

## Original Article



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## “Rachitomalacia” – Radiological Findings of a “New” Intermediate Entity in Adolescents

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### Abstract

**Background:** This study proposes an intermediate radiological entity in adolescents with calcium/vitamin D deficiency, exhibiting features of both rickets and osteomalacia but lacking classical signs of either. We have used the term “Rachitomalacia” to describe this unique radiographic presentation. The report describes the atypical radiological findings of rachitomalacia in adolescents and highlights its distinction from classical rickets and osteomalacia. The study will aid in the early diagnosis and appropriate management of this previously unrecognized clinical and radiographic entity.

**Material and Methods:** A retrospective analysis of 10 adolescents (8 females, 2 males; mean age 11.1±0.6 years) presenting to a tertiary pediatric hospital (2020–2021) with knee deformities or pain. Inclusion criteria: (1) radiographs showing metaphyseal lucency with vertical striations or widened physis without cupping/splaying; (2) biochemical evidence of vitamin D deficiency (25(OH)D <20 ng/mL) and/or elevated alkaline phosphatase; (3) exclusion of non-nutritional metabolic disorders (e.g., hypophosphatemic rickets). Biochemical and radiographic assessments were performed, followed by calcium/vitamin D therapy.

**Results:** All patients demonstrated hypovitaminosis D (18.9±4.8 ng/mL) and elevated alkaline phosphatase (1196.7±689.9 IU/L), with normal serum calcium/phosphorus. Radiographs revealed: (1) loss of metaphyseal architecture with vertical striations, (2) widened physis with osteopenia, and (3) incomplete metaphyseal fractures. Treatment normalized biochemical/radiological parameters.

**Conclusion:** Rachitomalacia presents with subtle, atypical radiographic features in adolescents, distinct from classical rickets or osteomalacia. Recognizing these signs—particularly metaphyseal striations and physal widening—is critical to prompt diagnosis and treatment, preventing deformities during rapid pubertal growth. Clinicians should consider rachitomalacia in adolescents with nonspecific musculoskeletal complaints and suboptimal vitamin D levels.

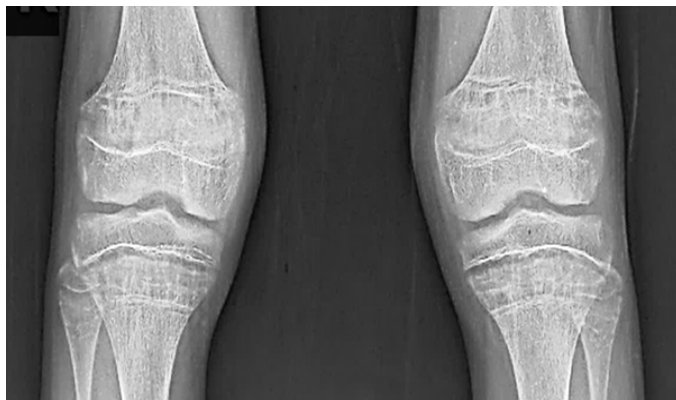
**Keywords:** Rickets, Osteomalacia, Adolescent, Radiograph

### Introduction

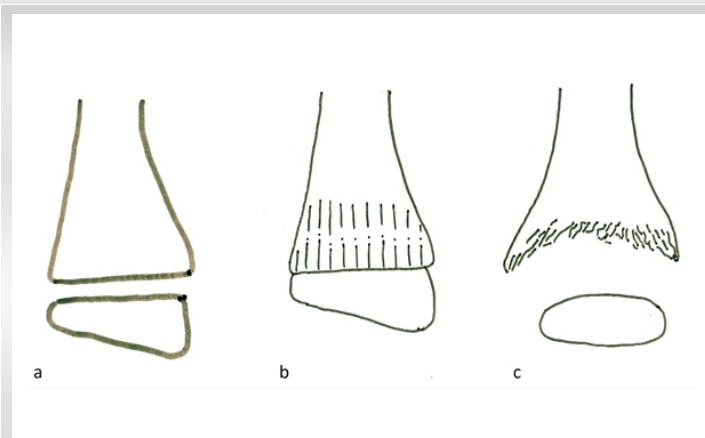
Rickets is a disorder of defective mineralization of the epiphyseal growth plate in children leading to various clinical and radiological changes. In contrast, osteomalacia is commonly a disorder of vitamin D deficiency in adults leading to low calcium levels. Rickets is characterized by characteristic radiological signs like cupping, splaying, and widening of the metaphysis. Osteomalacia is generally characterized by diffuse osteopenia as well as Looser’s zones in the bones.

Growth of the skeleton into early adolescence requires optimal calcium metabolism, the alteration of which leads to radiological abnormality and clinical symptoms in the affected child. The detection and diagnosis of derangement of calcium metabolism in adolescents is difficult since the clinical, biochemical, and radiological markers may

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**Figure 1:** Radiographs of knees showing loss of normal architecture on the metaphyseal side of the physis



**Figure 3:** Line diagram depicting the normal physis (a), osteomalacia (b, looser zone around the physis) and rickets (c, widening of physis, splaying, fraying and cupping)

be subtle and not marked as in ‘childhood’ rickets [1]. We found unique radiological features while investigating such adolescent children for calcium and vitamin D deficiency. The term ‘rachitomalacia’, as described in this study, refers to an intermediate and atypical radiological presentation of calcium/vitamin D deficiency in adolescents, which shares features of both rickets and osteomalacia but lacks classical signs of either. The current case series describes these radiological changes to improve awareness amongst clinicians regarding this clinical entity in adolescents.

### Methods

The study retrospectively analysed adolescents (aged 10–14 years) presenting to the outpatient department of a tertiary care pediatric teaching hospital between January 2020 and December 2021. Patients were included if they met the following criteria: (1) radiographs demonstrating atypical features (e.g., metaphyseal lucency with vertical striations, widened physis without cupping/splaying); (2) biochemical evidence of vitamin D deficiency (serum 25(OH)D <20 ng/mL) and/or elevated alkaline phosphatase; and (3) exclusion of non-metabolic causes. Ten patients fulfilled these criteria and were included. Deformity at the knee was the



**Figure 2:** Radiograph of the wrist showing widening of the physis with surrounding osteopenia

commonest presenting symptom.

Detailed history, physical examination, and biochemical workup (e.g., renal function tests, parathyroid hormone levels) were performed to exclude non-nutritional metabolic disorders (e.g., renal tubular acidosis, hypophosphatemic rickets) and other secondary causes of deformity. Only patients with biochemical and radiographic findings consistent with nutritional vitamin D/calcium deficiency were included.

Biochemical workup included serum calcium, serum phosphorous, serum alkaline phosphatase, and, vitamin D levels. Radiographs of the wrist, knee, and both hips were obtained. The radiological picture did not match the classical signs of rickets or osteomalacia. Treatment consisted of calcium supplementation and vitamin D therapy which resulted in the normalization of the biochemical and radiological signs reconfirming the clinical diagnosis.

### Results

#### Demographic data (Table 1)

10 children (8 females, and 2 males) with a mean age of  $11.1 \pm 0.6$  years were included. The cohort demonstrated lower levels of vitamin D ( $18.9 \pm 4.8$  ng/mL) with an increase in the levels of alkaline phosphatase ( $1196.7 \pm 689.9$  IU/L). Serum calcium ( $8 \pm 0.8$  mg/dL) and phosphorous ( $3.1 \pm 0.5$  mg/dL) were noted to be within normal limits.

**Table 1: Demographic data and biochemical findings of the children included in the study**

Age (Years)	Gender	Serum Vitamin D (ng/mL)	Serum Alkaline Phosphatase (IU/L)	Serum Calcium (mg/dL)	Serum Phosphorous (mg/dL)
11	Female	20.3	758	8.3	3.6
10	Female	19.2	1042	8.2	3.7
10	Male	15.7	967	7.9	3.5
12.7	Female	25.6	536	7.2	3.4
11.4	Female	26.7	541	8.8	2.8
10.3	Female	17.2	1314	8.8	2.2
12.9	Female	9.5	3034	7.1	3.2
11.6	Female	19.6	1316	8.7	2.5
11.1	Female	14.7	1560	6.5	3.7
11.4	Male	21.4	899	9	2.4

### Description of radiographic findings

Radiographs of the knees and wrists were commonly obtained as a part of the routine workup. The following changes were noted across the radiographs of the included cohort at the presentation.

1. The normal architecture was lost on the metaphyseal side of the physis. It contained irregular calcifications which were striated, more vertical than horizontal. This lucency had geographical margins with absence of the typical splaying and cupping seen in younger age groups (Fig. 1).
2. The physis was widened with surrounding osteopenia (Fig. 2).
3. Lines of incomplete fractures resembling fragility fractures were noted on the metaphyseal side which were sclerotic, horizontal, and rarely complete (Fig. 1).

### Discussion

Pathophysiology of radiological findings in rickets and osteomalacia

The growth plate at the end of long bones is an orderly continuation of three layers – namely, the germinal layer, the hypertrophic and proliferative layers, and the layer of mineralization. The zone of mineralization results from apoptosis of the hypertrophic layer accompanied by invasion of blood vessels from the metaphysis. This is followed by proliferation and calcification of cartilage. The following pathological changes occur in rickets - a) disordered proliferation of chondrocytes in the hypertrophic zone secondary to a lack of apoptosis with b) loss of the columnar arrangement of chondrocytes and resultant c) thickening and disorganization of the hypertrophic zone with d) tongue-like projections of cartilage extending into the spongiosa, e) irregularity of the region between the proliferative and

hypertrophic zones, and f) penetration of blood vessels into the hypertrophic zone [2]. The earliest radiological sign is the widening of the growth plate secondary to the accumulated non-ossified cartilage [3]. Later changes like cupping, splaying, fraying, and trabecular formation of the metaphysis result from the ensuing thickening and disorganization of the hypertrophic zone [4]. On the other hand, radiographic findings of osteomalacia include Looser's zones which represent poorly repaired insufficiency fractures and are visible as transverse lucencies perpendicular to the osseous cortex (Fig. 3).

### Pathophysiology of radiological findings in "rachitomalacia"

During adolescence, there is significant hyperactivity in the growth plate which manifests physiologically as an increase in the volume of the hypertrophic zone [5]. This leads to increased apoptosis of the cells in the hypertrophic zone and subsequent high cell turnover. Due to the faster turnover, the cells do not have sufficient time to progress to disorganization to manifest the typical features on radiographs. This results in the absence of typical rachitic features like cupping, splaying, and fraying. The lucency noticed on the metaphyseal side of the physis on radiographs is due to the increased volume of the hypertrophic zone. The striations noticed in the lucent zone can be attributed to the incompletely mineralized osteoid [6].

### Rachitomalacia vs. late-onset rickets vs. adolescent osteomalacia (Table 2)

Rachitomalacia is a transitional radiological presentation in adolescents with subclinical calcium or vitamin D deficiency. Unlike classical rickets, it lacks typical features such as metaphyseal cupping and splaying; instead, showing widened physis and vertical striations due to high growth plate turnover

**Table 2. Description of the rachitomalacia along with late-onset rickets and adolescent osteomalacia**

Feature	Rachitomalacia	Late-Onset Rickets	Adolescent Osteomalacia
<b>Age group</b>	Adolescents (~10–14 years)	Older children and adolescents	Adolescents and young adults
<b>Cause</b>	Subtle or subclinical calcium/Vitamin D deficiency during rapid bone growth	Classical nutritional rickets in older children	Prolonged vitamin D deficiency causing defective bone mineralization
<b>Pathology</b>	Increased hypertrophic zone activity; fast cell turnover prevents classic rachitic changes	Disordered mineralization of growth plate cartilage	Failure of mineralization in mature bone matrix (osteoid)
<b>Radiological Features</b>	Lucency and striated irregular calcifications in metaphysis; widened physis; no splaying/cupping	Widened physis, metaphyseal cupping, fraying, splaying (typical of rickets)	Looser zones (pseudofractures), generalized osteopenia, cortical thinning
<b>Clinical Features</b>	May present with knee deformity, limb pain, or be asymptomatic	Bowing of legs, knock knees, limb deformities	Bone pain, muscle weakness, waddling gait
<b>Biochemical Findings</b>	Low Vitamin D, high ALP; calcium/phosphate may be near normal	Low calcium/phosphorus, high ALP, low Vitamin D	Low calcium/phosphorus, high ALP, low Vitamin D
<b>Terminology Emphasis</b>	Radiological bridge between rickets and osteomalacia	Classical childhood presentation	Adult version of rickets with bone matrix involvement
<b>Key Insight</b>	Often missed due to atypical radiology; occurs during pubertal growth spurt	Clear clinical and radiological diagnosis	May be confused with other causes of musculoskeletal pain

during puberty [5]. Late-onset rickets retains classic features of growth plate mineralization failure. Adolescent osteomalacia, involving mineralization defects in mature bone, presents with bone pain, weakness, and Looser's zones [4, 6]. Rachitomalacia is often missed due to the atypical signs but requires early recognition and treatment to prevent deformities [1]. While rachitomalacia is itself a metabolic disorder secondary to nutritional deficiency, the term is used here to describe a distinct radiological phenotype in adolescents, differing from classical rickets or osteomalacia. This entity must be differentiated from other metabolic bone diseases (e.g., hereditary hypophosphatemia) by thorough biochemical and clinical evaluation.

### Clinical implications

1. The radiological features described in this study are atypical and were noted after the age of 10 years. This roughly corresponds to the pre-pubertal phase of bone growth where the limbs grow at a faster rate compared to the spine [5]. Hence, such findings on radiographs in the adolescent age group should alert the clinician of the underlying vitamin D deficiency.
2. Deformity may not be a universal complaint in such cases. Rather, physical complaints such as "growing pains" and malaise

may be prominent. Suspecting the cause and appropriate investigations/ radiographs will help early detection and subsequent treatment.

3. Awareness, investigation, and initiation of treatment are highly recommended for "rachitomalacia". Since the major gain in limb length occurs at this stage, the resulting physal abnormality has the propensity to cause angular deformities, if left untreated.

### Strength and limitations

This study highlights an under-recognized clinical entity — rachitomalacia — by identifying atypical radiological patterns in adolescents with subclinical calcium and vitamin D deficiency. A key strength lies in its focus on an age group in which rickets is not known to be common and providing new insights into the intermediate presentations between classical rickets and osteomalacia. The study also benefits from consistent radiographic evaluation and biochemical confirmation, enhancing diagnostic validity. The observed treatment response further supports the proposed diagnosis. The study is limited by its small sample size (10 patients) and retrospective design, which may introduce selection bias. Generalizability may also be affected by the single-centre nature

of the study. It lacks a control group for comparison and is retrospective, which may introduce selection bias. Additionally, clinical symptoms such as pain or functional impairment were not quantified, and long-term outcomes were not assessed. A larger, prospective study with standardized radiographic scoring and functional follow-up would strengthen the evidence and clinical applicability.

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**Declaration of patient consent :** The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given the consent for his/ her images and other clinical information to be reported in the journal. The patient understands that his/ her names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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