Original Article

Revision pedicle screws with impaction bone grafting: a case series

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Background: Pedicle screw fixation in spinal constructs can be subject to failure requiring revision surgery. In cases of aseptic loosening various salvage techniques have been described. Revision screws augmented with cement have become popular but are not without risks. Larger diameter screws are often used but result in reducing bone stock or expanding the pedicles. We present a novel technique of pedicle screw revision by impaction bone allografting and a case series.

Methods: The failed screws are removed. The screw track is probed to check its integrity. Milled bone allograft is funneled into the screw hole and sequentially impacted, before insertion of a replacement screw. We report a case series and describe a single case where this method has been used. Information was gathered from the electronic patient record in our hospital.

Results: Ten screws were revised in 7 patients. Mean age at first surgery was 60.86 (48–76) years. Average time between first surgery and revision was 12.6 (4.7–49.9) months. Average follow-up was 26.2 (5.7–62.2) months and no screws showed any signs of loosening.

Conclusions: Impaction grafting with bone allograft is a technique for pedicle screw salvage that can be used safely and effectively as an alternative to cemented screws, when pedicle screws have failed by aseptic loosening. It avoids the risks associated with cemented screws and in our series was successful.

Keywords: Pedicle; screw; revision; bone graft

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Introduction

A plethora of spinal conditions such as trauma, tumour, deformity and degenerative disease are treated using instrumented fixation. This commonly takes the form of pedicle screws. Other fixation methods include sublaminar wires or hooks, however, pedicle screws have been shown to create the most rigid and stable construct (1,2).

Like all metalwork, pedicle screws can fail. Aseptic loosening is a form of failure, that one comes across from time to time. This usually occurs due to failure of fusion. When pedicle screws fail, salvage may be attempted. This may take the form of a larger diameter screw; however, this will be limited by the anatomy and width of the pedicle. A longer screw may be used but this can risk anterior cortical breach and vessel injury. In the literature there are studies

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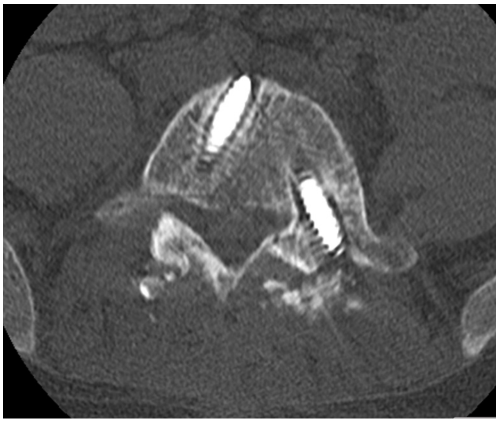

Figure 1 Image demonstrating radiolucency around the screw on computed tomography.

reporting on the use of calcium phosphate cement and Hydroxyapatite as an augment for the failed pedicle screws. The screw can be repositioned, but this often means adding on another level to the construct (2-7).

Aim of work

To our knowledge this is the first clinical paper demonstrating successful use of impaction allograft bone grafting in pedicle screw salvage. We present a case series where this method was used successfully in accordance with the STROBE reporting checklist (available at https://dx.doi.org/10.21037/jss-20-684).

Methods

A retrospective analysis of selected patients undergoing revision in our tertiary referral spinal unit was performed. All patients undergoing revision surgery were identified. Using the electronic patient record, notes were then reviewed and patients undergoing revision pedicle screw fixation using impacted allograft, for a loose screw, were selected. All patients with identified infection or rod breakage were excluded from the study. Screw loosening was defined as a minimum 1mm radiolucency on either plain X-ray or computed tomography (CT) and confirmed loose at the time of surgery (8). This loosening is demonstrated in *Figure 1*. Operation notes were reviewed and images assessed using the electronic patient record and picture archiving and communication system (PACS). Ethical approval was not required for this study as per NHS Health Research Authority guidelines. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). Informed consent was taken from all the patients.

Surgical technique

The technique was developed by the senior author (SM) who has used this technique for over 15 years for appropriate cases. In all cases the loose screws are removed, the track is probed and compared with the pre-operative CT scans. The walls of the screw tracks are checked. The base of the track is very gently assessed with the probe to keep any fibrous tissue intact, which may be obliterating the end. Small curettes (straight and curved) are used carefully, to prepare the walls of the tracks and used to remove any fibrous tissue and to achieve fresh bony surfaces.

In all cases the graft used is freeze dried, irradiated, ground bone. The bone is derived from cancellous and cortical bone of knee joints and femoral heads from deceased multi-tissue donors. It is packaged and frozen within 24 hours of donation. Aerobic and anaerobic bacterial and fungal cultures are taken and assessed against rejection criteria, including pathogenic organisms and gross contaminants. The graft is processed to remove cartilage and soft tissue, then cut and ground to small particles. It is freeze dried leaving it with less than 5% water content and irradiated to minimum dose 25 kGy in the final packaging.

The bone mill is used to grind the bone chips as much as possible to obtain a powder form (see *Figure 2*). Using a funnel and impactor (*Figure 3*), the prepared bone graft is delivered to the prepared track.

The distal end of the delivery tube is placed deep into the pedicle. Small quantities (less than 10 grams) of milled bone are placed into the funnel and the impactor rod is passed to empty the tube of graft in the vertebra. The process is repeated, each time a complete emptying of the tube is essential so as not to back fill the tube. The delivery tube is held by the other hand, directing it precisely in the direction of the screw track. The insertion tube is allowed to back out, rather than being held tight at the same depth. This allows for the track of the screw in the body and the pedicle to be filled backwards, with

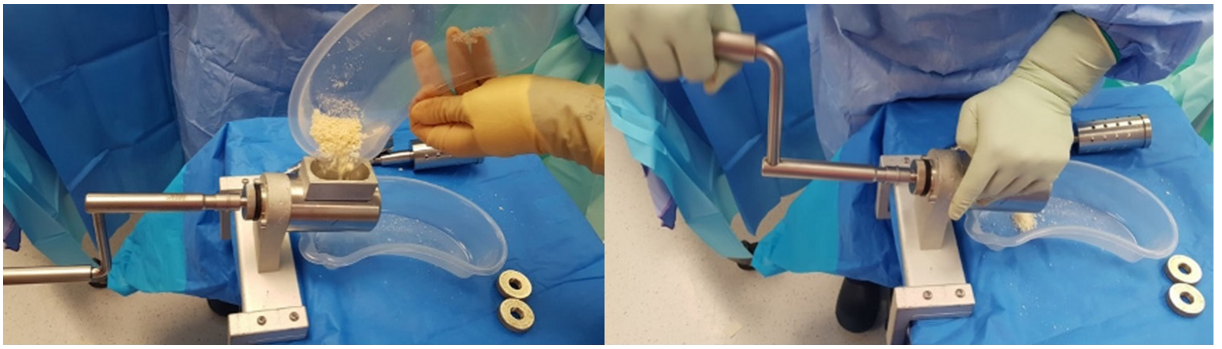

Figure 2 Image demonstrating the milling of the bone allograft.

Figure 3 Image demonstrating the funnel and impactor.

the tube finally backing out to the screw entry point. The firmness of the grafting is checked and confirmed. In some cases, grafting is guided with the image intensifier to be certain that the direction of impaction is maintained. Each screw is impacted with roughly 1.5–2 cc of bone graft. Each screw takes approximately 10 to 15 minutes, after preparing the graft and preparing the screw hole using the small curettes. Once the old screw hole is well impacted with bone graft, then a new track can be created for the revision screw, ideally under the image intensifier, in the desired direction. A tap is used to start the screw entry. The desired screw is then placed into the tract but with one important difference; a firm force is applied initially, otherwise the graft would be dislodged as the screw is turned. As the screw is in the mid pedicle one feels it requires similar force to turn as a primary screw, but sometimes firmer. There should be no toggle possible at this stage or the grafting would need repeating. The initial stability achieved by the screw/graft interface allows immediate weight bearing and loading of the screw. This is followed by the biological response of graft incorporation and re-modelling. No graft extenders or additives are used. The fusion sites are then revised following metalwork insertion. A screw placed in this manner is treated as any primary screw and can be placed at the end of construct if necessary. As long as the construct is sound, additional levels do not need to be instrumented to protect the revised screw, this is demonstrated in *Figure 4*.

Results

Our search yielded 7 patients, 4 women and 3 men. The average age at first surgery was 60.86 (48–76) years. The average time between the first surgery and the pedicle screw salvage was 12.6 (4.7–49.9) months. Ten screws were revised in our 7 patients using the technique described previously. All patients had evidence of radiological loosening (8). Six patients had negative tissue and swab cultures at the time of revision. All revised screws were radiologically assessed 6 months after the surgery to confirm incorporation of bone and lack of loosening. All patients underwent post-operative X-ray follow-up and 4 patients had post-operative CT. No patients had any evidence of metalwork failure or loosening at latest follow-

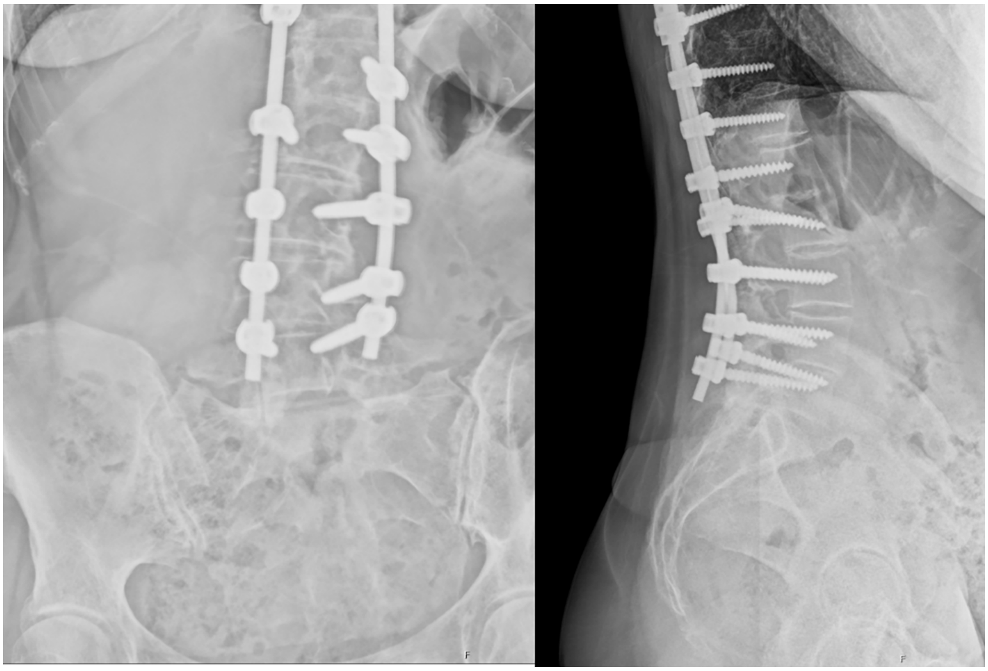

Figure 4 X-rays demonstrating incorporation of bone graft following revision of L5 at the end of a long construct.

Table 1 Summary of patient demographics

Patient	Age at 1st surgery (years)	Time between 1st surgery and revision (months)	Pathology	Smoking status	BMI (kg/m^2)	ASA grade	Intra-operative cultures	Pre-op CRP (mg/L)
A	73	10.3	Degenerative scoliosis	Ex-smoker	28.7	2	Negative	<5
B	76	6.3	Degenerative scoliosis	Ex-smoker	29.0	2	Negative	<5
C	61	5.8	Degenerative scoliosis	Never smoked	28.5	2	Negative	<5
D	52	5.6	Degenerative scoliosis	Ex-smoker	29.5	1	Negative	<5
E	48	5.7	Degenerative scoliosis	Ex-smoker	34.6	1	None recorded	<5
F	61	49.9	Degenerative scoliosis	Ex-smoker	27.0	2	Negative	<5
G	55	4.7	Spinal stenosis	Ex-smoker	25.3	2	Negative	<5

BMI, body mass index; ASA, American Society of Anesthesiologists; CRP, C-reactive protein.

up. Mean follow-up was 26.2 (5.7–62.2) months. The patient data is summarised in *Table 1*.

Patient reported outcome measures (PROMs) were available for 6 patients, these are summarised in the table below. A Student's *t*-test was performed. There was an improved in all scores following revision surgery, with a significant improvement in back pain visual analogue scale (VAS), this is summarised in *Table 2*.

A case example

We describe our first case in more detail. A 56-year-old man underwent an L4/5 posterior lumbar interbody fusion (PLIF) for bilateral posterior leg pain. A pre-operative magnetic resonance imaging (MRI) scan is demonstrated below (*Figure 5*), with immediate post-operative X-rays demonstrated in *Figure 6*.

Table 2 Summary of patient reported outcome measures with P values following a Student's *t*-test

PROM type	Pre-op	Post-op	Delta	P value
COMI score, mean (SD)	9 (1.12)	5.6 (3.9)	3.4 (4.12)	0.06
VAS back, mean (SD)	8 (1.9)	3.7 (3.6)	4.3 (4.5)	0.03
VAS leg, mean (SD)	8.3 (2.4)	5.3 (4.7)	3 (4.5)	0.10

COMI, Core Outcome Measures Index; PROM, patient reported outcome measure; SD, standard deviation; VAS, visual analogue scale.

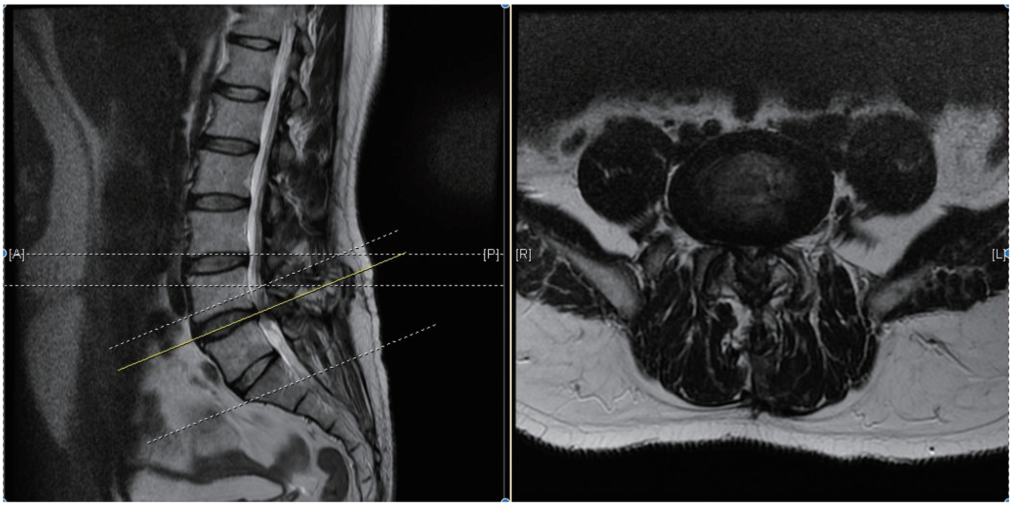

Figure 5 Pre-operative magnetic resonance scan.

He initially had a good result with relief of his radicular leg pain but continued with back pain, which became progressively more severe. A CT scan at 4 months post-operatively showed loosening of the L5 screws. This was due to mechanical failure and is demonstrated on the image below.

Following this, he underwent revision L4/5 PLIF. All four screws were found to be loose intraoperatively and were removed. The screw holes were probed and found to be intact with a sclerotic rim. Swabs were sent for infection, which later came back negative. The screw tracks were augmented with bone allograft which was impacted using the surgical technique described above. Screws of the same length and diameter were then inserted and felt subjectively to have a good hold. After insertion of the revision screws, the fusion was revised, both interbody and posterolateral. Post-operatively he was followed up with X-rays demonstrated in *Figure 7*. He underwent a CT scan at 6 months post-operatively to assess the success of the revision surgery. This showed integration of the graft and no radiological evidence of screw loosening, this is demonstrated in *Figure 8*. His back pain symptoms resolved.

Discussion

Pedicle screws are the instrument of choice and the workhorse of spinal fixation, the indications for their use is expanding and the use of pedicle screws has become a common practice. With the huge number of surgeries performed, there is an increased rate of revision surgeries as well as complications (9-11). Pedicle screw loosening is a recognised spinal complication and the options for screw rescue are not many.

We describe a method of pedicle screw salvage using impaction allograft bone graft. We have used this method of salvage with great success in our unit and continue to do so. The advantages of using this

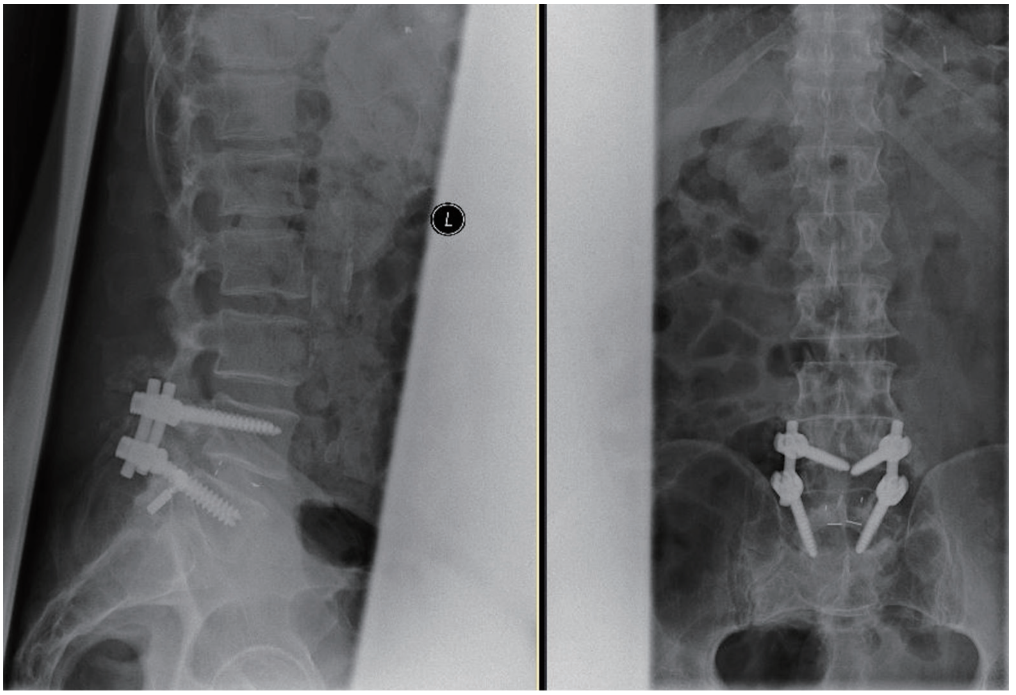

Figure 6 Post-operative X-rays.

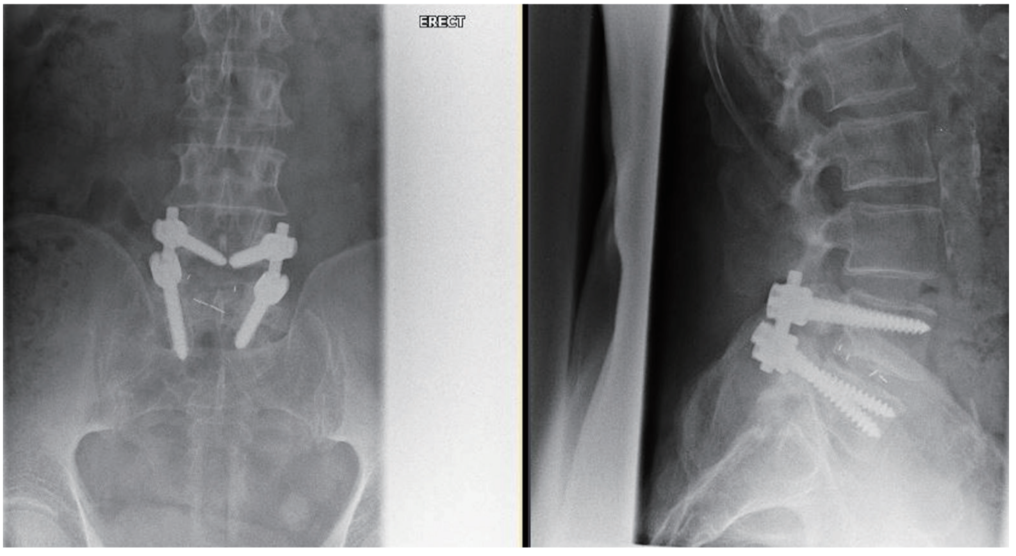

Figure 7 X-ray immediately post revision.

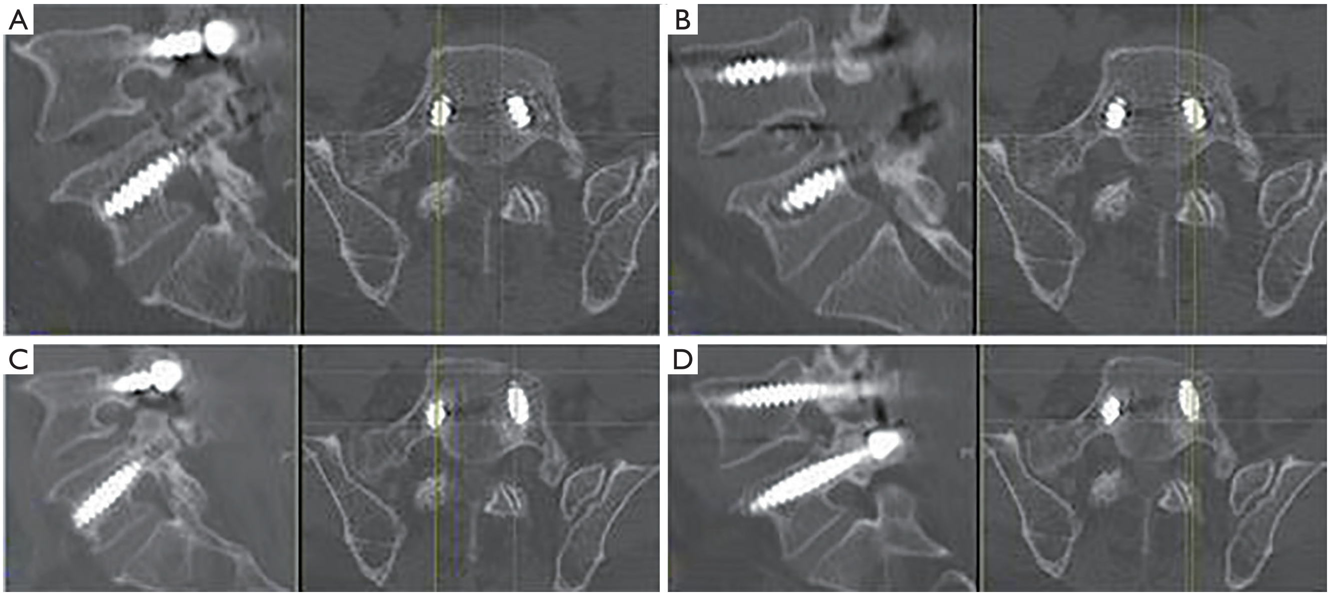

Figure 8 Computed tomography scans demonstrating pre- and post-operative appearances. (A,B) Demonstration of screw loosening; (C,D) graft integration following revision surgery.

method are that larger diameter or longer screws are not required. Polymethylmethacrylate (PMMA) has been used as an augment with fenestrated screws. PMMA has risks, such as thermal necrosis and leakage into the spinal canal causing neurological damage, should further surgery be required then there are often concerns surrounding screw extraction for cemented screws. The cases in this paper underwent open revision but this technique would lend itself to minimally invasive/percutaneous pedicle screw placement under image intensifier guidance.

The disadvantage to this technique is that impaction bone grafting requires an intact pedicle so it cannot be used in instances of pedicle fracture, or if infection is present. All our cases were failure by aseptic loosening. This provided an intact pedicle with a sclerotic rim against which bone could be impacted.

There are several papers reviewing screw pullout in cadaver models. Insertional torque is measured in these papers and used as a surrogate for pull out strength. In a paper by Polly *et al.*, different methods of screw salvage were compared, including, longer screws, larger diameter screws and screws reinserted with a shim. They demonstrated that simply removing and reinserting a screw reduced its insertional torque, increasing the length showed no statistically significant difference. Increasing the diameter had the best effect on increasing insertional torque and shims made no difference (12).

Pfeifer *et al.* compared PMMA, milled bone and matchstick bone as augments for revision pedicle screws in cadavers. The matchstick bone graft resulted in pedicle fracture and was not recommended. Milled bone resulted in approximately 70% of original pullout strength. PMMA inserted unpressurised resulted in a 149% increase in pullout strength. When the cement was pressurised, pullout strength was nearly double (5). The method of cement insertion was directly into the pedicle, followed by screw insertion. At the time of this paper cementation via fenestrated screws was not available. Choma *et al.* reviewed the outcomes of revision screws with cementation and found although all cemented screws resulted in increased pullout strength, partially fenestrated cannulated screws had the highest mean extraction torque value. They were able to remove all screws with failure occurring at the screw cement interface in every screw (13). Paré *et al.* described screw/cement failure in 88% of their pedicle screws when extracted (14). However, a study by Bullman *et al.* described failure at the cement bone interface before the screw/cement interface, resulting in catastrophic failure (15).

In our cases we did not consider using any graft additives to avoid any risk of mechanical failure. Bone morphogenetic protein-7 (BMP-7) or osteogenic protein (OP-1) are known to increase bone ingrowth in bone chamber models (16). However, the density of the new bone may be reduced because of an increase in resorption (17). An animal study of femoral impaction grafting with additional OP-1 showed improved initial graft resorption and hastened graft incorporation and remodelling (18). However, Tägil *et al.*reported one case of excessive stem subsidence in their OP-1 group, suggesting the possibility of increased early graft resorption reducing mechanical stability (19,20).

Our study is limited due the low patient numbers and the retrospective nature of the analysis. Only 4 of our 7 patients underwent a post revision CT scan. It is usual practice in our unit to obtain swabs and tissue samples for culture revision of loose screws. Due to the retrospective nature of the study, we were only able to obtain culture results for 6 of our 7 patients but all these cultures were negative. Leitner *et al.* described a 29.1% rate of subclinical infection in revision cases of spinal surgery, this was more common for cases revised for screw loosening rather than rod breakage. These patients were also more likely to have had multiple spinal surgeries and were more likely to result in failure (21). More recent papers have shown that sonication of loose screws after revision surgery resulted in infection rates of up to 42.7% (22,23). Our screws did not undergo sonication or other assessment for microscopy and culture, but our revisions in this series took place prior to the publication of these papers. Therefore, we cannot comment on subclinical infection in our series, related to screw sonication. However, all patients had normal C-reactive protein (CRP) and white cell count (WCC) prior to surgery and there were no overt signs of pyogenic infection at the time of operation. In addition to this none of our patient group had problems with wound healing or required further surgery following this initial revision.

We were able to obtain PROMs data for 6 patients. Overall, mean Core Outcome Measures Index (COMI) scores, low back pain scores and leg pain scores decreased after the second stage intervention. This trend is specially marked in the low back pain score. The biggest limitation is that the sample size (n=6) is very small. Further analysis with a larger sample size will be required to confirm this trend.

Conclusions

Impaction grafting with bone allograft is a technique for pedicle screw salvage that can be used safely and effectively as an alternative to cemented screws, when pedicle screws have failed by aseptic loosening with an intact sclerotic rim. It avoids the risks associated with cemented screws, the need to add on another level and in our series was successful radiologically and clinically. A good outcome using this method depends upon achieving adequate initial stability, which is followed by biological graft incorporation and remodelling. Freeze dried irradiated ground bone is an option for Impaction grafting.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://dx.doi.org/10.21037/jss-20-684

Data Sharing Statement: Available at https://dx.doi.org/10.21037/jss-20-684

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://dx.doi.org/10.21037/jss-20-684). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Ethical approval was not required for this study as per NHS Health Research Authority guidelines. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). Informed consent was taken from all the patients.

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