

Advances in Surgical Treatment of Osteoporotic Fractures of the Spine

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Abstract

Introduction: To highlight recent advances in the management of osteoporotic compression fractures of the spine. **Methods:** A MEDLINE search was conducted from January 1975 to October 2001. Keywords included osteoporotic compression fractures, osteoporosis and spine fractures. **Results:** Osteoporotic fractures of the spine often cause significant morbidity to the elderly individual. Diagnosis requires a detailed history and physical examination and investigations are usually required to exclude other causes of back pain. Magnetic resonance imaging (MRI) is often helpful in excluding other causes of pathologic fracture but may not be confirmatory. Conservative treatment was the traditional approach, but newer percutaneous treatments, such as vertebroplasty and kyphoplasty, are safe and simple day surgery procedures which allow for rapid recovery of symptoms and prevention of increasing spinal deformity. Neurological deficit as a result of spinal canal compromise from retropulsed fragments, though relatively uncommon, is well recognised as a cause of significant morbidity and is a major indication for open spinal surgery. Various spinal approaches including anterior or posterior decompression combined with a variety of stabilisation techniques have been reported in the literature. Rehabilitation is often required to improve physical function. **Conclusions:** Osteoporotic fractures of the spine are a common cause of morbidity in the elderly. Patients who have persistent pain despite conservative treatment require investigation to exclude other pathological causes of fracture. Percutaneous vertebroplasty and kyphoplasty are new techniques that offer much promise in the treatment of these elderly patients. Open surgery may still be required where there is significant neurologic compromise.

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Key words: Bone cement, Osteoporosis, Spinal instrumentation, Vertebral compression fracture, Vertebroplasty

Introduction

Osteoporosis is an important cause of fractures in the elderly. In the USA alone, at least 1.3 million fractures are attributed to osteoporosis a year.¹ Osteoporotic fractures increase with age.² Women are at a higher risk and are 2 to 4 times more likely to have an osteoporotic compression fracture compared to men.³ This is partly due to the fact that life expectancy is longer for women, and there are proportionally more older women than men.² The lifetime risk of a clinically evident vertebral fracture has been assessed as approximately 16% in Caucasian women and 5% in Caucasian men. The figure in women is comparable with the combined risk in women with breast, ovarian or endometrial cancer.⁴ The actual figure is likely to be higher as many patients are asymptomatic and never diagnosed.

The three most common sites of osteoporotic fractures are the distal radius, hip and spine.² Fractures of the spine have been recognised since antiquity. Hippocrates described post-traumatic deformity and its relationship to paraplegia more than 2000 years ago.⁵ While treatment was limited in those days, modern management of osteoporotic fractures includes conservative measures, such as bed rest and pain medication, and measures to treat osteoporosis. In some cases, a minimally invasive procedure like vertebroplasty or kyphoplasty is indicated while in others, surgery is necessary.

Clinical Presentation of Osteoporotic Fractures

Osteoporotic compression fractures may occur with minimal trauma due to the fragility of the osteoporotic

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bones. These patients have a wide spectrum of presentation. They may be asymptomatic and diagnosed incidentally on a radiograph after the acute event. On the opposite end of the spectrum, they may present with severe back pain, loss of height, physical deformity and varying degrees of physical limitation and loss of independence.⁶ Patients with osteoporotic compression fractures have been demonstrated to have reduced spinal motion, physical and functional performance and increased pain and psychiatric symptoms.⁷ Women with vertebral deformities have been demonstrated to have an increased risk of back pain, disability and psychosocial outcomes.⁸ Osteoporotic compression fractures have also been previously noted in the literature to be associated with neurological deficit and even paraplegia. In some cases, late onset of neurological complications have occurred as a result of progressive vertebral collapse even up to 1.5 years after the initial trauma. Furthermore, thoracic and even lumbar compression fractures have been reported to result in decreased lung capacity,^{9,10} loss of appetite and poor nutrition.¹¹ A careful physical examination is needed for elderly patients presenting with back pain. Other causes, such as mechanical disorders of the spine like lumbar spondylosis, spondylolisthesis and prolapsed disc, need to be excluded. Non-mechanical disorders, such as pathological fractures, infection and inflammatory disorders, also need to be excluded. The clinical examination may be supplemented by radiological and haematological investigations to aid in diagnosis.

Diagnostic Investigations

Osteoporosis is typically seen in the axial skeleton, proximal humerus, neck of femur, wrist and ribs. In general, there is a decreased bone density, cortical thinning and delayed fracture healing. In the spine, there may be vertical striations due to thinning of the transverse trabeculae with accentuation of the vertical striations and prominence of the endplates. "Picture framing" may be seen as a result of accentuation of the cortical outline due to endosteal and intracortical resorption.^{6,12} As a result of the decreased bone density, the intervertebral disc may protrude into the adjacent vertebral body causing bending of the endplates resulting in biconcavity.¹² Focal protrusion of disc material into the vertebral body (Schmorls nodes) may also be seen.^{6,12} Eventually, because of weakness of the vertebral structure, the osteoporotic vertebra may fracture and a wedge compression fracture is seen on the radiograph. The loss of height is usually mainly anterior resulting in a wedge-shaped appearance of the vertebra.

Microfractures which are not apparent on plain radiographs may be picked up on a bone scan. Technetium-99 labelled methylene diphosphonate or hydroxymethylene diphosphonate is given intravenously and Gamma camera

imaging is performed 2 to 3 hours later. Recent fractures are seen as areas of increased uptake and vertebral fractures may remain 'hot' for up to 2 years.¹² An alternative investigation is a magnetic resonance imaging (MRI) of the spine, which shows anatomic vertebral collapse and abnormal signal in the fractured vertebra. The signal intensity is typically decreased on the T1 weighted images and increased in the T2 weighted images in an acutely fractured vertebra due to bone oedema. MRI also has the advantage of assessing the spinal cord, nerve roots and the paravertebral soft tissue. However, similar signal intensity changes may be present in vertebral metastases, and as noted by Tan et al,¹³ misdiagnosis may occasionally occur.

For asymptomatic patients with suspected osteoporosis, ordinary radiographs are not the first line of investigation as they only demonstrate osteoporosis when it is fairly advanced. In current practice, X-ray-based absorptiometers are usually used. A dual-energy X-ray absorptiometry X-ray tube produces a two-peak energy spectrum which precisely (1% to 2%) measures the bone density. Typical sites measured are the spine, proximal femur and the wrist.

Traditional Management

Asymptomatic patients with vertebral fractures require evaluation and the priority is to maintain bone mass, improve functional status of the affected region and to prevent new fractures.⁶ Pharmacological treatments are available to treat osteoporosis and are often used in conjunction with calcium supplementation. Participation in physical therapy, exercising and attaining fitness are important ways of improving well being, mobility and flexibility. The osteoporotic spine is susceptible to fractures and patients also need to be taught work and lifestyle modifications to reduce compressive forces on the spine. This can be partly achieved by educating patients on means of avoiding stress on their backs when lifting, bending and reaching.

In the case of symptomatic vertebral compression fractures, prompt intervention can hasten recovery from pain and improve mobility.⁶ A multidisciplinary approach with individualised care is needed as the clinical symptoms vary widely. Initial management is focused on relief of pain usually with medication and bed rest. Analgesics are usually given, but narcotics and sedatives are sometimes necessary if the pain is severe. A lumbar corset or brace is useful in the early stages to control pain. Once the acute pain is reduced, active and progressive mobilisation is usually encouraged with exercises and physiotherapy given. Many elderly and neglected individuals have severe restriction of their mobility following the fracture as a result of pain, and they quickly develop severe physical disabilities as a result. In the case of persistent pain from the

fracture, patients require careful evaluation for other causes of pain. Percutaneous vertebroplasty or kyphoplasty may have a role in some of these patients.

Percutaneous Vertebroplasty—Indications and Techniques

Injection of polymethylmethacrylate (PMMA) into vertebral lesions percutaneously was first performed in France in 1984 by Deramond et al¹⁴ and was done for treatment of an aggressive angioma. Percutaneous vertebroplasty was not performed in the United States until 1994¹⁵ with the first series published by Jensen et al.¹⁶ To this point, vertebroplasty has been done to treat pain associated with compression fractures caused by osteoporosis or malignancy or less commonly due to vertebral angiomas.¹⁴

Patients selected for the procedure should have pain localised to the area of the compression fracture and should have no radicular symptoms to suggest coexistent nerve root or cord compression. In the case of multiple fractures, a bone scan or MRI would allow identification of the most appropriate level of treatment. The general health of the patient should be assessed as well as the patient's ability to lie prone for the duration of the procedure which usually lasts an hour.¹⁴

The procedure is usually done under biplane or single plane C-arm fluoroscopy. The patient is placed in a prone position and sedated. The vertebra is localised fluoroscopically and the overlying skin prepared in a sterile fashion. Local anaesthesia is given to the skin and periosteum at the entry site. A vertebroplasty needle is guided into the vertebra using a transpedicular approach. At the thoracic and lumbar levels, 10-11 G needles are usually used.^{14,16} A smaller gauge (14-15 G) may be used in the cervical spine.¹⁴ The tip is positioned in the anterior half of the vertebral body. Intraosseous venography may be performed prior to the injection of bone cement or PMMA (polymethylmethacrylate) to evaluate for communication with large venous channels.¹⁶ The needle is advanced if communication is demonstrated. Once the needle is in a satisfactory position, 5 to 10 mL of opacified PMMA is slowly injected while watching for extravasation. Commonly used opacifiers are barium sulphate and tantalum. The procedure may be repeated via the other pedicle.

Vertebroplasty for osteoporotic fractures is a generally safe procedure in experienced hands.¹⁵ The majority of patients report decreased pain and increased mobility after the procedure with up to 90% of patients describing significant pain relief.¹⁴ Complications rates are reported to be generally less than 10%.¹⁵⁻¹⁸ Other indications for vertebroplasty are symptomatic haemangiomas of the

vertebra and malignant fractures.¹⁶

Complications have included transient radiculopathy, presumably due to extravasation of cement with nerve root compression. Transient dysphagia, presumably due to extravasation of cement with oesophageal compression, has also been described.¹⁸ Foraminal stenosis as a result of extravasation of cement into the neural foramen which required surgery has been described.^{14,16} Spinal cord compression requiring urgent surgical decompression has also been reported,¹⁴ but these were in malignant fractures in which there is increased risk of cement extravasation. Leakage of cement into the paravertebral veins is not uncommon,¹⁴ and some centres inject contrast into the vertebroplasty needle prior to injection of cement to reduce the risk.¹⁶ Pulmonary embolism remains a theoretical risk but in practice is very rare.¹⁴ With proper aseptic technique, infection is extremely rare.

Both unipedicular versus bipedicular injection of PMMA have been described. Deramond et al¹⁴ performed a contralateral puncture where the PMMA fills less than 50% of the vertebral body. Some centres perform bipedicular injections routinely.¹⁶ Tohmeh et al¹⁹ published a cadaveric study in which vertebrae were injected using a unipedicular approach (6 mL cement) and bipedicular approach (total of 10 mL) and showed no difference in strength of the injected vertebrae.

From June 2000 to July 2001, a total of 30 patients with osteoporotic compression fractures of the spine who had been treated by the senior author (SB) were assessed prospectively using the SF-36 and Visual Analogue Scale (VAS) outcome scores. Patients were examined preoperatively as well as at 1 week and 1 month post-vertebroplasty. The mean age of the patients was 77.5 years (range, 56 to 94 years). The mean VAS score for back pain pre-vertebroplasty was 8.1, and this reduced to 3.6 at one week, with a further reduction to 2.9 at 1 month post-vertebroplasty. SF-36 scores for physical function, role function, bodily pain, emotional function and mental health were all improved at 1 month post-vertebroplasty compared to preoperative scores.

Case Study

Madam NDH, a 56-year-old female, had a fall and presented to the hospital on 14 March 2000. She sustained a compression fracture of T12 vertebra (Fig. 1). The initial plain lateral radiographs showed a kyphotic deformity of 17 degrees at T12. The anterior vertebral height (AVH) was 2.0 cm, while the posterior vertebral height (PVH) was 3.0 cm. She was treated conservatively for 6 months but continued to have severe back pain without neurological symptoms. Repeat radiographs on 29 August 2000 (Fig. 2) showed increasing collapse of the T12 vertebra, with an

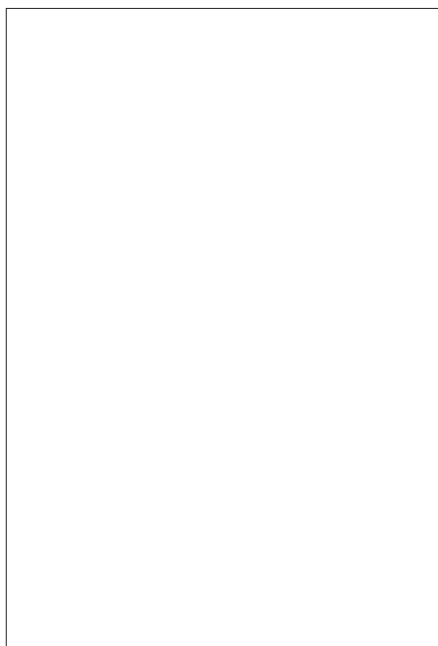


Fig. 1. Lateral radiograph of a 56-year-old female on 17 March 2000 showing a compression fracture of T12 vertebra with a 17 degree kyphotic deformity.



Fig. 2. Lateral radiograph of the same patient on 29 August 2000 showing increased collapse of the T12 vertebra with kyphotic deformity of 23 degrees.

increase in the kyphotic angle to 23 degrees, a decrease in the AVH to 1.4 cm, while the PVH was maintained at 2.9 cm. A bone scan showed increased uptake at T12, while MRI of the spine showed a decreased signal intensity on the T1 weighted image, and an increased signal intensity on the T2 weighted image consistent with a compression fracture. Percutaneous vertebroplasty under local anaesthesia was performed on 14 September 2000 using a

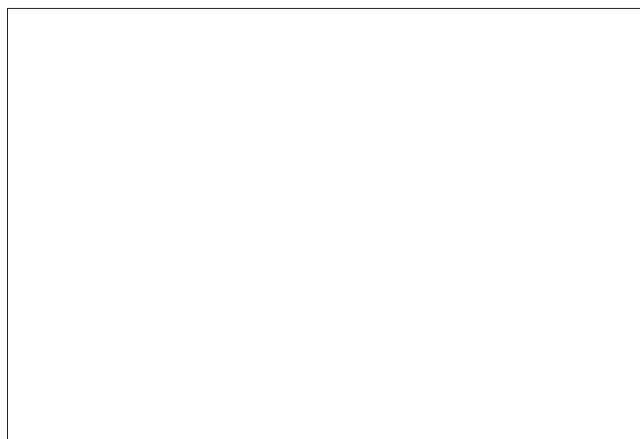


Fig. 3. Intraoperative lateral radiograph showing bipedicular placement of 2 vertebroplasty needles prior to cement injection.

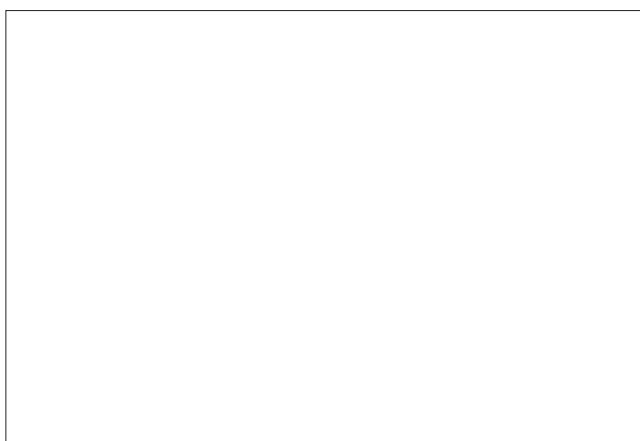


Fig. 4. Anteroposterior radiograph of the same patient showing good cement filling within the T12 vertebral body.

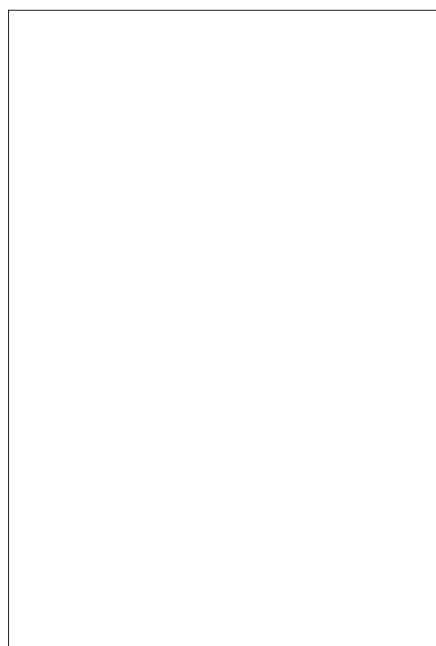


Fig. 5. Lateral radiograph showing good filling of cement with no extravasation and improvement of kyphotic deformity to 19 degrees.

bipedicular technique (Fig. 3), and a total of 7.5 mL of bone cement (Simplex P, Stryker-Howmedica) was injected. The total time taken for the procedure was 40 minutes. Postoperative anteroposterior and lateral radiographs (Figs. 4 & 5) showed good filling of cement within the vertebral body. The kyphotic deformity at T12 was reduced to 19 degrees, the AVH had increased to 1.8 cm, while the PVH was maintained at 3.1 cm. Her VAS score for back pain was reduced from 8.0 preoperatively to 5.0 postoperatively.

Kyphoplasty

Kyphoplasty is a new technique developed by Dr Mark Reiley. Unlike vertebroplasty which simply involves percutaneous injection of cement into the vertebral body, kyphoplasty requires the insertion of an inflatable bone tamp or balloon via a cannula into the vertebral body under image guidance. Once inflated, the balloon compacts the cancellous bone and increases the vertebral body height by elevating the endplates. Usually, a bilateral insertion is required. Kyphoplasty, therefore, allows some correction of the kyphotic deformity caused by anterior wedging of the collapsed vertebra. Once correction has been achieved, the balloons are deflated and removed. Cement is then injected through the cannula under low pressure to fill the cavity within the vertebral body created by the balloons. It has been reported in an ongoing multicentre study²⁰ that the average anterior height of the vertebral body was increased from $83 \pm 14\%$ of predicted height before treatment to $99 \pm 13\%$ of predicted height after treatment ($P < 0.01$). Ninety per cent of the 340 patients treated using this procedure demonstrated symptomatic and functional improvement. In a separate study, Lieberman et al²¹ reported the results of kyphoplasty in 30 patients. The mean percentage of height lost that was restored by this procedure was 35%. However, in 15 of the 70 levels treated, there was no appreciable height restoration. In both reports,^{20,21} there were no complications related to the balloon tamps.

Indications and Techniques of Open Surgery

The major indication for open surgical intervention in patients with osteoporotic compression fractures of the spine is the presence of neurologic deficit. It had previously been thought that vertebral fractures causing neurological deficit were extremely rare.²² Early literature consisted mainly of case reports.²³⁻²⁵ However, several more recent articles²⁶⁻²⁸ have detailed larger series of patients with neurological deficit as a result of spinal canal compromise due to vertebral osteoporotic fractures. Shikata et al²⁶ reported on 7 patients with varying degrees of neurological deficit as a result of vertebral fractures in patients with senile osteoporosis. All these patients were women and the duration of their symptoms ranged from 2 to 9 months. Decompression of the spinal canal was achieved by first

performing a laminectomy and facetectomy at the level of the deformed vertebra, followed by resection of the retropulsed part of the vertebral body. This was achieved by curettage lateral to the dural sac, leaving a thin shell of cortical bone which was subsequently pushed anteriorly away from the dural sac. Spinal fixation was achieved using Harrington instrumentation and sublaminar wires two segments below and above the fracture site.

Kaneda et al²⁷ reported the surgical results of 22 patients with spinal cord and/or cauda equina syndrome due to osteoporosis and delayed posttraumatic vertebral collapse. The mean age of their patients was 66 years (range, 53 to 79 years). All the patients were operated upon using anterior decompression, which consisted of resection of the collapsed vertebral body through an extrapleural-retroperitoneal approach to the thoracolumbar junction. Reconstruction was then performed using bioactive ceramic and stabilisation with the Kaneda anterior device. All patients in their series regained ambulatory abilities without support following surgery. Bladder disturbance was present in 15 patients before surgery and only 4 postoperatively. Baba et al²⁸ described 27 patients with osteoporotic vertebral collapse and late neurological complications. In their series, the duration between back trauma and symptomatic onset ranged from 1 month to 1.5 years. Progressive vertebral collapse led to increasing neurologic complications. Anterior surgery was performed in 7 patients using a variety of instrumentation. Twenty patients underwent posterior transpedicular decompression via a laminectomy, pediculotomy and medial facetectomy at the affected vertebral level, followed by stabilisation with Cotrel-Dubousset (CD) instrumentation. Seventy-eight per cent patients obtained good to excellent results. All patients with cauda equina deficits alone due to lower lumbar involvement had good to excellent results. There was no significant difference in improvement rate between those who had anterior spinal surgery and those who had posterior procedures.

Another surgical procedure that may be considered in patients with neurological deficit following an osteoporotic compression fracture of the spine is a posterior spinal shortening. Posterior spinal osteotomy had been first described for correction of flexion deformity with anterior opening by Smith-Petersen et al.²⁹ Subsequently, Thomasen³⁰ modified the procedure by shortening the spine, thereby correcting the deformity without an anterior opening. Since then, the procedure has been widely used for the correction of deformity from ankylosing spondylitis and posttraumatic kyphosis. Posterior spinal shortening was first performed for an osteoporotic compression fracture in a 74-year-old woman with a T12 vertebral collapse by Saita et al.³¹ The procedure, as described by Saita, consisted

of an initial resection of the lamina and caudal facet joints of the fractured vertebra. Pedicle screws were then inserted 2 vertebrae above and below. Resection of the pedicles of the fractured vertebra was then performed followed by decancellation of the vertebra. Compression forces were then applied until the 2 endplates came into contact with each other. This resulted in a short vertebral body and correction of the kyphosis.

A less commonly described indication for surgery in patients with osteoporotic spinal fractures is the presence of chronic back pain as a result of vertebral collapse and spinal deformity. The use of anterior spinal fusion with tricortical iliac crest graft without spinal instrumentation was reported in 4 patients by Hasegawa et al.³² The authors described the presence of an unstable pseudarthrosis at the level of the fracture. Excision of the pseudarthrosis and bone grafting led to resolution of symptoms in all their patients.

Surgery in these often very elderly patients is not without risk. Apart from the risks of anaesthesia and prolonged recumbency, there are significant risks of hardware failure when instrumentation of the osteoporotic spine is performed. Hardware pull-out may occur during surgery or after. Pedicle screw insertion in the osteoporotic spine may result in pedicle fracture. It has been suggested that screw diameters should not exceed 70% of the outer diameter of the pedicle in cases of osteoporosis where the vertebral bone mineral density is less than 0.7 g/cm.^{2,33} Various

techniques to reduce hardware pull-out include the use of multiple points of segmental fixation, the use of sublaminar wires, undertapping or not tapping at all the screw hole prior to the use of pedicle screws, combining the use of pedicle screws with the use of laminar hooks at the same level, accepting fewer degrees of deformity correction, and taking care to avoid ending the instrumentation within a kyphotic segment.³⁴

Case Study

Madam L YK, a 57-year-old female, first presented on 1 July 1997 to the orthopaedic specialist clinic with acute back pain after lifting a heavy load 2 days previously. X-rays of the lumbar spine demonstrated a wedge compression fracture of the first lumbar (L1) vertebra (Fig. 6). She was treated conservatively with medications, physical therapy and a lumbar corset. However, her symptoms continued to deteriorate. She had to quit her job as a cleaning lady 1 year later because of persistent back pain. She was unable to stand or walk for more than several minutes because of back pain which radiated down the thighs. She was unable to lift a 1 kg bag from the floor because of pain. Repeat X-rays (Fig. 7) on 15 February 2000 showed progressive collapse of the fracture with a kyphotic deformity at L1. MRI of the lumbar spine (Fig. 8) revealed cord compression at L1. Surgery was finally performed on 13 April 2000 via an anterior approach. The 11th rib was removed and an extrapleural-retroperitoneal dissection performed. Complete corpectomy of L1 was performed followed by

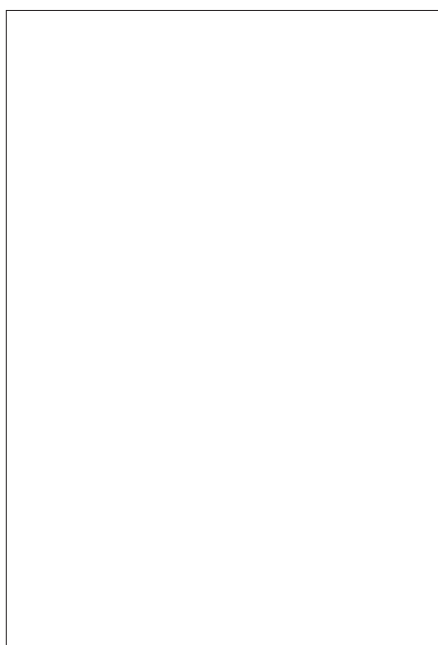


Fig. 6. Lateral radiograph of a 57-year-old female on 1 July 1997 showing a wedge compression fracture of L1 vertebra.



Fig. 7. Lateral radiograph of the same patient on 15 February 2000 showing increased collapse of the L1 vertebra.

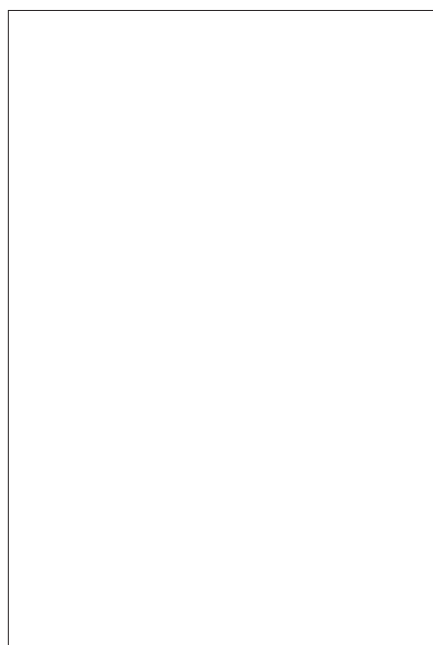


Fig. 8. T1 weighted MRI of the patient showing compression of the conus medullaris from a posteriorly retropulsed fragment of the vertebral body.

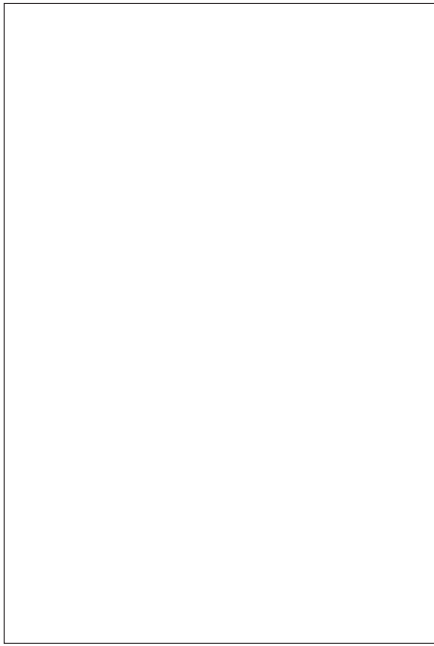


Fig. 9. Anteroposterior radiograph of the patient on 31 October 2001 18 months after anterior corpectomy and fusion with a Moss Miami cage and Kaneda device showing solid union of bone graft around the cage.

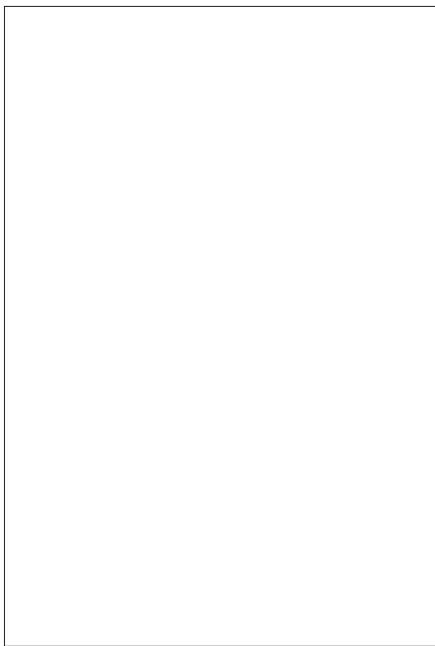


Fig. 10. Lateral radiograph of the patient on 31 October 2001 showing placement of the Moss-Miami cage and Kaneda device.

reconstruction using a Moss-Miami cage and Kaneda device. She was discharged from hospital on 27 April 2000. At final follow-up on 31 October 2001, her back pain had almost entirely resolved. She had no longer any neurological symptoms and did not require any pain medications. She was able to walk for several hours at a stretch. X-rays (Figs. 9 & 10) showed good bony union around the cage with no loss of fixation.

Conclusion

Osteoporotic fractures of the spine are a major medical problem in our ageing society. Early diagnosis and treatment of osteoporosis are necessary. When fractures do occur, they often cause significant morbidity to the individual. Time-honoured treatments of bed rest, pain medications, a lumbar corset or brace and physiotherapy remain important. However, newer treatments such as vertebroplasty and kyphoplasty are highly effective and should be considered in patients with persistent pain or increasing deformity as a result of osteoporotic spine fractures. Future studies comparing conservative versus interventional techniques on a prospective basis would be useful and of interest. Patients with significant vertebral collapse may develop neurological deficits that eventually require surgery.

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