

MRI Detection of Osteoporosis Bone Fractures Opposed to DEXA Scan

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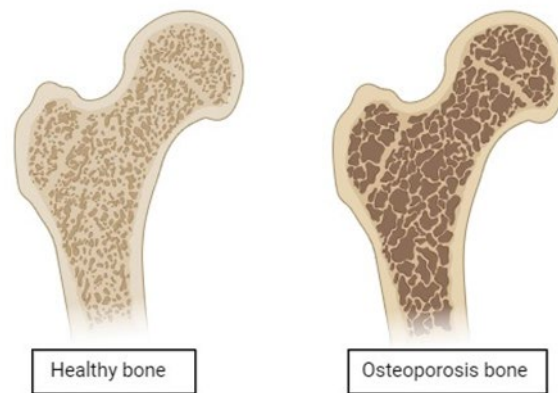
ABSTRACT

The study emphasizes the advancement achieved through Magnetic Resonance Imaging (MRI) technology in identifying bone fractures, particularly in cases such as osteoporosis. The paper explores the utilization of MRI in examining bone health to determine fracture risks, particularly those caused by osteoporosis while identifying the limitations of Dual-Energy X-ray absorptiometry (DEXA) scans for comprehensive insights. As evident, the utilization of DEXA scans permits the measurement of Bone Mineral Density (BMD) and the identification of fracture susceptibility. However, the depth of information provided by DEXA scans falls short of that attainable through MRI scans. The researcher's strategy involves a comprehensive evaluation of methods for assessing bone health, encompassing the significance of BMD and the limitations associated with DEXA scans. Moreover, the study delves into the potential utilization of MRI in offering a holistic measurement of bone health and mitigating the risk of osteoporotic fractures. As revealed, MRI meticulously examines bone properties via a process involving magnetic manipulation of protons, creating cross-sectional images that offer unique insights into internal structure. MRI surpasses DEXA in detecting Osteoporotic Bone Fractures, offering a comprehensive understanding essential for treatment planning and patient recovery. Its early detection prevents complications and guides interventions effectively. This technique employs T1-weighted, T2-weighted, and proton-density imaging to analyze complex bone webs. Therefore, the researcher strongly recommends further research to harness MRI's evolving capabilities, enabling more accurate, individualized assessments of fracture risks and treatment strategies, ultimately enhancing fracture care with precise diagnoses and tailored approaches for improved health outcomes.

Introduction

The toughness and resistance to fractures that come with adequate bone density enable humans to tolerate the impacts that occur to them during day-to-day tasks. Contrarily, decreased bone density heightens the risk of fractures, making bones more brittle even under little to no strain. Not only can physical interruptions cause fractures, but they can indicate deeper issues with bone health. Bone mineral density (BMD) is measured based on the concentration of minerals including calcium and phosphorus which in turn is a main factor of robust bone health. Osteoporosis, a debilitating condition, weakens the bones as a result of reduced tissue mass and bone mineral density. Additionally, it can increase the risk of fractures due to fragile bones. It frequently results in hip, spine, and wrist fractures, which can cause pain, decrease movement, and negatively impact quality of life, especially in the elderly population. Bone density scans are a crucial element in the quest for an accurate bone health assessment, but looking at the overall structure of the bone results in greater accuracy (Sozen 2017). The utilization of magnetic resonance imaging, also known as MRI, offers substantial detection and assessment capabilities for a bone fracture risk that results from osteoporosis, surpassing a Dual-Energy X-Ray Absorptiometry (DEXA) scan, due to its ability to understand bone health holistically: bone structure and geometry (Guerri 2018). This research lays the groundwork for a thorough study of how an MRI offers an improved and

sophisticated method of assessing bone health and determining the risk of osteoporotic fractures as opposed to a DEXA scan.



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Figure 1. A healthy bone is formed so the spaces are close together. The osteoporotic bone has honeycomb-like walls and are farther apart, leaving a thinner and weaker structured bone. Created and Copyrighted by the author with Biorender.com

Methodology of DEXA Scan

A non-invasive imaging technique known as a Dual-Energy X-Ray Absorptiometry (DEXA) scan has become indispensable for determining bone mineral density (BMD) and spotting probable diseases like osteoporosis. This diagnostic instrument analyzes crucial regions like the spine, hip, and wrist by using two different frequencies of low-energy X-ray beams. DEXA scans are a great option for routine health evaluations and follow-ups since they are quick, convenient, and offer a relatively low-radiation way to monitor bone health. Due to their convenience, DEXA scans are incredibly useful for identifying those who are more likely to suffer from osteoporosis and fractures—a factor that is especially important considering the growing elderly population. BMD, bone mineral density, is an essential indicator in assessing bone health and predicting fracture susceptibility through calculation of DEXA scans. The method is based on the way that bone and adjacent tissues absorb X-ray rays. This quantitative analysis makes it easier to categorize patients into different risk groups, enabling doctors to take preventive action as necessary (“Radiation in healthcare: Bone density (DEXA scan)”). However, DEXA scans have their share of restrictions and drawbacks, much like any medical procedure, mandating a thorough awareness of its bounds.

Disadvantages of DEXA Scan

Although low-energy X-ray beams are used, extended exposure associated with routine scans has some possible long-term dangers, such as the possibility of developing cancer (“Radiation in healthcare: Bone density (DEXA scan)”). This factor emphasizes the significance of using DEXA scans with caution. The mere dependence on BMD data for determining fracture risk is another significant issue. Contrary to what is widely held to be true, research has demonstrated that fractures regularly happen in people whose BMD levels are higher than the diagnostic criterion for osteoporosis. While it is undeniable that decreased BMD increases the risk of fracture,

it is important to understand that other parameters, including bone structure, geometry, and turnover, also play important roles. Strictly focusing on BMD can lead to a faulty risk assessment. Such restrictions are more noticeable in people with unusual bone features, which could cause the danger of fracture to be overlooked. Errors in both technical and linguistic interpretation are equally problematic. Precision BMD assessments can be impacted by soft tissues like muscles and fat, making the diagnostic process more challenging. The likelihood of faulty readings is increased by variations in body composition and the existence of anomalies in the tissues above the measurement site (Kelley, 2017). Variations in subcutaneous fat depth have a considerable impact on the precision of BMD in the lumbar spine (Yang, 2022). This situation emphasizes the complex nature of BMD assessment and the importance of being cautious when interpreting results.

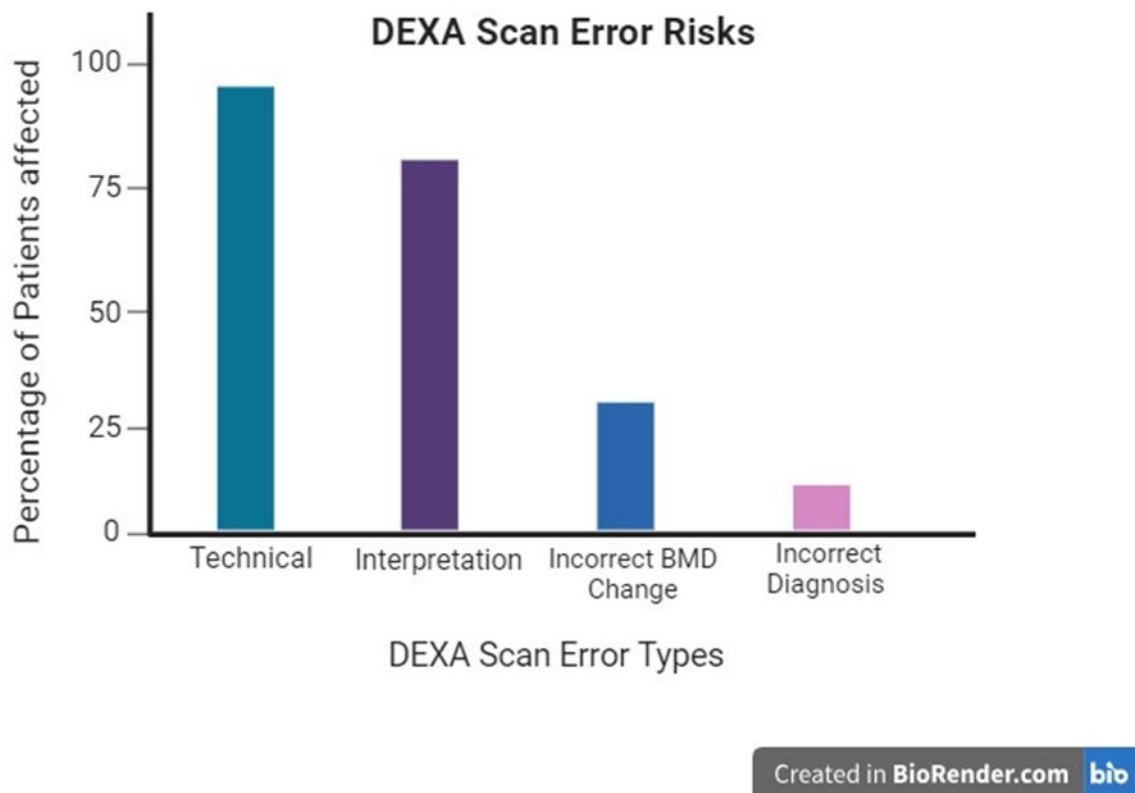


Figure 2. Illustration demonstrates the error types that occur when using a DEXA Scan. The four types occur very commonly showing how it can have a faulty assessment when predicting bone fracture risk (Krueger, 2019). Created and copyrighted by the author through Biorender.com.

MRI Technology

Focusing on a more reliable radiological detection method, MRI, a breakthrough development in the field of medical imaging, has come to light. This non-invasive method transforms the field of medical diagnostics by providing a complex three-dimensional image of the internal anatomy of the human body. Instead of using ionizing radiation like traditional X-rays and computed tomography (CT) scans do, MRI uses the principles of nuclear magnetic resonance to produce extremely accurate and vivid images. The avoidance of ionizing radiation guarantees patient safety, especially for pregnant women and others who must undergo repeated scans over time, aligning with the top priority of patient well-being (Shapiro, 2012).

Limitations and Advantages of MRI Scan

Establishing soft tissue structures with MRI is still one of its key strengths. This distinguishing feature sets MRI apart from other imaging methods that place a lesser emphasis on anatomical features. With unmatched resolution, its scans enable the visualization of soft tissues like ligaments, muscles, tendons, and organs (Shapiro, 2012). This quality makes MRI a crucial diagnostic tool for a variety of problems, including brain injuries to orthopedic diseases.

While MRI's higher resolution enables detailed examination of complex structures, which makes it easier to capture minuscule details (MRI (magnetic resonance imaging) and MR angiography). Even while capturing these details, MRI technology is, nevertheless, constantly developing. Stronger magnetic field strengths and improvements in MRI sequences help to advance the imaging capabilities of this technology, overcoming any limitations that would prevent correct diagnosis. In terms of fracture detection, MRI stands as an exceptional tool with distinct advantages that overcome its inherent limitations.

Although MRI scans often demand longer processing durations compared to other imaging modalities, the wealth of information they provide regarding bone health is significantly greater. MRI technology meticulously explores the microarchitecture of bones, distinguishing between trabecular and cortical structures, and revealing structural anomalies (Chang, 2017). This capability is of utmost significance in the early identification of bone conditions and fractures, as well as in the comprehensive assessment of overall bone health. It also not only identifies but also monitors fractures with exceptional precision. By illuminating the intricacies of bone microarchitecture, MRI offers a comprehensive understanding of bone health and fractures, which is invaluable for medical professionals crafting treatment plans and ensuring patient recovery. The radiance of MRI lies in its ability to detect these fractures even at their nascent stages, preventing potential complications and guiding effective interventions.

Bone Structure Assessment with MRI

MRI reveals the complex terrain of bone properties through a meticulously planned multi-step process, providing a thorough insight of the internal bone structure. The magnetic field is used to manipulate protons in the body's tissues, a process that is most prominent in bones and forms the basis of this treatment. Protons are forced into alignment by the magnetic influence, and this alignment persists long after the magnetic field disappears. The following release of signals, which are then picked up by sensors, serves as the basis for the creation of cross-sectional images, each of which carries a unique visual representation of the internal structure of the bone. In order to analyze the complex web of bone structure, MRI uses three major techniques to produce images: T1-weighted imaging, T2-weighted imaging, and proton density imaging.

T-1 Weighted Imaging

Using T1-weighted imaging, fatty tissue signal is boosted while water signal is subdued. Its sequences highlight changes in relaxation times, illuminating changes in tissue characteristics. This technique makes use of exceptional structural precision to enable a thorough examination and segmentation of the interior structure of the bone. The extraordinary capacity of T1-weighted images to distinguish between bone and nearby soft tissues is the clinical importance of these pictures. In the diagnosis of bone illnesses and irregularities, this dichotomy becomes an effective indicator, allowing physicians to negotiate the complexity of bone-related pathologies with increased acuity (Kawahara 2021).

T-2 Weighted Imaging

On the other hand, T2-weighted imaging blocks water signals. Its sequences play a key role in this study by emphasizing variations in tissue water content. They are a useful tool for defining cartilage, ligaments, and fluid-filled spaces within joints because of this feature. Their diagnostic value extends to the detection of bone edema, inflammation, or marrow changes, providing details that might be missed by conventional radiography methods (Grande, 2014). Additionally, T2-weighted pictures have an amazing capacity to reveal fractures that might be hidden in traditional radiographs, improving the exactness of diagnostic evaluations.

Proton Density Imaging

Images with moderate tissue contrast are produced via proton density imaging, which enables an ideal balancing of the intrinsic contrasts in T1 and T2 sequences. This equilibrium helps us understand bone health and potential marrow anomalies better. Proton density imaging elucidates trends in bone growth and promotes a full study of bone-marrow connections by revealing information about the chemical makeup (Mezer, 2016). This interplay of methods offers an extensive framework for assessing bone health and illnesses that relate to its complex structure.

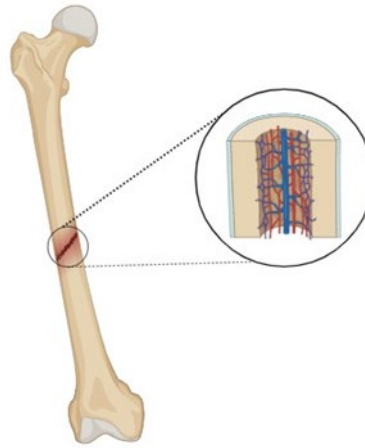
Detection of Fractures

Bone structure imaging shows potential as a powerful technique for highlighting key aspects that support clinical judgments. Bone fractures are now recognized as a major threat to the health of the musculoskeletal system. Beyond the fracture itself, the force frequently reverberates to the surrounding soft tissues—muscles, tendons, ligaments, and blood vessels—making diagnosis and treatment more challenging.

Fractures fall under the category of musculoskeletal injuries, which set off a chain reaction in the body that is typically characterized by fluid retention (edema) and inflammation. Edema and inflammation—reactions that frequently follow fractures—can be identified thanks to MRI's sharp ability to discern soft tissue subtleties. On MRI scans, the dynamic interaction between the fracture site, surrounding soft tissues, and bone marrow changes can readily be observed (Orejel Bustos, 2021).

In-depth analysis of MRI's ability to identify fractures reveals that the changes in the bone's inherent architecture brought on by fractures appear as stronger signal intensities on MRI scans. Bone marrow edema, a condition marked by an accumulation of fluid within the bone marrow, is what causes this visible expression. These unique MRI signals are important markers because they provide a clear picture of water content fluctuations that are related to the risk and severity of fractures (“MRI (magnetic resonance imaging) and MR angiography”).

It's important to note that as fractures get worse, they leave visible marks on the form of the bone, which are then visible on MRI scans. Under MRI's high-resolution analysis, minute changes in the shape of the bone can be seen, providing information about the mechanics of the fracture. This fine-grained comprehension of bone morphology enables a more thorough assessment of the fracture's features, facilitating individualized treatment regimens.



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Figure 3. In the bone marrow shown, the fracture is causing an accumulation of fluid. Created and copyrighted by the author through Biorender.com.

Assessment of Bone Shape and Geometry

The protons in the body's tissues react to the magnetic field's impact by briefly aligning themselves using radiofrequency pulses under controlled conditions. This realignment prepares the way for the disclosure of hidden knowledge stored in bones, tissues, and the parts that go with them. The protons return to their normal condition after the radiofrequency pulses stop, generating signals that are subsequently picked up by MRI sensors. Cross-sectional images—fine visualizations that give physicians thorough insights into bone structures and their complex surroundings—are produced when these signals are subjected to tedious processing.

The value of this imaging goes beyond simple observation and includes areas like analysis and clinical use. By utilizing these photos, medical professionals can examine bone structures from several angles, each of which offers a different lens for better medical comprehension. They can explore the body's complex topography by using the axial, sagittal, and coronal planes—distinct perspectives into the three-dimensional interior—while deciphering the subtleties of bone structure from a variety of angles (Rayward, 2023). The use of specific measurement methods within the context of specialized software enables the accurate assessment of bone geometry and morphology. This data bank makes it easier to explore in-depth complex anatomical features like joint connections or bone curvature. Every measurement adds a new piece of information to the diagnostic puzzle, encouraging a coherent clinical story.

In making clinical decisions, a comprehensive understanding of bone geometry and morphology is of utmost relevance. Orthopedic surgery planning is infused with information obtained through careful examinations. Think about the intricate nature of corrective osteotomies or joint replacements—procedures where the subtleties of bone shape are crucial. Understanding bone structure helps surgeons, improving the accuracy of their treatments and delivering the best possible surgical results. Furthermore, these measurements act as the basis for forecasts—predictions about mechanical weaknesses and fracture hazards. It can create a profile of susceptibility by comparing observed geometry to accepted standards, enabling proactive interventions and preventive measures for bone fractures.

Clinical Applications

MRI has been used clinically to diagnose fractures, which is a revolutionary development that has reshaped patient care and diagnostic accuracy. This cutting-edge imaging technique goes beyond conventional approaches by giving a thorough image of fractures that goes beyond the boundaries of bone structures. The capabilities of MRI have revolutionized fracture assessment, providing medical practitioners with a variety of insights that guide diagnosis, treatment planning, and post-treatment evaluation. These insights cover mild stress fractures to complicated fracture patterns. In this discourse, we explore how MRI has changed clinical practice by delving into its practical uses in fracture identification.

With the help of this technology, fracture patterns can be fully understood, facilitating precise diagnosis, treatment planning, and post-treatment evaluation. Accurate diagnoses are made possible by the capability of MRI to identify soft tissue injuries and evaluate the surrounding ligaments, muscles, and cartilage, in addition to assessing bone health. The soft tissue contrast and multiplanar imaging functions in the field of bone fracture contribute to a full examination allowing doctors to see the degree of bone damage and detect possible implications. In this case, because of its sensitivity in identifying bone marrow edema and microfractures, stress fractures, which may not be seen on X-rays, can be correctly detected. This level of accuracy enables early intervention and stops small fractures from developing into more serious issues. Beyond the stages of initial diagnosis and therapy planning, MRI has clinical applications.

Professionals can watch healing dynamics, evaluate the disappearance of bone marrow edema, and evaluate the effectiveness of management measures by performing MRI scans at various time intervals after surgery. With the help of this long-term strategy, they may customize rehabilitation plans and make sure that patients advance along the best possible recovery paths. Additionally, it offers a way to quickly spot any issues or deviations from the anticipated healing trajectory, enabling prompt intervention and reducing the risk of relapse.

The capacity of MRI to track changes in soft tissue structures and the composition of the bone marrow over time facilitates longitudinal monitoring of fracture healing. Specialists can assess the course of healing and adjust therapies by assessing bone marrow edema and monitoring its resolution. This method makes sure that treatment plans, including weight-bearing limitations or physical therapy, are modified as needed to improve recovery outcomes (Fiani, 2020). The field of medicine has given MRI integration into fracture care regimens a strong authorization. The inclusion of MRI in fracture treatment plans is evidence of its revolutionary therapeutic uses. By utilizing its capabilities, doctors may make accurate diagnoses, carry out individualized treatment plans, and track the progression of recovery. The seamless fusion of MRI technology and medical expertise improves patient outcomes by enabling a depth of understanding that goes beyond conventional diagnostic limitations.

Future Implications

With evolving techniques and technology leading improvements that promise to get past present constraints and transform fracture identification, the future of MRI bone imaging is set to unveil unparalleled diagnostic potential. This trajectory's advantages to conventional approaches, which is especially clear in its ability to diagnose osteoporosis fractures more precisely than DEXA scans, is a key component.

Another transformational aspect is the incorporation of innovative imaging hardware. High-field MRI devices that operate at 3 Tesla and higher magnetic field strengths improve spatial resolution by highlighting complex bone structures and minute alterations. This improved clarity is essential for making an osteoporosis fracture diagnosis since minor structural irregularities may act as early warning signs. The accuracy of bone

assessments is further increased by the use of specialized musculoskeletal coils, which boosts bone signal detection (Schmitt 2004). In order to fully appreciate MRI's advantage over DEXA scans in identifying osteoporosis fractures, it is essential to understand the subtle synergy between sophisticated sequences and technology.

The potential use of new contrast substances holds great potential as well. Traditional contrast chemicals have mainly enhanced the visibility of soft tissues, leaving bones relatively underserved. However, recent developments in bone-affinity-exhibiting tailored contrast agents present a game-changing possibility. These substances improve bone visualization and can spot subtle fractures due to osteoporosis that DEXA scans might miss. This advancement broadens the diagnostic toolkit, allowing for earlier disease identification and wiser treatment choices (Jung 2019).

Another interesting option is the combination of MRI with additional modalities like positron emission tomography (PET) and single-photon emission computed tomography (SPECT). For instance, PET-MRI fusion imaging combines the anatomical accuracy of MRI with the functional understanding of PET, offering a whole perspective of bone health. The structural information provided by MRI is supplemented by the quantitative metabolic data obtained from PET, enabling thorough osteoporosis fracture identification that exceeds the capability of DEXA scans (Pichler 2008).

MRI bone imaging still faces obstacles despite these encouraging advancements. Long scanning times, especially with complex sequences, are a practical problem, especially for individuals with mobility problems. To meet this challenge, protocols must be continually improved, and sequence parameters must be optimized, while maintaining a balance between diagnostic precision and patient comfort.

Conclusion

The use of MRI in the evaluation of bone fractures, especially those caused by diseases like osteoporosis, represents a significant development in the fields of orthopedics and diagnostic medicine. As emphasized throughout, traditional imaging methods like Dual-Energy X-Ray Absorptiometry (DEXA) scans cannot match the comprehensive insights provided by MRI. Although DEXA scans are a useful tool for calculating bone mineral density (BMD) and identifying those who are at risk of fractures, they are fundamentally unable to offer a comprehensive knowledge of bone health that takes into account structural complexity and geometry. While the MRI employs its capabilities to examine bone health to determine fracture risks, the DEXA scan uses them to anticipate concerns. A full evaluation of not just bone integrity but also the surrounding ligaments, muscles, tendons, and cartilage is made possible. The MRI is a versatile technology that goes beyond simple diagnosis and includes treatment planning and follow-up care. The evaluation of bone fractures is a striking monument to the medical community's unwavering dedication to enhancing patient care and improving outcomes in the future of medical development. Building on the device's present abilities, MRI's future developments may result in the creation of imaging methods that not only extensively assess bone health but also offer further knowledge into bone microstructure and early biomechanical changes, enabling an even more accurate and individualized fracture risk evaluations and treatment approaches. MRI ensures that every action taken in the field of fracture care is an advancement regarding more precise diagnoses, more specialized treatment approaches, and ultimately, better health.

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