.05$
VAS leg	6 (3)		2 (2)	$P < 0.05$
ODI scores	66 (16)	24 (14)	14 (34)	$P = 0.0167$

Data expressed as median (interquartile range)

median 8 [6, 9] preoperatively to median 3 [2, 4] at 12 months follow-up. Similarly, leg pain showed median 7 [5, 8] at first assessment and median 2 [1, 3] at follow-up. Both improvements represent highly significant changes ($P < 0.001$; Table 3).

Fig. 2 Box plots showing ODI and VAS for back and leg pain with fusion and no fusion as a grouping factor

Figure 2 shows the change in ODI score, back and leg pain distinguished between fused and non-fused levels. We found no significant differences between these two groups.

Radiological assessment

X-rays were available for all patients and levels. Mean time between surgery and radiological investigations was 91.5 days at 3 months, 193.6 days at 6 months and 373.3 days at 12 months follow-up. CT scans were available for 44 of 45 levels at 12 months follow-up (mean follow-up time 373.3 days).

The fusion rate evaluated by X-ray increased from 16 (36.4 %) being probably fused or fused to 21 (47.7 %) at 12 months follow-up ($P < 0.001$; Fig. 3).

CT assessment of fusion revealed, that 27 (61.4 %) levels were fused. 17 (38.6 %) levels showed inadequate fusion anteriorly (9 pseudarthrosis, 8 probably not fused; Table 1; Fig. 4). CT assessment of fusion showed an inadequate fusion anteriorly in 14 patients. One of these patients was revised due to pseudarthrosis. Of 44 levels 20 (45.4 %) showed no intersegmental bone bridging posteriorly (Table 1).

Comparison of fusion rate between single level and multilevel PLIF showed no significant difference ($P = 0.68$). No correlation between clinical outcome and radiological fusion was observed.

Investigating the available patient characteristics (age, gender, occupational status, smoker), only smoking [odds ratio 0.105; 95 % CI (0.0220, 0.504)] had a significant impact on fusion.

Fig. 3 Showing the fusion status evaluated by X-ray 3 months, 6 months and 1 year after surgery

Fig. 4 Showing the fusion status evaluated with CT scan for anterior and posterior column of treated levels

CT assessment of fusion showed an inadequate fusion anteriorly in 14 patients.

Discussion

In the early days of spinal fusion techniques posterolateral fusion with pedicle screws was the gold standard [11]. However, with the expansion of the indications for degenerative, trauma, tumor, infectious and deformity

cases, posterolateral fusion, even when used with spinal instrumentation, was often unable to restore segmental lordosis as well as disc space height [12]. Cloward introduced the PLIF technique into spinal surgery to overcome these problems [13]. The iliac crest has been considered an appropriate source of graft to achieve solid bone fusion for the PLIF technique. It has ideal characteristics as an intervertebral graft, such as a trabecular structure, osteoconductive and osteoinductive properties. However, harvesting bone from the iliac crest not only increases

intraoperative complications, such as operation time and blood loss, but may also lead to postoperative complications, like fracture of the ileum and donor site pain for several months [2]. As a result, much effort was put on the development of alternatives. Cages have been established as intervertebral fusion device more recently [14]. Cages seem to be advantageous as compared with bone graft alone, because they provide initial distraction and segmental stability as well as axial load support [14]. As filling material, synthetic materials may be very useful because they can be provided in infinite supply, can be easily sterilized and stored, and the significant risk of disease transmission by allograft bone is avoided. However, their disadvantages are that they are brittle and have low shear strength. Therefore, ceramic scaffolds are used with rigid fixation, which protects them from loading forces. The ceramic products most commonly used as filling material for PLIF cages are calcium phosphates such as hydroxyapatite, tricalcium phosphate, and a combination of these materials.

The aim of our study was to investigate the radiological and clinical outcome after implantation of PLIF cages filled with β -TCP. Although β -TCP used for spinal fusion has been found to be satisfactory in animal models [15], lumbar posterior fusion [5] and anterior cervical fusion [16], no reports on β -TCP as the single filling material for PLIF cages have been found. Several studies have shown that there is good evidence to support the use of β -TCP as a bone graft extender for posterolateral fusion [17].

For scoliosis β -TCP is a valuable alternative to allografts as a bone extender for posterior fusion, even when large amounts of bone are needed [5]. A recently published study showed significantly higher fusion rates for hybrid graft of β -TCP combined with harvested bone sticks/autologous bone marrow aspirate than for autologous local bone graft alone in posterior lumbar fusion [6]. However, no study was found that investigated the fusion rate when using β -TCP alone as a substitute for bone in PLIF cages.

Our results showed a high rate of inadequate fusion anteriorly (17 of 44 levels; 38.6 %) assessed by CT scan. In nine levels the CT scan revealed a pseudarthrosis while in eight levels the intervertebral space was probably not fused.

To verify that the results were not biased by the number of levels treated, we compared the union rate of patients treated at only one level (64.0 %) with the union rate of patients with multilevel PLIF (57.9 %). This difference was not significant ($P = 0.68$).

Hashimoto reported on PLIF cages filled with a mixture of local morselized bone and bioactive ceramic granules that yielded a solid fusion in 23 of 25 patients within 6 months of surgery [18]. However, he investigated the fusion status with plane radiography. A retrospective study of 42 patients

treated with PLIF using local facet joint graft and pedicle screw fixation showed a fusion rate of 92.9 %. [19]. However, again postoperative plain radiographs, including flexion–extension views were obtained to assess fusion progress. A 100 % bony union rate was seen with plane radiography 12 months after PLIF using a carbon cage filled with local bone and segmental pedicle screw fixation [20], demonstrating the clinical viability of local bone as a source of bone graft in PLIF. Ito compared the bone union rate in 101 patients who received either an autologous iliac crest bone graft or a local bone graft with PLIF using carbon cages at 2 years follow-up. He found a fusion rate of 94.5 versus 95.8 % observed by plane radiography [21].

However, it was recently reported that the rate of pseudarthrosis after PLIF detected on extension CT images was significantly higher (69.1 %) than that on flexion–extension radiographs (90.7 %) [22]. Therefore, plain radiographs have less validity as compared with CT scans (Fig. 5).

The present results show similar differences between plain radiographs (pseudarthrosis rate 2.2 %) and CT evaluation (pseudarthrosis rate 38.63 %) of fusion. It is generally accepted that the gold standard for diagnosing spinal non-union is surgical exploration [23]. However, this method is not applicable in the majority of cases. It has been shown that fine-cut CT scans with reconstructions as used in the present study are moderately predictive of the presence of non-union when both facets are not fused [24]. Comparing anterior fusion evaluated by CT scan and surgical exploration fair reliability has been found [25].

There is currently no consensus on the best non-invasive means of determining spinal fusion [23]. Multiple radiological methods, like dynamic and static radiographs [8–10, 17, 23], magnetic resonance imaging [16] and CT scans [9, 26], have been used to assess fusion status. In addition, a wide variety of criteria and classification systems have been published [3, 27]. The radiologic assessment of interbody fusion using plain radiographs and flexion–extension radiographs produced much higher fusion rates than did assessment with thin-section helical computed tomography scans [27]. Therefore, our study shows higher rates of pseudarthrosis and intermediate fusion than reported by other studies using X-ray assessment of fusion. Santos et al. [27] already published data showing that the fusion rate assessed by CT is 2.5 times lower compared to plain radiographs, and 1.3–15 times lower to flexion–extension radiographs.

Lee et al. [26] showed an overall fusion rate of 90.0 % with local bone graft in PEEK cages, and of 96.2 % with local bone graft in titanium cages [28], both assessed by CT 1 year after surgery. However, the fused area of local bone inside the cages at regions exposed to endplates was only 58.5 % for PEEK cages and less than 50 % for

Fig. 5 X-ray (**a**) and CT scan (**b**, **c**) of the same patient. **a** lateral X-ray showing bony bridging anterior to the cage, bony continuity between endplates through the implants and no radiolucent lines around implants. This X-ray was classified as fused. **b**, **c** Coronal and

sagittal CT scan showing a pseudarthrosis with cystic lucencies around the cage, fragmentation of the β -TCP inside the cage and no fusion anterior to the implant. This level was classified as non-union (A-5)

titanium cages. The fused area inside the cage in the present results (61.37 %) is similar. Although there is a high rate of pseudarthrosis in the present study, the clinical outcome is similar to that published in the literature. [6–8, 10, 11, 28].

The correlation between radiographic solid fusion and favorable clinical outcome has not been fully established. Many surgeons believe that patients who achieve a radiographic solid fusion will exhibit a more positive clinical outcome than those with a non-union. However, there is no clear evidence that radiographic solid fusion is associated with better clinical outcome scores than radiographic non-union [29]. Tsutsumimoto et al. [30] demonstrated that the union group achieved better clinical results than the non-union group at the 5-year and final follow-up although no significant difference was observed at the 1- and 3-year follow-up. Additionally, the scores of LBP and leg symptoms in the union group were better than those observed in the non-union group at the final follow-up, while these scores were not significantly different between the two groups at 1-year follow-up.

Our patient sample consisted of 32 % smoker. Our results showed a high effect of smoking on fusion assessed by CT scan [odds ratio 0.105; 95 % CI (0.0220, 0.504)]. Several studies have shown a negative effect of smoking, resulting in delayed healing, increased rates of pseudarthrosis, and a negative impact on the long-term maintenance of fusion [31]. Smoking has been reported to have a negative effect on fusion and overall patient satisfaction, but no impact on the functional outcome [31].

The limitations of the present study are that the sample size is relatively small and a control group using autologous iliac crest was not included. Another limitation of the study is that it includes no long-term follow-up. However, the manufacturer states that β -TCP (Chronos) should be converted to bone in 6–18 months. Therefore, a follow-up at 1 year postoperatively was considered adequate to determine the fusion rate. Another shortcoming is that the study design was not prospective randomized. The present study was a cohort analysis and comparison with with autologous bone, mixture bone + β -TCP or using graft material outside the PLIF cages should be investigated in future studies.

Conclusion

The overall fusion rate of cages using β -TCP in PLIF was low. However, the high non-union rate was not reflected by the clinical outcome. Nevertheless, β -TCP with bone marrow aspirate perfusion is currently not recommended for the PLIF technique as described in the present study. Further research is needed to show if β -TCP in combination with autograft will show better fusion rates.

Conflict of interest None.

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