Sabuncuoglu Serefeddin Health Science (SSHS)

ISSN: 2667-6338, 2023/Vol.5:3/31-41

TRENDS IN VERTEBRAL AUGMENTATION PRACTICE FOR OSTEOPOROTIC VERTEBRAL FRACTURE

[*1]Ahmet GÖKYAR

[*1]Faculty of Medicine, Department of Neurosurgery, Medical Faculty of Amasya, Türkiye

Review

Received: 30.11.2023, Accepted: 29.12.2023

*Corresponding author: ahmet.gokyar@amasya.edu.tr

Abstract

Osteoporosis is characterized by low bone mass, primarily affecting older individuals and a common complication is vertebral fractures. The collapse-induced height loss in vertebrae can result in spinal instability and progressive kyphotic deformity. Surgical intervention for osteoporotic vertebrae poses challenges due to poor bone quality and frequent medical comorbidities. In recent years, it has become the predominant method for vertebral augmentation in acute fractures, aiming to relieve pain, strengthen the vertebral structure, and prevent deformities by restoring height. These procedures involve percutaneous placement of cannulas into each collapsed vertebral body through a unipedicular or bipedicular approach. Novel products are emerging to strengthen vertebrae in treating osteoporotic compression fractures. Balloon kyphoplasty and vertebroplasty are widely accepted and recognized as effective vertebral augmentation methods. Treatment guidelines are evolving with the introduction of innovative systems like Vertebral Body Stenting, Titanium Mesh, and Sky Bone Expander, claiming to achieve exceptional vertebral height restoration. Controversies persist regarding the optimal timing for vertebral augmentation post-fracture. Polymethylmethacrylate cement is extensively used to stabilize fractured vertebral bodies. Additionally, new calcium phosphate-based nanocomposite cements are gaining prominence. These advancements underscore the ongoing development in the treatment of osteoporotic vertebral compression fractures. Each innovative implant introduces unique features and indications. Precise

confirmation of the source of the painful fracture is crucial for effective and safe treatment, ensuring proper timing and indication.

Key Words: Osteoporosis, Osteoporotic vertebral fracture, Vertebral augmentation

Özet

Osteoporoz, öncelikle yaşlı bireyleri etkileyen düşük kemik kütlesi ile karakterizedir ve yaygın bir komplikasyonu da vertebra kırıklarıdır. Omurgada çökmeye bağlı yükseklik kaybı, omurganın instabilitesine ve ilerleyici kifotik deformiteye neden olabilir. Osteoporotik vertebralara yönelik cerrahi müdahale, zayıf kemik kalitesi ve sık görülen tıbbi komorbiditeler nedeniyle zorluklar yaratmaktadır. Vertebra güçlendirme teknikleri son yıllarda akut vertebra kırıklarında sık kullanılan cerrahi girişim yöntemleridir. Bu cerrahi girişimlerin temel amacı ağrıyı gidermek, vertebra kemik yapısını güçlendirmek ve vertebra yüksekliği yeniden sağlayarak omurga deformitesini önlemektir. Bu işlemler unipediküler veya bipediküler yaklaşımla çökmeye başlamış vertebral gövdeye perkütan olarak yerleştirilen kanüllerle gerçekleştirilir. Vertebral güçlendirmeye yönelik yeni ürünler geliştirilmektedir. Balon kifoplasti ve vertebroplasti omurga güçlendirme yöntemleri arasında en sık uygulanan etkili tedaviler olarak kabul edilmekte ve tedavi kılavuzları oluşturulmaktadır. Kırık sonrası vertebral güçlendirmenin optimal zamanlaması konusunda tartışmalar vardır. Kemik sementi (polimetilmetakrilat) kırık vertebra stabilizasyonunda en yaygın kullanılan sementdir. Polimetilmetakrilat yanı sıra kalsiyum fosfat bazlı nanokompozit sementlerden de yararlanılmaktadır. Osteoporotik vertebra kompresyon kırıklarının tedavisinde vertebranın güçlendirilmesine yönelik yeni ürünler kullanıma girmeye devam etmektedir. Vertebral Body Stentleme, Titanyum Mesh ve Sky Bone Expander gibi geliştirilen sistemler olağanüstü vertebra yükseklik restorasyonu elde etme iddiasındadır. Bu yeni innovatif implantların her biri benzersiz özelliklere ve endikasyonlara sahiptir. Ağrılı vertebra kırık kaynağının kesin olarak belirlenmesi, uygun zamanlama ve doğru endikasyonla güvenle kullanılabilecek etkili tedavi yöntemleridir.

Anahtar Kelimeler: Osteoporozis, Osteoporotik vertebra kırıkları, Vertebra güçlendirmesi

1. Introduction

Initially defined in 1940 as a condition marked by impaired bone formation due to estrogen deficiency, osteoporosis manifests as low bone mass, particularly affecting individuals aged 50 and above. A common complication of osteoporosis is vertebral fractures, with a lifetime risk reaching 1 in 2 for women and 1 in 5 for men in this age group (Wright et al., 2014; Johnell et al., 2005).

While vertebral fractures do not typically cause significant neurological losses, they significantly restrict mobilization, particularly in older individuals, leading to increased morbidity and mortality. Annually, 70,000 admissions in the United States are attributed to osteoporotic vertebral fractures (OVCFs), with approximately one-third of cases presenting symptoms (Ensrud et al., 2011; Longo, 2012). Some OVCFs result in minimal or mild pain, with symptoms typically subsiding over 6-8 weeks during recovery. Treatment modalities include analgesics, activity restriction, bed rest, back supports, drugs promoting bone formation, and physical therapy methods, forming the basis of conventional treatment (Gehlbach et al., 2003). However, persistent limiting pain often prevents patients from returning to their daily activities. As little as 2 days of bed rest causes bone mass loss, with the rate of bone loss at rest for up to 1 week reaching 50 times the normal age-related rate (Baecker et al., 2003; Marie et al., 2011). After 10 days of bed rest, 15% of aerobic capacity and lower extremity strength are lost, equivalent to 10 years of age-related loss (Kortebein et al., 2008).

Open surgical intervention in patients with osteoporotic vertebrae is challenging due to poor bone quality and frequent medical comorbidities. The intensity of pain resulting from acute vertebral fractures is directly proportional to the patient's activity. Vertebral collapse-induced height loss can lead to spinal instability and progressive kyphotic deformity. This development may contribute to a gradual decrease in mobility, deterioration in the quality of life, worsened respiratory functions, and a tendency toward depression. Following hospitalization, 50% of patients require ongoing care (Gehlbach et al., 2003). While medical treatment is widely employed, it carries serious adverse effects, and chronic pain occurs in 40% of cases (Venmans et al., 2012).

1.1. Surgical Technique

In recent years, percutaneous vertebroplasty and subsequently developed kyphoplasty have emerged as the most common methods for vertebral augmentation in cases of acute OVCFs. The primary distinction between vertebroplasty and balloon kyphoplasty, the latter being an advancement of vertebroplasty, lies in the goal of restoring the vertebral body to its previous height. C-arm fluoroscopy image during the vertebral strengthening procedure of osteoporotic lumbar 3 vertebra fracture and control radiograph images after 1 month are seen (figures).

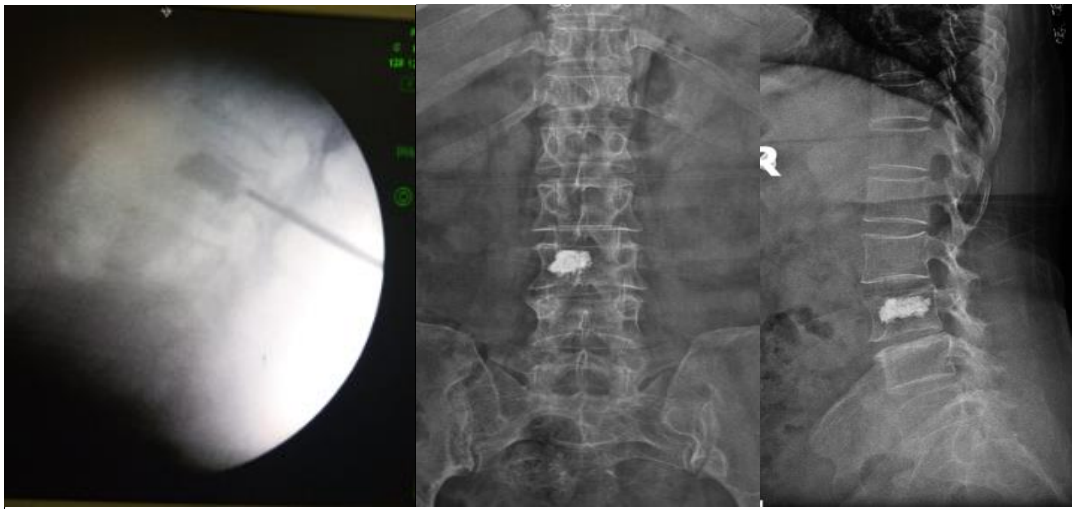

Figure.1 C-arm scopy during the procedure of osteoporotic L3 vertebra fracture and control radiograph images after 1 month

In the vertebroplasty technique, delivering cement under positive pressure presents a challenge, particularly for inexperienced surgeons. If the posterior ligament is not intact, there is a risk of cement leakage into the canal, leading to neurological deficits (Zhan et al., 2017). Balloon kyphoplasty, a surgical procedure employing an inflatable balloon, was first attempted by Dr. Mark Reiley in the 1990s. In this procedure, inflatable balloons are strategically placed transpedicularly in the lumbar, thoracolumbar, and thoracic regions to elevate the collapsed vertebral body (Mathis et al., 2004). In kyphoplasty, the vertebral height is restored by applying balloon tampers or creating a cavity within the collapsed vertebral body before injecting cement into the created volume with low pressure.

1.2. Timing, Indications and Complications

The procedure is usually performed through a unipedicular or bipedicular approach, in which cannulas are placed percutaneously into each collapsed vertebral body. This minimally invasive technique typically involves the injection of polymethylmethacrylate (PMMA) directly into the vertebral body through the pedicles. The primary objective of percutaneous treatment is to alleviate pain by reinforcing the vertebral bone structure, restoring vertebral height, achieving anatomical reduction, and preventing spinal deformity. Its principal indication is painful osteoporotic compression fractures.

While there is controversy regarding the optimal timing of kyphoplasty surgery after a fracture, many authors recommend a minimum of 3 weeks of conservative treatment. The decision on kyphoplasty should be made after detailed history, examination and imaging methods. Localized back pain that does not respond to three weeks of conservative treatment is a clinical indication for kyphoplasty surgery (Gangi et al., 2006).

Balloon kyphoplasty and vertebroplasty are now considered effective treatments for chronic back pain resistant to traditional therapies, and treatment guidelines are beginning to be established (Tsoumakidou et al., 2017). Kyphoplasty is indicated for various conditions, including traumatic or non-traumatic OVCFs causing severe pain, spinal hemangiomas, primary vertebral tumors, painful osteolytic lesions, multiple myeloma, post-malignant infiltration, osteonecrosis, and non-union of post-traumatic fracture fragments (Gangi et al., 2006). The procedure is most effective in correcting vertebral height when performed within the initial 8 weeks after the onset of symptoms (Takahashi et al., 2018).

Additional indications include chronic fractures with nonunion or internal cystic changes, need for vertebral body or pedicle reinforcement before surgical stabilization, and traumatic stable type I-II OVCFs according to the AO-Magerl classification with a local kyphotic angle greater than 15 degrees and symptomatic vertebral planes (Tsoumakidou et al., 2017)

1.3. Innovations

In the last twenty years, new products have been introduced for strengthening vertebrae in the treatment of OVCFs. Each of these innovative implants possesses unique features and indications. The advantages and disadvantages of these implants are considered in personalized applications. Developed systems, including Vertebral Body Stenting (Spine Jack system), Titanium Mesh

(Osseofix), and Sky Bone Expander (SBE), claim to achieve extraordinary vertebral height restoration. The Vesselplasty and Optimesh system is reported to effectively reduce the incidence of PMMA leakage. Additionally, systems such as V-Strut are recommended for osteolytic fractures caused by vertebral tumors (Luo et al., 2023).

However, challenges persist, including the risk of neurological damage from the surgical technique, implant biocompatibility, and the substantial difference in mechanical properties between the implant and the vertebral body. Therefore, newly designed implants must adhere to the principles of good biocompatibility, offering sufficient mechanical strength to preserve vertebral stability without inducing secondary fractures in adjacent vertebrae. Luo et al.'s study also suggests that clinicians should explore new surgical techniques and approaches to minimize the occurrence of puncture complications. They express the belief that as technology and biomaterials continue to improve, minimally invasive surgery for OVCFs will become safer and more effective (Luo et al., 2023).

1.4. Cements

The volume of PMMA cement is typically 2-3 ml in the thoracic region, 4-5 ml at the thoracolumbar junction, and an average of 5-6 ml in the lumbar regions. PMMA is a widely used material for stabilizing fractured vertebral bodies. It induces thermal necrosis in the vertebral body due to the chemical effect of the toxic monomer and the heat generated during polymerization. Aebli et al. demonstrated that intravertebral temperature levels, resulting from the use of intravertebral PMMA cement, induce thermal necrosis. They emphasize the importance of recognizing that both thermal and chemical nerve ablation may be consequential (Aebli et al., 2006). In addition to polymethylmethacrylate cement (PMMA), calcium phosphate-based nanocomposite cements are also utilized. Primarily employed in young patients, these cements are endothermic and biocompatible (osteoconductive), promoting bone formation and integration. The biological advantages of calcium phosphate cements contribute to better integration within the body. However, they are also susceptible to osteoclast resorption and remodeling (Lu et al., 2019)

It is noteworthy that the clinical and radiographic results of unilateral and bilateral approaches are almost identical. This suggests that unilateral balloon kyphoplasty can be successfully employed in multilevel OVCFs. Considering factors such as surgery time, cement volume, cement

leakage, radiation dose, and hospital stay costs, unilateral kyphoplasty may be a preferable choice for osteoporotic vertebral body fractures. The unilateral technique offers several operative advantages. With a single needle placement and a more lateral entry point compared to the bilateral approach, risks such as spinal cord injury, pedicle and facet joint fracture, and spinal epidural hematoma are reduced. Research indicates that the radiation applied to each patient in the unilateral group is only 50% of the dose received by the bilateral group. A meta-analysis by Sun et al. found that unilateral kyphoplasty primarily reduces cement leakage, differing from the results reported in previous meta-analyses (Sun et al., 2016).

While percutaneous vertebroplasty and kyphoplasty are generally safe procedures, potential complications may arise. These can include, but are not limited to, cement leakage into the surrounding tissues, vascular injury, and rare instances of neurological deficits. Additionally, there is a slight risk of infection or allergic reactions associated with the materials used during the intervention.

Numerous clinical studies investigating the outcomes of vertebroplasty consistently assert that it offers significant pain relief and helps in maintaining the height of the vertebral body when compared to conservative treatment (Farrokhi et al., 2011). Studies have investigated the clinical outcomes and effectiveness of balloon kyphoplasty in comparison to conservative treatment. who underwent kyphoplasty compared to those receiving conservative treatment (Mathis et al., 2004). Similarly, Jin et al. found comparable results in their study, noting that kyphoplasty patients exhibited greater improvements in pain scores, height restoration, bone union rate, and lower kyphosis angles at the 1-year follow-up compared to patients treated conservatively alone (Jin et al., 2018).

Balloon kyphoplasty and vertebroplasty are effective treatments for OVCFs. Studies have indicated a correlation between greater volumes of cement injected and improvement in vertebral body height at the 6-month post-operative follow-up. Notably, these studies demonstrate a significant difference between balloon kyphoplasty and vertebroplasty regarding height restoration. A study by Patel et al. suggests that balloon kyphoplasty may be preferable for vertebral height restoration. (Patel et al., 2022). Overall, studies have consistently reported an average kyphotic angle restoration of 5°-8.4° for vertebroplasty and 3.4°-9.9° for kyphoplasty (Mathis et al., 2004). The incidence of cement leakage for percutaneous vertebroplasty and percutaneous balloon kyphoplasty was reported as 54.7% and 18.4%, respectively. Notably, age,

gender, fracture type, operation level, and surgical approach did not emerge as significant risk factors. Despite concerns about the occurrence of new vertebral fractures following augmentation techniques like vertebroplasty and kyphoplasty in the treatment of OVCFs, a meta-analysis of 22 studies involving 2872 patients with 4187 vertebrae found no evidence of an increased risk of fractures in the treated or adjacent vertebral bodies when compared with conservative treatment (Zhang H, 2017).

2. Conclusion

The success of vertebral augmentation techniques employed in the treatment of osteoporotic vertebral fractures relies on careful patient selection. Absolute confirmation of the fracture source of pain, appropriate and correct timing, is an effective treatment method that can be used safely by experienced surgeons with the correct indication and appropriate technique. However, it should not be forgotten that possible complications may increase the risk of morbidity and mortality.

The author declare that there are no potential conflicts of interest relevant to this article.

Conflicts of interest: Authors deny any conflict of interest.

Funding Statement: This research received no specific grant from any funding agency, commercial or not-for-profit sectors.

References

Aebli, N., Goss, B. G., Thorpe, P., Williams, R., & Krebs, J. (2006). In vivo temperature profile of intervertebral discs and vertebral endplates during vertebroplasty: an experimental study in sheep. Spine, 31(15), 1674–1679.

Baecker, N., Tomic, A., Mika, C., Gotzmann, A., Platen, P., Gerzer, R., & Heer, M. (2003). Bone resorption is induced on the second day of bed rest: results of a controlled crossover trial. Journal of applied physiology (Bethesda, Md.: 1985), 95(3), 977–982.

Ensrud, K. E., & Schousboe, J. T. (2011). Clinical practice. Vertebral fractures. The New England journal of medicine, 364(17), 1634–1642.

Farrokhi, M. R., Alibai, E., & Maghami, Z. (2011). Randomized controlled trial of percutaneous vertebroplasty versus optimal medical management for the relief of pain and disability in acute osteoporotic vertebral compression fractures. Journal of neurosurgery. Spine, 14(5), 561–569.

Gangi, A., Sabharwal, T., Irani, F. G., Buy, X., Morales, J. P., Adam, A., & Standards of Practice Committee of the Society of Interventional Radiology (2006). Quality assurance guidelines for percutaneous vertebroplasty. Cardiovascular and interventional radiology, 29(2), 173–178.

Gehlbach, S. H., Burge, R. T., Puleo, E., & Klar, J. (2003). Hospital care of osteoporosis-related vertebral fractures. Osteoporosis international : a journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA, 14(1), 53–60.

Kortebein, P., Symons, T. B., Ferrando, A., Paddon-Jones, D., Ronsen, O., Protas, E., Conger, S., Lombeida, J., Wolfe, R., & Evans, W. J. (2008). Functional impact of 10 days of bed rest in healthy older adults. The journals of gerontology. Series A, Biological sciences and medical sciences, 63(10), 1076–1081.

Longo, U. G., Loppini, M., Denaro, L., Maffulli, N., & Denaro, V. (2012). Osteoporotic vertebral fractures: current concepts of conservative care. British medical bulletin, 102, 171–189.

Lu, Q., Liu, C., Wang, D., Liu, H., Yang, H., & Yang, L. (2019). Biomechanical evaluation of calcium phosphate-based nanocomposite versus polymethylmethacrylate cement for percutaneous kyphoplasty. The spine journal : official journal of the North American Spine Society, 19(11), 1871–1884.

Luo, Y., Yang, D. M., Yang, H. M., Wu, D., & Xie, F. Y. (2023). Innovative minimally invasive implants for osteoporosis vertebral compression fractures. Frontiers in medicine, 10, 1161174.

Jin, C., Xu, G., Weng, D., Xie, M., & Qian, Y. (2018). Impact of Magnetic Resonance Imaging on Treatment-Related Decision Making for Osteoporotic Vertebral Compression Fracture: A Prospective Randomized Trial. Medical science monitor : international medical journal of experimental and clinical research, 24, 50–57.

Johnell, O., & Kanis, J. (2005). Epidemiology of osteoporotic fractures. Osteoporosis international : a journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA, 16 Suppl 2, S3–S7.

Marie, P. J., & Kassem, M. (2011). Extrinsic mechanisms involved in age-related defective bone formation. The Journal of clinical endocrinology and metabolism, 96(3), 600–609. https://doi.org/10.1210/jc.2010-2113

Mathis, J. M., Ortiz, A. O., & Zoarski, G. H. (2004). Vertebroplasty versus kyphoplasty: a comparison and contrast. AJNR. American journal of neuroradiology, 25(5), 840–845.

Patel, N., Jacobs, D., John, J., Fayed, M., Nerusu, L., Tandron, M., Dailey, W., Ayala, R., Sibai, N., Forrest, P., Schwalb, J., & Aiyer, R. (2022). Balloon Kyphoplasty vs Vertebroplasty: A Systematic Review of Height Restoration in Osteoporotic Vertebral Compression Fractures. Journal of pain research, 15, 1233–1245.

Sun, H., Lu, P. P., Liu, Y. J., Yang, X., Zhou, P. H., Shen, X. F., Sun, S. W., & Yang, H. (2016). Can Unilateral Kyphoplasty Replace Bilateral Kyphoplasty in Treatment of Osteoporotic Vertebral Compression Fractures? A Systematic Review and Meta-analysis. Pain physician, 19(8), 551–563.

Takahashi, S., Hoshino, M., Terai, H., Toyoda, H., Suzuki, A., Tamai, K., Watanabe, K., Tsujio, T., Yasuda, H., Kono, H., Sasaoka, R., Dohzono, S., Hayashi, K., Ohyama, S., Hori, Y., & Nakamura, H. (2018). Differences in short-term clinical and radiological outcomes depending on timing of balloon kyphoplasty for painful osteoporotic vertebral fracture. Journal of orthopaedic science : official journal of the Japanese Orthopaedic Association, 23(1), 51–56.

Tsoumakidou, G., Too, C. W., Koch, G., Caudrelier, J., Cazzato, R. L., Garnon, J., & Gangi, A. (2017). CIRSE Guidelines on Percutaneous Vertebral Augmentation. Cardiovascular and interventional radiology, 40(3), 331–342.

Venmans, A., Klazen, C. A., Lohle, P. N., Mali, W. P., & van Rooij, W. J. (2012). Natural history of pain in patients with conservatively treated osteoporotic vertebral compression fractures: results from VERTOS II. AJNR. American journal of neuroradiology, 33(3), 519–521.

Wright, N. C., Looker, A. C., Saag, K. G., Curtis, J. R., Delzell, E. S., Randall, S., & Dawson-Hughes, B. (2014). The recent prevalence of osteoporosis and low bone mass in the United States based on bone mineral density at the femoral neck or lumbar spine. Journal of bone and mineral research : the official journal of the American Society for Bone and Mineral Research, 29(11), 2520–2526.

Zhan, Y., Jiang, J., Liao, H., Tan, H., & Yang, K. (2017). Risk Factors for Cement Leakage After Vertebroplasty or Kyphoplasty: A Meta-Analysis of Published Evidence. World neurosurgery, 101, 633–642.

Zhang, H., Xu, C., Zhang, T., Gao, Z., & Zhang, T. (2017). Does Percutaneous Vertebroplasty or Balloon Kyphoplasty for Osteoporotic Vertebral Compression Fractures Increase the Incidence of New Vertebral Fractures? A Meta-Analysis. Pain physician, 20(1), E13–E28.