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

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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 obsession 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 ob- session in spine surgery among osteoporotic patients, its ef- ficiency 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 meet 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 i 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

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 Organiz's (T-score ≤ -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
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***PMMA: Polymethylmethacrylate***  
**ODI: Oswestry Disability Index**  
*VAS: Visual Analog Scale*

### 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 vertebra | 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 |
|-------|--------------|-------------|---------------------------------|-------------------------------------|-------------------------------------------|-----------------|----------------------------------|-----------------|-----------------------------------------------|--------------------------------------------------|
| Shen et al. [26] | A retrospective clinical trial | 71 | Mean age 71.5 years | Grade I and Grade II Spondyloolisthesis & osteoporosis BMD T-score ≤ -2.5 | 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 |
| Dai et al. [22] | A prospective clinical trial | 48 | 52-91 years (mean age 71.5 years) | Percutaneous PMMA cement kyphoplasty | Change in anterior and middle vertebral column height, Cobb angle, (VAS) and Oswestry functional score | 171 vertebrae | Not reported | Follow up 7-18 months (average 14 months) | Rapid and significant improvement in back pain following PKP | Lung-related complications, recurrences vertebal fractures |
| Zeng et al. [21] | A retrospective clinical trial | 49 | Mean age 77.4 years | 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) | 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 |
| 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 | Kyphoplasty using PMMA*** cement via bilateral portals and Vertebralplasty, PMMA was injected into the vertebral body via bilateral portals | Not reported | Not reported | Follow up 12-24 months | No new neurological deficits or wound-related complications | |
| Song et al. [25] | A prospective clinical trial | 52 patients | 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 | Thromboembolism, paraplegia, pulmonary embolism, dyspnea, tachypnea, and neurological deficit | |
| Dai et al. [22] | A prospective clinical trial | 45 | 54 to 65 years (mean age 60.5 years) | Not reported | Not reported | Not reported | Not reported | Follow up 6 to 25 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 |
| Vemula et al. [21] | A prospective study | 25 participants | Mean age 71 years (mean age 64.4±9.8 years) | Not reported | Not reported | Not reported | Not reported | Follow up 26 to 75 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 |

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*VAS: Visual Analog Scale  
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***PMMA: Polymethylmethacrylate*
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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 out weight 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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