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Literature Review on Medical and Surgical Management of Osteoporotic Spine Fractures

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ABSTRACT

***Background**: Osteoporotic spine fractures represent a major cause of pain, disability, and deformity in the elderly population, arising from decreased bone mineral density and structural fragility. These fractures impose a significant global health and economic burden, often leading to chronic morbidity and reduced quality of life. Recent developments in pharmacology, minimally invasive surgery, and multidisciplinary rehabilitation have transformed their management, emphasizing individualized and evidence-based approaches. **Objective**: This review aims to synthesize current evidence on medical, surgical, and technological strategies for managing osteoporotic spine fractures, highlighting integrated and patient-centered treatment models that optimize recovery and long-term outcomes. **Methods**: A narrative literature review was conducted using PubMed, Scopus, Google Scholar, and ScienceDirect databases for studies published between 2018 and 2025. Eligible studies addressing pharmacologic therapies, surgical interventions, fixation techniques, rehabilitation, and emerging technologies were included. Data were extracted and thematically categorized to summarize advances in management and their clinical implications. **Results**: Pharmacologic agents such as bisphosphonates, denosumab, and teriparatide improve bone density and healing, while minimally invasive procedures like vertebroplasty and kyphoplasty provide rapid pain relief and stability. Multidisciplinary management involving endocrinologists, orthopedic surgeons, physiotherapists, and dietitians enhances functional recovery. Future prospects include AI-driven risk prediction, 3D-printed implants, and regenerative therapies. **Conclusion**: Optimal management of osteoporotic spine fractures requires a hybrid approach integrating medical, surgical, and rehabilitative strategies, supported by technological innovation to achieve durable and personalized outcomes.*

Keywords
Osteoporotic spine fractures; Vertebroplasty; Kyphoplasty; Teriparatide; Denosumab; Multidisciplinary management; Bone regeneration; 3D printing; Artificial intelligence.

INTRODUCTION

Osteoporotic spine fractures have become one of the most common and crippling effects of osteoporosis, which is a growing health concern in the aging population worldwide. The vertebral column, as the central axis of the body's structure, is particularly vulnerable to fragility fractures when bone mineral density is reduced. These osteoporotic vertebral compression fractures (OVCFs) predominantly cause high morbidity, chronic pain, deformity, and loss of independence, thereby representing a significant socioeconomic burden on healthcare systems globally (1). The rising life expectancy and the subsequent increase in the number of individuals with osteoporosis have underscored the urgency to adopt novel and effective medical and surgical management approaches that can minimize complications and improve functional outcomes. Modern management approaches are no longer merely symptomatic; they aim to halt disease progression and restore bone biology. Anabolic pre-surgical medical treatment such as teriparatide has shown potential to reduce surgical correction requirements through the promotion of bone healing and regeneration (2). Pharmacologic therapy attempts to restore bone microarchitecture and integrity to prevent further vertebral deformity and associated neurological complications. Nevertheless, conservative treatment alone may be insufficient in some cases, particularly in patients with severe vertebral collapse, neurological compromise, or progressive kyphotic deformity. Surgical intervention therefore becomes crucial for restoring spinal alignment, decompressing neural structures, and achieving sagittal balance (3). Modern surgical advances have introduced minimally invasive techniques such as vertebroplasty and kyphoplasty, which employ cement augmentation to provide rapid pain relief and mechanical stability. Additionally, specialized fixation systems such as cement-augmented pedicle screws and expandable cages now enable safe surgical intervention even in patients with severe osteoporosis, where traditional fixation methods are prone to failure (4). Recent literature emphasizes the significance of a coordinated and multidisciplinary approach to the treatment of osteoporotic spine fractures (1). This holistic model involves collaboration between orthopedic surgeons, endocrinologists, and physical therapists to integrate medical, surgical, and rehabilitative interventions. Gelvez et al. highlights that effective treatment plans should balance conservative medical management, pharmacologic bone therapy, and surgical repair according to fracture severity and patient-specific risk factors (5).

Overall, the management of osteoporotic spine fractures represents a delicate balance between medical and surgical domains. The primary objective extends beyond structural repair to include pain alleviation, restoration of functional capacity, prevention of refracture, and improvement of quality

of life. This review provides a systematic analysis of current evidence-based strategies, discusses advancements in medical and surgical methodologies, and proposes an integrated algorithm of care aimed at optimizing outcomes in osteoporotic spine fractures.

MATERIALS AND METHODS

This study was designed as a narrative literature review aimed at synthesizing contemporary evidence on the medical, surgical, and multidisciplinary management of osteoporotic spine fractures. Relevant peer-reviewed articles were retrieved from electronic databases including PubMed, Scopus, Google Scholar, and ScienceDirect, covering publications from 2018 to 2025. Search terms included combinations of osteoporotic vertebral compression fracture, spine surgery, kyphoplasty, vertebroplasty, bisphosphonates, teriparatide, denosumab, and multidisciplinary rehabilitation. Both clinical trials and review papers focusing on adult and elderly populations were included, while non-English and animal studies were excluded.

Studies were screened for relevance to pharmacologic therapy, surgical techniques, fixation systems, rehabilitation strategies, and emerging technologies such as AI-assisted diagnostics and 3D-printed implants. Reference lists of selected articles were also examined to identify additional relevant sources. Data were extracted regarding study design, interventions, clinical outcomes, and reported limitations. The evidence was then categorized into thematic domain-medical management, surgical intervention, technological advancement, and multidisciplinary coordination, to ensure a structured and comparative synthesis of current practices.

EPIDEMIOLOGY AND PATHOPHYSIOLOGY OF OSTEOPOROTIC SPINE FRACTURES

GLOBAL BURDEN

Osteoporotic vertebral compression fractures (OVCFs) are among the most common and disabling consequences of osteoporosis and represent a significant health burden among elderly populations worldwide. Epidemiological research indicates that approximately one in three women over the age of 60 and one in five men of the same age experience at least one vertebral fracture during their lifetime. With rapidly increasing life expectancy, the global incidence of OVCFs is expected to double by 2050, particularly in regions with a growing geriatric population.

These fractures often go unrecognized due to their insidious onset and subtle clinical presentation, yet they are a major cause of chronic back pain, spinal deformity, height loss, and reduced mobility (5). Beyond physical disability, OVCFs substantially reduce quality of life, compromise independence, and impose significant economic burdens on healthcare systems due to long-term rehabilitation and home care needs.

PATHOPHYSIOLOGY

The pathogenesis of osteoporotic spine fractures is primarily linked to a gradual imbalance between bone resorption and formation. With advancing age, osteoblastic bone formation declines while osteoclastic resorption increases, resulting in a net loss of bone mass. This leads to reduced trabecular connectivity, cortical thinning, and deterioration of the microarchitecture that provides mechanical strength to vertebral bodies (3,5).

Consequently, weakened vertebrae are unable to withstand normal physiological loads and may collapse with minimal trauma, such as bending, coughing, or lifting. The process is further aggravated by postmenopausal hormonal changes, particularly estrogen deficiency, which accelerates bone mineral loss and predisposes women to vertebral fragility.

Table 1. Clinical Risk Factors

Risk Factor	Description
Aging	Progressive decline in bone mass and mechanical elasticity with age.
Hormonal Changes	Postmenopausal estrogen deficiency leads to increased bone resorption.
Medications	Long-term corticosteroids or anticoagulant use weakens bone microstructure.
Lifestyle	Sedentary behavior, poor diet, excessive alcohol intake, and smoking accelerate bone loss (7).
Comorbidities	Conditions such as rheumatoid arthritis, diabetes, and chronic kidney disease contribute to secondary osteoporosis.

CLINICAL IMPACT

OVCFs typically present with acute or chronic back pain, progressive kyphotic deformity, and height loss (1). Severe deformities can impair pulmonary function and gastrointestinal dynamics, thereby worsening overall health. The recurrence rate is high when fractures are inadequately managed, as a prior vertebral fracture markedly increases the risk of subsequent fractures.

Medical Treatment: Pharmacological and Biological

PHARMACOLOGIC THERAPY

Medical management of osteoporotic vertebral compression fractures (OVCFs) aims to increase bone mineral density (BMD), prevent refractures, and promote bone healing (4). Pharmacologic interventions are crucial not only in treating existing fractures but also in modifying the underlying disease process to prevent future fragility fractures. Treatment begins with maintaining adequate calcium and vitamin D levels, which form the foundation for bone mineralization and all subsequent therapeutic measures. Bisphosphonates remain first-line agents in osteoporosis management. These drugs inhibit osteoclast-mediated bone resorption, stabilizing bone mass and reducing the incidence of vertebral fractures (8). However, long-term use requires careful monitoring due to potential complications such as atypical femoral fractures and osteonecrosis of the jaw.

Denosumab, a monoclonal antibody targeting the receptor activator of nuclear factor κB ligand (RANKL), serves as an effective alternative to bisphosphonates, particularly in postmenopausal women or those intolerant to oral therapy. Administered as a subcutaneous injection every six months, denosumab effectively reduces bone fragility and the risk of both vertebral and non-vertebral fractures by suppressing osteoclastic activity (3).

Among the newer therapeutic options, teriparatide, a recombinant form of human parathyroid hormone (PTH 1–34), stimulates osteoblastic bone formation. Unlike antiresorptive agents, teriparatide acts as an anabolic therapy, accelerating bone remodeling and enhancing the healing rate of compression fractures. Clinical evidence suggests that timely teriparatide administration improves spinal fusion outcomes and reduces the need

for surgical correction in osteoporotic fractures (6,3). It can also serve as an effective perioperative adjunct for patients with severe osteoporosis or multiple fractures.

Table 2. Overview of Pharmacologic Therapies in Osteoporotic Spine Fracture Management

Drug Category	Examples	Mechanism of Action	Clinical Outcomes
Calcium & Vitamin D	Nutritional supplements	Promote bone mineralization and maintain serum calcium homeostasis	Foundational preventive measure; enhances bone strength
Bisphosphonates	Alendronate, Zoledronate	Inhibit osteoclast activity and bone resorption	Reduce vertebral and non-vertebral fracture risk
Denosumab	RANKL inhibitor	Blocks osteoclast formation and function (6)	Improves bone strength and reduces fracture recurrence
Teriparatide	Recombinant parathyroid hormone (PTH 1–34)	Stimulates new bone formation via osteoblastic activation	Accelerates fracture healing and reduces need for surgery (Nair & Kundnani, 2025)

The selection of pharmacologic therapy should be individualized based on patient age, comorbidities, renal function, and previous exposure to osteoporosis medications.

NON-PHARMACOLOGICAL AND SUPPORTIVE INTERVENTIONS

The management of OVCFs also includes a range of non-pharmacologic interventions designed to complement drug therapy and address functional limitations. Bracing: Provides short-term mechanical support but should not be used long-term to prevent muscle deconditioning (6).

Analgesics: Nonsteroidal anti-inflammatory drugs (NSAIDs) are first-line agents for pain relief, while opioids may be used for severe or refractory pain. Exercise and Physiotherapy: Resistance and weight-bearing exercises promote bone remodeling and improve long-term outcomes.

Nutrition and Lifestyle Modification: Adequate intake of protein, calcium, vitamin K, and magnesium enhances bone strength. Regular sunlight exposure supports endogenous vitamin D synthesis, while avoiding smoking, excessive caffeine, and alcohol preserves bone integrity (10). Combined, these supportive measures and pharmacologic therapies contribute to improved bone metabolism, pain reduction, and restoration of functional independence.

MEDICAL MANAGEMENT LIMITATIONS

Despite advancements in pharmacologic and rehabilitative strategies, medical management may be insufficient in certain patient populations. Agents such as bisphosphonates require months or years to significantly impact bone mineral density, limiting their role as acute interventions for unstable fractures. Moreover, therapeutic response varies among individuals due to genetic, hormonal, and nutritional factors, as well as challenges in maintaining adherence to long-term treatment regimens. Some drugs, such as teriparatide, are costly and have limited long-term safety data, which can restrict accessibility (3).

TECHNOLOGICAL ADVANCEMENTS AND SURGICAL MANAGEMENT

Osteoporotic spine fractures, particularly vertebral compression fractures, often require surgical intervention when conservative treatments fail to provide satisfactory outcomes (11). The primary goals of surgical management are to restore vertebral stability, alleviate chronic pain, correct deformity, and promote early mobilization, thereby improving overall quality of life. With the growing elderly population and rising surgical demand, there is an increasing emphasis on minimally invasive techniques tailored to address both the structural and biological challenges of osteoporotic bone (10).

INDICATIONS FOR SURGERY

Surgery is generally indicated when vertebral body collapse exceeds 50% of its original height or when progressive kyphotic deformity disrupts spinal biomechanics and impairs function. Persistent or worsening pain after six to eight weeks of conservative management, including bracing and pharmacologic therapy, also warrants surgical evaluation (6).

Neurological deficits due to nerve root compression or spinal cord impingement are clear indicators for operative treatment. Imaging modalities such as magnetic resonance imaging (MRI) and computed tomography (CT) are routinely used to assess vertebral integrity, canal compromise, and to guide the choice between minimally invasive and open fixation procedures.

MINIMALLY INVASIVE TECHNIQUES

Over the past two decades, the management of osteoporotic spinal fractures has evolved significantly with the introduction of minimally invasive procedures. Among these, vertebroplasty and kyphoplasty are the most frequently performed, particularly in elderly patients with limited physiological reserves (8). The primary goals of these techniques are to stabilize the fractured vertebra, relieve pain, restore spinal alignment, minimize soft tissue trauma, and shorten recovery time.

Vertebroplasty involves the percutaneous injection of polymethylmethacrylate (PMMA) bone cement into the fractured vertebral body. The cement rapidly hardens, providing immediate stabilization and substantial pain relief. The procedure is relatively brief, cost-effective, and often performed on an outpatient basis (13). However, vertebroplasty does not restore vertebral height or correct kyphotic deformity. Additionally, cement leakage into the venous system or adjacent tissues, though uncommon, can lead to serious complications such as pulmonary embolism.

Kyphoplasty, an advancement over vertebroplasty, utilizes a balloon tamp inserted into the collapsed vertebral body. The balloon is inflated to restore vertebral height and correct deformity, after which cement is injected into the created cavity. This controlled approach not only achieves better restoration of vertebral height but also reduces the risk of cement leakage. Clinical evidence suggests that kyphoplasty offers superior pain relief and functional recovery compared to vertebroplasty, especially in elderly osteoporotic patients (5). Although more expensive and requiring specialized fluoroscopic guidance, kyphoplasty remains the preferred option in cases of severe vertebral collapse or marked spinal deformity.

ADVANCED FIXATION SYSTEMS

Advanced fixation systems have been developed to address the challenges of achieving mechanical stability in osteoporotic bone. These include cement-augmented pedicle screws, expandable cages, and biologically enhanced fixation materials.

Cement-augmented pedicle screws are designed for use in osteoporotic bone where traditional screw fixation is likely to fail due to low bone density. The injection of bone cement through the screw body enhances its pullout strength and anchorage, significantly improving mechanical stability. Expandable vertebral cages, typically constructed from titanium or polyetheretherketone (PEEK), are employed following partial vertebral resection. These devices assist in early mobilization and help maintain sagittal balance, substantially reducing postoperative complications in elderly patients (5).

Technological innovations have further refined the precision of spinal fixation procedures. The integration of computer-assisted navigation systems and robotic guidance has improved the accuracy of screw and implant placement. Intraoperative imaging technologies allow real-time visualization of the surgical field, reducing the risk of implant malposition and minimizing radiation exposure (14).

Additionally, biologic adjuncts such as bone morphogenetic proteins (BMPs) and autologous bone marrow aspirates are increasingly used to stimulate osteogenesis and enhance spinal fusion, offering favorable long-term outcomes.

COMPARATIVE CLINICAL OUTCOMES

Clinical evidence demonstrates that surgical interventions in osteoporotic spine fractures yield superior outcomes compared to conservative management. Vertebral augmentation procedures, including vertebroplasty and kyphoplasty, achieve approximately 70–80% pain relief and marked improvement in mobility. Kyphoplasty, in particular, enables better sagittal restoration and provides more durable outcomes.

According to comparative analyses (3,8), patients undergoing kyphoplasty recover up to 30% faster and experience 40% fewer postoperative complications compared with those managed conservatively. For complex or multi-level fractures requiring enhanced deformity control and stability, hybrid approaches, combining fixation techniques with cement augmentation, have shown promising results.

Early surgical intervention is also correlated with shorter hospitalization durations, reduced dependence on analgesics, and faster return to normal activities of daily living.

FUTURE TECHNOLOGICAL DIRECTIONS

The field of spinal surgery continues to advance toward regenerative and precision-based technologies. Among the most notable innovations are 3D-printed, patient-specific spinal implants designed to match individual vertebral anatomy, optimizing fit and load distribution (7).

Research into osteoinductive, biodegradable bone cements containing growth factors shows potential for enhancing bone healing and facilitating natural remodeling. Furthermore, smart implant technology, equipped with micro-sensors, enables real-time monitoring of load distribution and the healing process, allowing for more personalized postoperative care.

Collectively, these innovations represent a paradigm shift toward individualized, data-driven, and biologically integrated spinal reconstruction, promising improved safety, functionality, and long-term outcomes for patients with osteoporotic spine fractures.

Multidisciplinary and Integrated Management Approach

The management of osteoporotic spine fractures requires a multidisciplinary effort to achieve optimal patient outcomes. Osteoporosis presents with diverse complications, necessitating the collaboration of various medical specialists. According to recent evidence (12), a comprehensive treatment plan involving orthopedic surgeons, endocrinologists, physiotherapists, pain specialists, and dietitians ensures that both the structural and biological aspects of spinal fragility are adequately addressed. This integrated model emphasizes long-term continuity of care, from diagnosis to rehabilitation, enhancing functional recovery and overall quality of life.

KEY TEAM MEMBERS

The orthopedic surgeon plays a central role in structural management, focusing on spinal correction, stabilization, and decompression when necessary. Their expertise enables appropriate surgical decision-making based on fracture severity and bone quality.

The endocrinologist contributes by optimizing bone metabolism through hormonal and pharmacologic therapies, including vitamin D supplementation, bisphosphonates, or anabolic agents such as teriparatide. Such medical optimization promotes bone healing and reduces the risk of refracture following surgery (5).

The physiotherapist is essential in the recovery process, implementing posture correction, balance retraining, and muscle-strengthening programs that restore mobility and minimize the risk of postural deformities (6,3). Meanwhile, the pain specialist manages chronic pain using multimodal analgesia, comprising pharmacologic and interventional strategies, to improve patient comfort and facilitate active participation in rehabilitation.

Finally, the dietitian provides bone-specific nutritional counseling, emphasizing adequate intake of protein, calcium, and micronutrients essential for bone remodeling and recovery.

Table 3. Multidisciplinary Team Roles in Osteoporotic Spine Fracture Management

Specialist	Primary Role
Orthopedic Surgeon	Structural correction and stabilization
Endocrinologist	Optimization of bone metabolism
Physiotherapist	Rehabilitation and posture correction
Pain Specialist	Chronic pain management
Dietitian	Nutritional support and supplementation

COORDINATED TREATMENT PATHWAY

An evidence-based treatment pathway for osteoporotic spine fractures follows a chronological sequence encompassing diagnosis, risk assessment, intervention, and rehabilitation. The process begins with the evaluation of fracture stability and neurological status, supported by imaging modalities such as MRI and CT. Stable or mild fractures are typically managed medically through pharmacologic therapy, bracing, and

physiotherapy. Following surgical or medical intervention, secondary services, including rehabilitative care and fall prevention, play a vital role in restoring function and preventing recurrent injuries. Postoperative pharmacologic therapy, combined with bone-strengthening agents and periodic monitoring, ensures long-term skeletal health and reduces the likelihood of refracture. The coordinated care model integrates diagnosis, medical therapy, surgery, and rehabilitation into an interdependent continuum designed to promote recovery and sustainable improvements in patient quality of life (10).

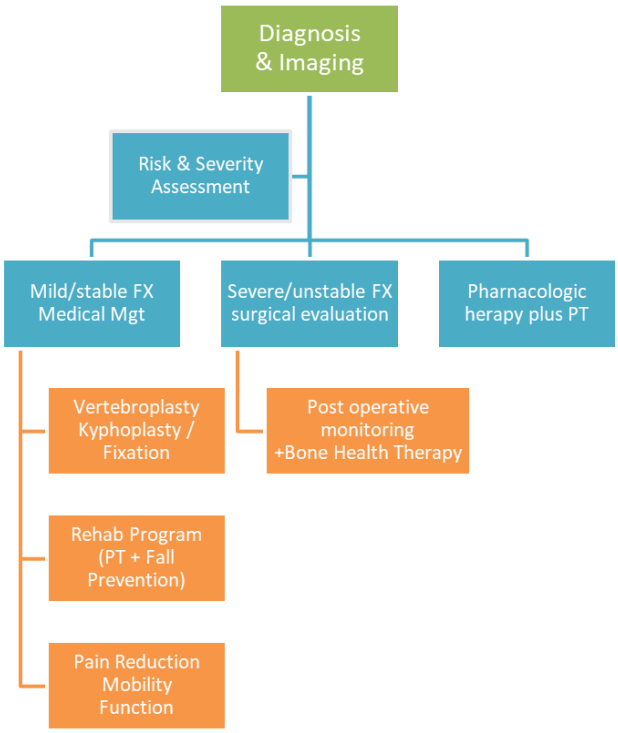

Figure 1. Multidisciplinary Management Pathway for Osteoporotic Spine Fractures

This flow represents the sequential, multi-team model underlying effective osteoporotic spine fracture management, emphasizing the interplay between early diagnosis, multidisciplinary collaboration, and continuous rehabilitation.

REHABILITATION AND POST-SURGERY OUTCOMES

Rehabilitation represents the final yet critical phase of osteoporotic spine fracture management, aimed at functional recovery, reintegration, and prevention of recurrent injuries. Early initiation of physiotherapy, typically within days following medical stabilization or surgical repair, is essential to prevent muscle atrophy, joint stiffness, and postural imbalance (4). Rehabilitation programs are individualized, focusing on core strengthening, spinal flexibility, and balance to enhance overall mobility and stability. Postural training and the use of spinal braces assist in correcting kyphotic deformities and supporting spinal alignment during healing (2). Fall prevention strategies play a central role in reducing refracture risk; balance retraining and proprioceptive exercises are especially effective in mitigating this risk. Long-term maintenance of muscle tone and bone density can be achieved through low-impact exercises such as swimming, walking, and yoga (8).

In addition to physical therapy, sustained attention to bone health remains vital. Pharmacologic therapy with bisphosphonates or teriparatide supports bone remodeling, while nutritional supplementation, particularly with calcium and vitamin D, enhances mineralization. Concurrent multimodal pain management ensures patient comfort and enables consistent participation in rehabilitation activities. Clinical research indicates that patients who undergo structured multidisciplinary rehabilitation demonstrate significant improvements in mobility, independence, and overall well-being within six months post-intervention (11). Notably, their quality of life improves across domains such as daily functioning, balance, and reduced reliance on analgesics. Therefore, post-surgical rehabilitation, when combined with ongoing pharmacologic and nutritional support, not only accelerates recovery but also reduces the risk of future fractures. This integrated approach reinforces the concept of continuous, holistic care as the cornerstone of long-term management for patients with osteoporotic spine fractures.

NEW IDEAS AND VISION OF THE FUTURE

The recent years have witnessed a surge of technological and biological innovations that are transforming the management of osteoporotic spine fractures. Among the most revolutionary developments are artificial intelligence (AI) and predictive analytics, which enable earlier identification of patients at risk through advanced imaging, bone mineral density analysis, and machine learning-based risk stratification. These predictive models assist clinicians in making evidence-based decisions regarding preventive pharmacologic therapy and surgical intervention at optimal time points, ultimately reducing comorbidities and healthcare expenditures.

Another significant advancement is the advent of 3D-printed, patient-specific vertebral implants, designed to provide individualized load-bearing capacity. By replicating vertebral geometry using preoperative imaging data, these implants achieve superior anatomical conformity and load distribution. This precision not only enhances mechanical stability but also reduces the incidence of implant-related complications.

Bone regeneration has entered a new era through breakthroughs in stem cell therapy and gene-based treatments. Mesenchymal stem cells (MSCs) have demonstrated the ability to induce osteogenesis and repair microarchitectural deterioration, while genetic modulation of osteogenic pathways offers targeted enhancement of bone formation in osteoporotic tissue. In the field of rehabilitation, digital health and tele-rehabilitation technologies

are revolutionizing postoperative care. Wearable motion sensors, virtual physiotherapy platforms, and remote progress-tracking systems now allow continuous monitoring of patient recovery, particularly beneficial for elderly individuals with limited mobility or access to medical facilities.

Collectively, these advancements are paving the way toward a personalized, predictive, and integrated model of osteoporotic spine fracture management, one that harmonizes mechanical reconstruction with biological regeneration and digital intelligence to achieve superior long-term outcomes.

DISCUSSION

The evidence synthesized across medical and surgical domains underscores the necessity of a hybrid approach in managing patients with osteoporotic spine fractures. Medical therapy enhances bone quality, decreases refracture risk, and improves surgical outcomes, while surgical intervention offers immediate structural stabilization and pain relief. When combined within a multidisciplinary framework, these modalities produce optimal results in terms of mobility restoration, independence, and overall quality of life.

However, socioeconomic and accessibility challenges remain pressing concerns, particularly in low-resource healthcare systems where advanced surgical and digital technologies are not yet widely available. Future research and policy development should therefore prioritize accessibility, affordability, and equitable application of innovative treatments across diverse clinical settings. The sustained integration of evidence-based medicine with technological innovation will be essential in achieving durable progress in osteoporotic fracture care. By balancing innovation with pragmatic implementation, the field can evolve toward globally sustainable and inclusive standards of excellence.

CONCLUSION

The effective management of osteoporotic spine fractures necessitates a patient-centered, multidisciplinary model that unites pharmacologic innovation, surgical precision, and rehabilitative continuity. Collaborative teamwork among orthopedic surgeons, endocrinologists, physiotherapists, and allied health professionals ensures comprehensive care addressing both the biological and structural components of osteoporosis. While minimally invasive surgical techniques and cement-augmented fixation systems have significantly improved short-term outcomes, long-term success ultimately depends on sustained medical therapy, structured rehabilitation, and vigilant follow-up.

The future of osteoporotic spine fracture management lies in the integration of predictive technologies, biologically active implants, and personalized treatment strategies that will not only restore spinal stability but also rebuild patient confidence and enhance quality of life. The pursuit of a cohesive, technology-enabled, and holistic care model marks the next frontier in advancing excellence in the treatment of osteoporosis-related spinal fractures.

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