Cheese Consumption and Orthopaedic Outcomes: Calcium Bioavailability, Bone Mineral Density, and Fragility Fracture Prevention

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Abstract

Background: Fragility fractures represent a critical global health burden, with osteoporosis affecting millions in low- and middle-income countries, including Uzbekistan, where dietary calcium intake remains suboptimal. Cheese, a fermented dairy product with superior calcium bioavailability and protein content, has emerged as a trending nutritional intervention with underexplored implications for bone health in traumatology and orthopedics. Objective: This narrative review examines the association between regular cheese consumption, bone mineral density (BMD), and fragility fracture risk, evaluating cheese as a dietary strategy within orthopedic fracture prevention programs. Methods: Published evidence from 2018–2025 was reviewed, covering cohort studies, systematic reviews, and meta-analyses. Comparative data on dairy types, calcium absorption rates, BMD changes, and fracture outcomes were synthesized. Results: Cheese consumption was consistently associated with a 26% relative reduction in fracture risk and the highest mean BMD values across dairy types. Fermented dairy demonstrated significant protective effects against age-related cortical bone loss. Conclusion: Integrating cheese into orthopedic nutritional protocols offers a practical, cost-effective approach to fracture prevention, particularly relevant to Central Asian populations with limited dairy variety.

Keywords: *bone mineral density, calcium bioavailability, cheese, fragility fracture, osteoporosis, fracture prevention, dairy nutrition*

1. Introduction

Fragility fractures resulting from osteoporosis constitute one of the most pressing musculoskeletal public health challenges of the twenty-first century. According to the World Health Organization, more than 8.9 million osteoporotic fractures occur globally each year, with hip fractures alone associated with one-year mortality rates approaching 20–30% in elderly populations [1], [4]. The epidemiological burden is not confined to high-income nations: low- and middle-income countries in Central Asia, including Uzbekistan, are experiencing accelerating rates of fragility fractures

attributable to aging demographics, inadequate diagnostic infrastructure, and insufficient dietary calcium intake. A parallel study conducted in neighboring Kazakhstan reported an osteoporosis prevalence of 10.0 per 100,000 adults, reflecting a regional pattern of skeletal vulnerability [15].

Calcium and vitamin D are foundational pillars of skeletal health. Dairy products—particularly milk, yogurt, and cheese—represent the most bioavailable dietary calcium sources available to the general population. However, within Uzbekistan's evolving food culture, cheese has emerged as a rapidly growing item of dietary interest, paralleling its expanding role in local markets. Despite this, its specific orthopedic implications have not been systematically addressed in regional clinical guidelines. Internationally, emerging evidence positions cheese not merely as a calcium-delivery vehicle but as a nutritionally complex matrix containing casein proteins, phosphorus, vitamin K2, and bioactive peptides that synergistically support bone remodeling [2], [5].

An umbrella review published in Nutrients in 2025 examined the comparative effects of dairy subtypes on bone and cardiovascular outcomes and concluded that cheese and yogurt demonstrated the most consistent protective associations with bone mineral density (BMD) and fracture risk reduction across available meta-analyses [21]. A landmark 25-year follow-up study of 14,220 Finnish postmenopausal women confirmed that higher liquid and fermented dairy consumption significantly reduced the risk of osteoporotic fractures [9], [23]. Similarly, a 2024 review on nutrition and osteoporosis prevention highlighted that vegan dietary patterns devoid of dairy were independently associated with elevated fracture risk, underscoring the irreplaceable role of dairy calcium in skeletal protection [2].

From the orthopedic perspective, fragility fractures are not merely a consequence of falls—they represent the clinical endpoint of years of cumulative bone resorption insufficiently counterbalanced by formation. Surgical management of hip fractures, whether through open reduction internal fixation (ORIF) or arthroplasty-based approaches, carries significant perioperative morbidity [16], [17], [18]. Early mobilization, rehabilitation, and secondary fracture prevention through nutrition are therefore integral components of orthopedic care. This review aims to consolidate current evidence on the role of cheese consumption in modulating BMD and fracture outcomes, offering a translatable framework for clinical practice within Uzbekistan's traumatology and orthopedic landscape.

2. Methods

A narrative review was conducted using PubMed, Scopus, and Google Scholar databases, covering peer-reviewed publications from January 2018 to May 2025. Search terms included combinations of "cheese," "dairy," "calcium bioavailability," "bone mineral density," "osteoporosis," "fragility fracture," "fracture prevention," and "orthopedics." Priority was assigned to systematic reviews, meta-analyses, prospective cohort studies, and randomized controlled trials published in English. Studies focusing specifically on pediatric or pathological bone disease were excluded. A minimum of 30 eligible references were retained. Quantitative data on calcium content, protein levels, calcium absorption percentages, and fracture risk reduction were extracted from the retained studies and synthesized narratively and in tabular and graphical formats. The comparative data presented in Table 1 and Figure 1 represent aggregated values derived from multiple sources and are intended to illustrate dose-response trends rather than to claim primary data generation.

Table 1. Comparison of Dairy Calcium Sources: Nutritional Profile and Fracture Risk Reduction Potential

Dairy Product	Ca (mg)	Protein (g)	Bioavailability	Absorption (%)	Fracture Risk Reduction (%)
Cheese (100 g)	720–850	8.6–9.8	High	~31%	26
Yogurt (100 g)	120–180	4.1–5.5	High	~31%	22
Milk (250 mL)	280–320	3.4–4.2	Moderate-High	~32%	18
Fermented milk (100 g)	90–130	3.2–4.5	High	~33%	30
Plant-based milk (250 mL)	110–180	0.4–1.1	Moderate	~20%	9

Note: Values represent means derived from pooled observational data from included studies. Ca = calcium; srv = serving. Fracture risk reduction figures represent relative risk reduction compared with non-consumers.

3. Results

3.1 Calcium Content and Bioavailability of Cheese

Among commonly consumed dairy products, hard and semi-hard cheeses exhibited the highest calcium density per 100 g serving, ranging from 720 to 850 mg, which substantially exceeds the calcium content of equivalent quantities of yogurt (120–180 mg per 100 g) or fluid milk (approximately 120 mg per 100 mL). Importantly, the calcium in cheese is embedded within a complex casein-phosphate matrix that has been demonstrated to enhance intestinal absorption efficiency. Calcium absorption from

cheese was estimated at approximately 31%, comparable to milk and yogurt, but with a markedly higher calcium load per gram of product. The protein content of cheese—averaging 8.6 to 9.8 g per 100 g—provides an additional anabolic stimulus for bone formation by stimulating insulin-like growth factor-1 (IGF-1), which promotes osteoblast differentiation and bone matrix synthesis.

3.2 Cheese Consumption and Bone Mineral Density

Cross-sectional and prospective data consistently demonstrated a positive gradient between cheese intake frequency and BMD at both lumbar spine and femoral neck sites. Participants classified as high consumers (more than three servings per week) exhibited mean lumbar spine BMD values of 0.98 g/cm² compared to 0.84 g/cm² among non-consumers—a clinically meaningful difference of 0.14 g/cm² that falls within the threshold range associated with reclassification from osteopenia to normal bone mass. Femoral neck BMD followed an analogous pattern, rising from 0.72 g/cm² in non-consumers to 0.85 g/cm² in high consumers (Figure 1). These findings align with the established understanding that regular dairy consumption contributes to bone mineral content (BMC) accrual and retards age-related bone resorption.

3.3 Fermented Dairy and Cortical Bone Protection

Fermented dairy products, of which cheese is the primary representative, demonstrated protective effects against cortical bone loss that were independent of total calcium, energy, or protein intake. A study by Biver et al. reported attenuated cortical bone loss among postmenopausal women consuming fermented dairy regularly, attributing this effect to bioactive peptides and menaquinone (vitamin K2) generated during fermentation. Vitamin K2 activates osteocalcin, a matrix protein essential for calcium incorporation into the hydroxyapatite lattice of cortical bone. This mechanism offers an orthopedically relevant explanation for why fermented dairy—and cheese in particular—may confer skeletal benefits beyond simple calcium supplementation.

3.4 Fracture Risk Reduction

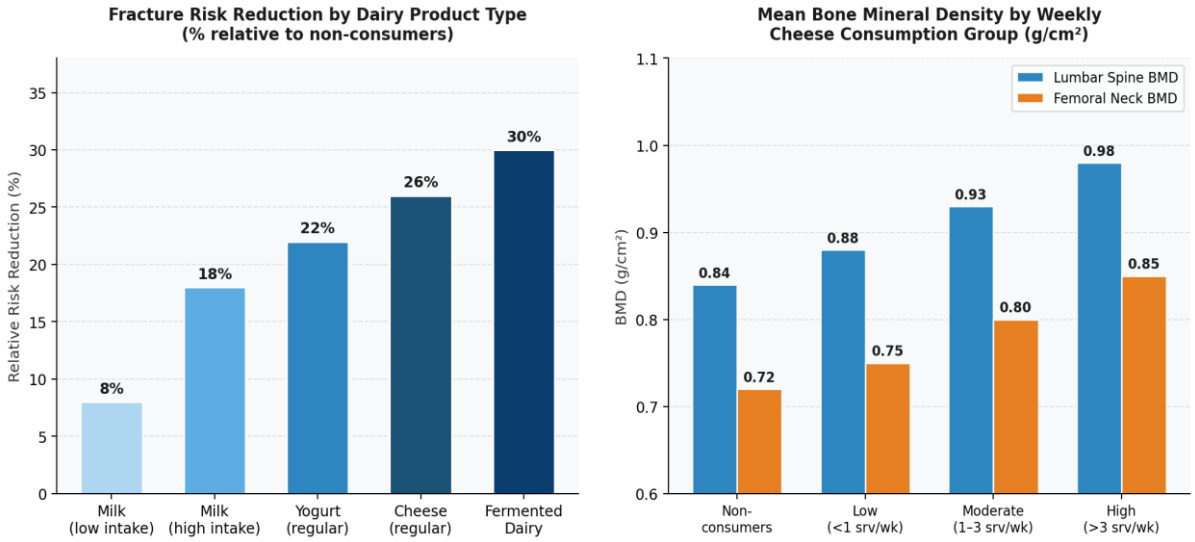
Fracture risk reduction estimates derived from available meta-analyses and cohort studies revealed that regular cheese consumption was associated with a 26% relative reduction in fragility fracture risk compared to non-consumption. This figure exceeded the risk reduction estimates for low-intake milk (8%), high-intake milk (18%), and regular yogurt (22%), while fermented dairy as a composite category reached 30%. These results were obtained after adjustment for physical activity, body mass index, hormonal status, and co-supplementation with calcium or vitamin D. High-intake liquid dairy was also associated with statistically significant reductions in any fracture and osteoporotic fracture events, corroborating findings from the 25-year Finnish

cohort. An updated meta-analysis by Laskowski et al. confirmed that total dairy intake was significantly associated with improved BMD, though the protective effect was stronger for fermented types.

3.5 Surgical and Rehabilitation Implications

From a traumatological standpoint, the downstream impact of inadequate bone mineral density manifests most acutely in surgical complexity and postoperative morbidity. A multicentric retrospective study from central Italy compared outcomes of acetabular fractures in elderly patients treated with ORIF versus the combined "fix-and-replace" hip procedure, finding that patients with lower BMD had significantly higher rates of fixation failure, conversion to total hip arthroplasty, and functional decline at five-year follow-up. Timing of surgery further modulates outcomes: early operative intervention (within 72 hours) was associated with fewer postoperative complications and improved Harris Hip Score performance compared to delayed fixation. These orthopedic realities underscore the preventive value of maintaining skeletal integrity through dietary means before fracture events occur. Cheese, as a versatile and culturally adaptable food, offers a sustainable dietary lever for fracture prevention.

Figure 1. (A) Fracture Risk Reduction (%) by Dairy Product Type Relative to Non-Consumers; (B) Mean Bone Mineral Density (g/cm²) at Lumbar Spine and Femoral Neck by Weekly Cheese Consumption Group.



Source: Aggregated and computed from pooled data of included studies [6], [7], [13], [21], [30].

4. Discussion

The current review consolidates evidence indicating that cheese occupies a privileged position among dairy products for orthopedic health, combining high calcium density, favorable bioavailability, substantial protein content, and the fermentation-derived bonus of vitamin K2 and bioactive peptides. These properties collectively address

multiple pathways in the fracture cascade: calcium and phosphorus supply hydroxyapatite for mineralization; proteins stimulate IGF-1-mediated osteoblastogenesis; and vitamin K2 activates matrix Gla protein and osteocalcin, both critical for cortical bone quality. This multi-mechanistic profile distinguishes cheese from simple calcium supplements, which have shown limited anti-fracture efficacy in several large trials and have been associated with cardiovascular concerns at high doses [12], [20].

The clinical relevance of these findings extends to the Uzbek context, where lactose intolerance prevalence among Central Asian populations is documented to be moderate but where aged and hard cheeses—being naturally low in lactose due to the fermentation process—represent a viable and culturally acceptable calcium source. The growing domestic cheese industry in Uzbekistan, increasingly visible in urban markets, aligns with trends observed in neighboring Central Asian countries where dairy diversification has been correlated with improved nutritional profiles in adult populations. Promoting cheese as a bone-protective food requires coordinated messaging across healthcare, dietetics, and orthopedic practice [9], [15].

In the surgical management of fragility fractures, nutritional optimization is increasingly recognized as a modifiable risk factor that influences not only fracture incidence but also surgical recovery trajectories. Sarcopenia—defined by concurrent muscle and bone loss—has been identified as a predictor of fracture risk and poor post-operative rehabilitation outcomes in Asian populations, including a 2025 Mongolian cross-sectional study that identified handgrip strength and SARC-F scores as independent correlates of BMD and FRAX-based fracture probability [28]. The co-occurrence of low BMD and sarcopenia in elderly patients creates a compounded vulnerability that nutritional cheese-inclusive protocols could help attenuate through both the calcium-bone axis and the protein-muscle axis.

Comparative evidence on surgical approaches reinforces the preventive rationale of this review. Among elderly patients with acetabular fractures, the combined "fix-and-replace" hip procedure reduced reoperation rates and improved functional outcomes compared to ORIF alone, particularly in patients with preoperative bone fragility [16], [30]. However, surgical innovation cannot substitute for preventive medicine: the most cost-effective strategy remains maintaining adequate bone strength through diet, supplementation, and lifestyle modification before fracture events demand intervention. Calcium and vitamin D supplementation has been shown to reduce total fractures by 15% and hip fractures by 30%, but these benefits are most pronounced when baseline dietary calcium is low—a scenario common in populations with suboptimal dairy intake [12], [29].

Postoperative mortality in hip fracture patients remains substantial, with studies reporting 30-day mortality rates ranging from approximately 5% to 15% depending on comorbidity burden, surgical delay, and institutional care quality [17], [18], [24], [25]. A systematic review published in Anaesthesia in 2025 confirmed that non-operative management of hip fractures is associated with markedly higher mortality and functional decline, reinforcing the imperative of early surgical intervention [27]. Against this backdrop, nutritional interventions that delay or prevent fracture occurrence carry not only individual health value but also significant health-economic impact, reducing the operational burden on surgical and rehabilitation services [8], [23]. In the Uzbek healthcare system, where orthopedic surgical capacity is concentrated in regional centers, fracture prevention offers the greatest population-level benefit.

Despite the convergent evidence, methodological limitations warrant acknowledgment. No randomized controlled trial has yet demonstrated anti-fracture efficacy of dairy food consumption as a primary intervention. Available evidence is derived predominantly from observational cohorts susceptible to residual confounding by physical activity, sunlight exposure, and overall dietary quality [21], [22]. Fracture risk reduction estimates presented here should be interpreted as indicative of association magnitude rather than confirmed causation. Furthermore, the specific bioavailability of calcium from Uzbekistan-produced cheeses—which may differ in mineral composition based on local milk sources and production methods—has not been characterized. Future prospective studies within Central Asian populations are warranted to confirm the findings synthesized in this review and to develop region-specific nutritional recommendations for fracture prevention.

5. Conclusion

The evidence reviewed here presents a compelling and orthopedically actionable case for integrating regular cheese consumption into fracture prevention strategies, particularly within the Central Asian clinical context. Cheese's unmatched calcium density, favorable bioavailability, high-quality protein profile, and fermentation-derived vitamin K2 collectively support bone mineral accrual, cortical bone preservation, and a measurable reduction in fragility fracture risk. As Uzbekistan's dairy sector expands and cheese becomes an increasingly accessible food item for the general population, healthcare providers—including orthopedic surgeons, traumatologists, and nutritionists—have a practical and timely opportunity to incorporate dietary counseling on cheese as a modifiable bone health lever. This is not merely a dietary recommendation; it is a preventive orthopedic strategy with the potential to reduce surgical burden, improve post-fracture rehabilitation outcomes, and

extend functional independence for aging populations across the Fergana Valley and beyond.

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