

Cement augmentation of pedicle screw fixation in spine surgery among patients with osteoporosis: a systematic review

Spine surgery among patients with osteoporosis

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Abstract

Polymethylmethacrylate-augmented screw fixation is regarded to be an effective technique however many complications can occur after augmented screw fixation due to a leakage of cement. The aim of this systematic review was to evaluate the evidence supporting the use of cement expansion of pedicle screw fixation in spine surgery among osteoporotic patients, its efficacy and the associated complications. An electronic search in MEDLINE was conducted using a search strategy of related keywords and the reference lists of the resultant articles were screened for relevant articles. Studies included in the review met the predetermined inclusion criteria of studies which were clinical trials published in English. The evidence supported an application of cement augmented screw fixation since it increased the strength of the placed screws in the osteoporotic bone. It decreased the degree of spondylolisthesis, improved the quality of life, contributed to the protection against re-collapse and reduce back pain and spinal dysfunction in osteoporotic patients.

Keywords

Vertebrae; Surgery; Injuries; Spine; Outcomes; Spondylolisthesis

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Introduction

In recent decades, osteoporosis vertebral compression fractures (OVCFs) has become progressively more common and a worldwide public health problem [1,2]. In addition to vertebral compression fractures, degenerative spinal diseases with osteoporosis may present as spinal canal stenosis and intervertebral disc protrusion [3]. Pedicle screw instrumentation is commonly used to achieve rigid internal fixation for the surgical treatment of degenerative spinal diseases in osteoporotic patients [4].

Because of the low bone mineral density, augmenting the screw fixation strength in osteoporotic patients can be a challenge for spinal surgeons [5-7]. Many complications can occur when applying pedicle screws such as pullout, migration and screw loosening [7,8]. In order to increase the strength of fixation, several techniques have been established like using bone cement-augmented pedicle screw [9-11], improving the design of the screw-rod, and increasing the diameter [12,13] or length of the screw [14,15]. Nowadays, polymethylmethacrylate (PMMA)-augmented screw fixation is regarded to be an effective technique [16,17]. Many complications can occur after PMMA augmented screw fixation due to PMMA leakages such as paraplegia, pulmonary embolism, ventricular fibrillation, and death. In order to prevent these complications, bone cement injectable cannulated pedicle screw (CICPS) has been developed [18,19]. The aim of this systematic review was to evaluate the evidence supporting the use of cement expansion of pedicle screw fixation in spine surgery among osteoporotic patients, its efficacy and the associated complications.

Material and Method

An electronic search in MEDLINE was conducted using search strategy (osteoporosis AND (“spine surgery” OR “pedicle screw fixation”) AND (cement) AND (healing OR complications OR fracture OR stability)). There were no exclusion criteria regarding years of publication, however, included studies were mainly clinical trials published in English. Population characteristics include osteoporotic patients who underwent spine surgery with cement augmentation used in pedicle screw fixation. The search was conducted in May 2018, and no limits were applied regarding the age of the patients or the type of spine injury because the studied surgical procedures are relatively recent and any available study would add significantly to the review. Included studies were aimed to evaluate the effectiveness and associated complications of PMMA cement augmentation used in pedicle screw fixation in spine surgery in patients with osteoporosis. Any study met these inclusion criteria were eligible to be selected during the primary screening stage when the researcher read the titles and abstracts of the articles and based on this reading they excluded articles which were irrelevant (have different aim) or duplicated. No previous systematic review was found in the search; only a literature review conducted in 2005 exploring the initial clinical experience of the intervention [20]. In addition, the reference list of this review was screened and any relevant studies were evaluated for inclusion in the review. Then the full texts of the eligible studies were retrieved and further studies with inconsistent outcomes were excluded. Studies with inconsistent outcomes were those with outcomes other than efficacy or complications of surgery. The

data about important characteristics and outcomes of included studies were extracted using data extraction sheet and summary of the findings was demonstrated in the Table 1. These characteristics included study design, sample size, the mean age of patients, the severity of osteoporosis, the technique of intervention. Moreover, data about the method of assessment, duration of follow up, outcomes and complications of surgery were extracted. The findings of the included studies were discussed in a qualitative approach and the effectiveness of the intervention was highlighted.

Results

The search resulted in 32 studies, of which 28 were as a result of electronic search and 4 were retrieved after the screening of the reference lists. During primary screening, 22 studies were excluded because they had irrelevant aims, in addition to one study because it was a literature review. Thus, the full texts were retrieved for nine studies, and then two studies were excluded due to inconsistent outcomes.

Finally, seven studies were included in this review as they met the inclusion criteria (Table/Figure1). Total of 313 patients with osteoporosis were recruited in the included studies. Both sexes were included, although females were predominant in most of the included studies since they constituted 70% of the studied patients.

Age of the included patients ranges from 46 up to 91 years old. Only one study mentioned its inclusion criteria regarding the severity of osteoporosis in vertebrae, as they included only grade I and grade II spondylolisthesis [21]. Two of the included studies mentioned that osteoporosis was diagnosed according to the osteoporosis diagnostic criteria of the World Health Organization's (T-score \leq -2.5) as demonstrated in Table and in Figure 2 [21,22].

Regarding type and technique of cement augmentation, four included studies assessed fixation of the pedicle screw using bone cement [21-24]. Two of included studies used kyphoplasty by PMMA cement via bilateral portals and vertebroplasty. After that, PMMA was inoculated into the vertebral body using bilateral portals [25,26]. Only one study used high and low viscosity bone cement introduced by injection syringe and special hydraulic propulsion pump [27]. Only three included studies documented the number of vertebrae recruited in fixation. Song et

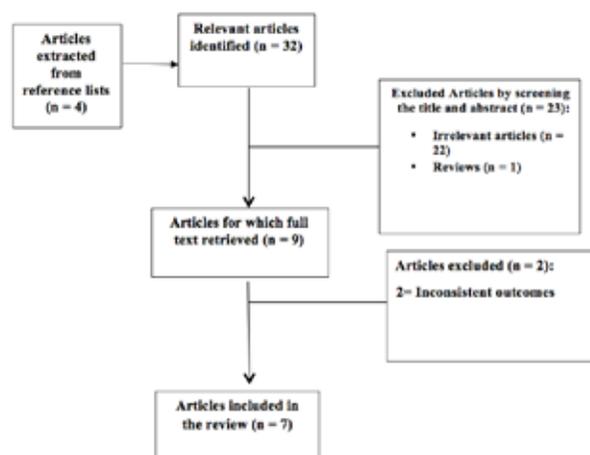


Figure 1. Flow diagram of the included studies in the systematic review

Table 1. Study characteristics and summary of the findings reported by the included studies

Study	Study design	Sample size	Age of patients (Mean or range)	Severity of osteoporosis in vertebrae	Type and technique of cement Augmentation	vertebrae involved in fixation	Assessment of treatment efficacy	Follow up period	The outcome of cement augmented screw fixation	The complications of cement augmented screw fixation
Vemula et al. [21]	A prospective study	25 participants	54 to 65 years old Mean age 61.05 years old	Grade I and Grade II Spondylolisthesis & osteoporosis BMD T-score <-2.5)	Fenestrated pedicle screw fixation with bone cement augmentation. Using bone fillers, adapters, and screw extenders	Not reported	(VAS)* (ODI)**	Follow up 6 to 25 months Mean follow-up of 18 months	Increase the pullout strength of screws placed in the osteoporotic bone. Reduction of the grade of listhesis. Significant improvement in the quality of life.	No new neurological deficits or wound-related complications
Song et al. [25]	A prospective clinical trial	51	Mean age of 78.10 years	Not reported	Kyphoplasty using PMMA*** cement via bilateral portals and Vertebralplasty, PMMA was injected into the vertebral body via bilateral portals	51 vertebrae	Not reported	Follow up 12 to 24 months	Protection against re-collapse	(PMMA) leakage, post-operative neurologic deficit and pulmonary embolism
Girardo et al. [23]	A prospective, clinical trial	52 patients	65 and 82 years .. Mean age 73.4 years	Not reported	Fenestrated pedicle screw fixation with PMMA bone cement augmentation	Not reported	VAS scale	Follow up 12- 24 months	The mean VAS score decreased from 8.5 to 4.8 Oswestry questionnaire showed a mean decrease of low back pain of 24% in post-op period	Thrombophlebitis, Death due to ventricular fibrillation
Erdem et al. [24]	A retrospective clinical trial	31	Mean age 68.1 years in group A and 67.2 years in group B	Not reported	Application of PMMA cemented pedicle screws	111 cement applications in group A, and 38 in group B	Not reported	Follow up period: Group A: 31 to 80 months (mean period 51.8 months) Group B: 26 to 61 months 15 (mean period 41.2 months)	cemented pedicle screws increase the cement volume and rate of cement-related complications	Cement leakage, pulmonary cement embolism, dyspnea, tachypnea, and neurological deficit
Zeng et al. [27]	A retrospective clinical trial	40	59 to 88 years old (mean age 66.4±9.8 years)	Not reported	High and low viscosity bone PMMA cement injected by injection syringe and special hydraulic propulsion pump	Not reported	(VAS), (ODI), injured vertebral height restoration (Cobb Angle) and bone cement leakage rate, subsequent fracture rate of vertebrae body with or without surgical treatment were measured	Follow up 0.8 to 3.0 years	bone cement leakage rate reduced obviously in high viscosity bone cement with good clinical effect and prognosis in vertebroplasty for treatment of osteoporotic thoracolumbar compression fractures	Not reported
Dai et al. [22]	A prospective, clinical trial	43	46 to 82 Mean age =???	Osteoporosis (T-score ≤-2.5)	PMMA augmentation of bone cement-injectable cannulated pedicle screws.	Not reported	Not reported	Follow up 6 to 35 months (mean of 15.7±5.6 months)	Significant reduction in back pain and improve spinal dysfunction in osteoporotic patients	Intraoperative cement leakage, no neurological complications were observed
Shen et al. [26]	A retrospective clinical trial	71	52-91 years (mean age 71.5 years)	Not reported	Percutaneous PMMA cement kyphoplasty	171 vertebrae	Change in anterior and middle vertebral column height, Co-bb angle, (VAS) and Oswestry functional score	Follow up 7-18 months (average 14 months)	Rapid and significant improvement in back pain following PKP	Lung-related complications, recurrence vertebral fractures

*VAS: Visual Analog Scale
 **ODI: Oswestry Disability Index
 ***PMMA: Polymethylmethacrylate

al. treated 51 vertebrae in 51 patients [25], while Shen et al. reported fixation of 171 vertebrae in a sample size of 71 patients with osteoporosis [26], while a total number of 149 vertebrae was involved in a study done by Erdem et al. [24].

Visual Analog Scale (VAS) score and the Oswestry Disability Index (ODI) were used in the assessment of treatment efficacy in four of the included studies [21,23,26,27]. Shen et al. used in addition to (ODI) and (VAS) score, the change in anterior and middle vertebral column height and the Cobb angle to assess the efficacy of the treatment [26]. Zeng et al. used in addition to (ODI) and (VAS) score, the Cobb Angle and leakage rate of the bone cement. Additionally, they measured the subsequent rate of the vertebral body's fracture with or without operating treatment [27]. All of the included studies reported the follow up period. The minimum duration of follow-up was 6 months and the maximum duration was 80 months.

Regarding the main studied outcome, it was reported that application of cement augmented screw fixation increased the strength of the placed screws in the osteoporotic bone. In addition, it decreased the degree of listhesis and improved the quality of life [21]. Similarly, it played an important role in protection against re-collapse [25] and result in a significant decline in back pain and spinal dysfunction in osteoporotic patients [22,26]. Girardo et al. measured the outcomes of the patients after spine surgery by the decrease in the mean VAS score and Oswestry questionnaire, as they reported the reduction in mean VAS score from 8.5 to 4.8. The Oswestry questionnaire revealed a mean reduction of low back pain of 24% in the post-op period [23]. Erdem et al. concluded that application of cemented pedicle screws in patients with osteoporosis increased the cement volume and therefore increased the proportion of cement related complications [24].

Concerning the complications of cement augmented screw fixation, Vemula et al. reported an absence of idiopathic neurological deficits or wound-related problems [21]. Song et al. in their prospective observational study, excluded those who developed complications such as PMMA leakage, pulmonary embolism and postoperative neurologic deficit [25]. Girardo et al. reported thrombophlebitis after the bone cement augmentation and occurrence of death secondary to ventricular fibrillation [23]. In Erdem et al. study, both tachycardia, tachypnea, dyspnea, cement leakage, and pulmonary cement embolism occurred during and after surgery. In addition, they reported a neurological deficit in some cases as a long-term complication [24]. Dai et al. reported intraoperative cement leakage in the absence of observed neurological complications [22]. Shen et al. reported the occurrence of lung-related complications and recurrence vertebral fractures [26].

Discussion

Pedicle screw instrumentation is commonly used in surgical treatment of degenerative spinal illnesses in osteoporotic patients [5,6]. This systematic review aimed to assess the evidence investigated the effectiveness of pedicle screw fixation and cement augmentation in spine surgery. The strength of this review included the novelty of the topic since no systematic review has been conducted in the effectiveness of this recent surgical approach.

Fixation with pedicle screw using bone cement is found to be an effective technique in surgical treatment of osteoporotic patients. It resulted in marked improvement in the quality of life, as most patients end up with a marked decrease in back pain and improvement of the spinal dysfunction [21,22,26]. In addition, it was noted that after cement augmentation there may be a significant reduction of the already existing listhesis [21]. One of the important outcomes of the application of the pedicle screw fixation is their effect in re-collapse protection [25]. Furthermore, such adverse effects of the cement pedicle screw in spine surgery as increase the rate of cement-related complications were reported [24]; however, the benefits outweigh the harms. The patients with osteoporosis usually have good outcomes with improved life quality and low relapse rate. The absence of significant neurological complaints in most cases may be considered as an evidence of the effectiveness of this procedure and its importance in the treatment of patients with osteoporosis.

Intra-operative complications such as PMMA leakage and pulmonary cement embolism [24,25] are preventable and treatable, and they could be considered as iatrogenic complications rather than being side effects of the treatment. One of the serious reported complications is pulmonary embolism [25] since it is a common postoperative complication especially in elderly patients and it also can be preventable. Other reported complications such as thrombophlebitis, pulmonary complications, and ventricular fibrillation are common postoperative problems [23,26]. The reported dyspnea, tachypnea and tachycardia [24] can be regarded as anesthesia-related complications rather than procedure-associated complications.

Limitations of this review included the lack of quality assessment of the included studies, which can provide a basis for grading the evidence obtained in this review. If the primary data of the included studies can be obtained, then the test of heterogeneity and meta-analysis techniques can be applied.

Thus, fixation with cement augmented screw has many advantages, particularly, among patients with osteoporosis and associated complications were similar to those related to major surgeries due to anesthesia, immobility, and bleeding.

Conclusions

We concluded that application of pedicle screw with bone cement augmentation is very effective in the spinal surgery of osteoporotic patients. Surgeons should choose the most appropriate modality and proper timing of spinal surgery based on patient fitness. If the benefits outweigh harm or if the patient cannot tolerate the pain the screw fixation with bone cement augmentation is the best treatment option.

Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement

All procedures performed in this study were in accordance with

the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

Conflict of interest

None of the authors received any type of financial support that could be considered potential conflict of interest regarding the manuscript or its submission.

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