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The Role of Ultrasound in Pediatric Cases of Rickets and Developmental Dysplasia of the Hip

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Abstract: This study investigates the role of ultrasonography in diagnosing pediatric cases of rickets and developmental dysplasia of the hip (DDH). Using a cohort of 80 patients aged 1 month to 2 years, we assessed specific ultrasound parameters, identifying patterns linked to each condition. Our findings highlight that ultrasonography serves as a non-invasive, reliable diagnostic tool in early detection and treatment monitoring of these conditions, with notable differences in femoral morphology and joint congruence for DDH and metaphyseal thickening in rickets. Laboratory assessments of vitamin D levels provided critical biochemical correlations. We also found that rickets increases the risk of DDH development, with 40 out of 50 rickets cases showing concurrent DDH. This research underscores the importance of standardized ultrasound criteria and biochemical analysis for pediatric skeletal abnormalities.

Keywords: Pediatric rickets, developmental dysplasia of the hip, ultrasonography, skeletal abnormalities, metaphyseal thickening, hip joint congruence, vitamin D deficiency, diagnostic sensitivity and specificity.

Introduction

Rickets and developmental dysplasia of the hip (DDH) are both significant pediatric skeletal conditions that require timely diagnosis for effective treatment. Rickets, often caused by vitamin D deficiency, leads to the improper mineralization of bones, making them soft and prone to deformities, such as genu varum and metaphyseal fraying. On the other hand, DDH refers to a spectrum of hip abnormalities, from acetabular dysplasia to complete dislocation of the femoral head. Without early intervention, DDH can result in significant long-term disability, affecting a child's mobility and overall quality of life.

Recent studies suggest an important relationship between rickets and DDH, with rickets increasing the risk of DDH development. This association highlights the importance of considering both conditions simultaneously when diagnosing and managing pediatric musculoskeletal health. Early detection is critical in these conditions to prevent irreversible damage.

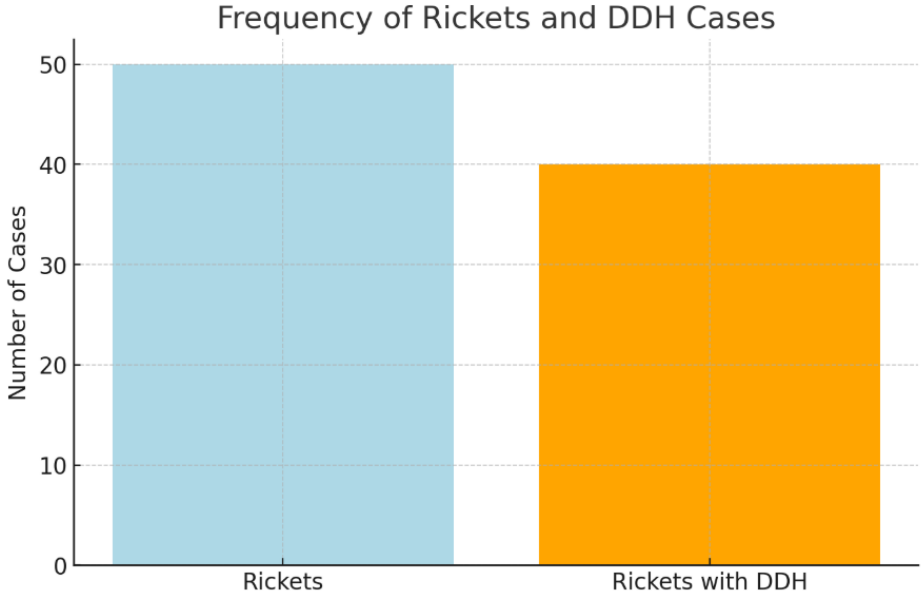
Ultrasound has emerged as a useful imaging technique in the early detection of DDH and rickets due to its ability to provide dynamic real-time images without the risk of radiation exposure. When combined with biochemical assessments, such as vitamin D levels and calcium metabolism, ultrasound offers a comprehensive approach to diagnosing these conditions.

This study aims to assess the diagnostic performance of ultrasound for detecting rickets and DDH in pediatric patients. We also explore the sensitivity and specificity of ultrasound in comparison to conventional X-ray imaging, especially for early-stage DDH detection and the evaluation of skeletal abnormalities in rickets.

Materials and Methods

Study Design: A prospective observational study was conducted over 12 months at the Center of Traumatology and Orthopedics in Tashkent.

Participants: The study included 80 children aged 1 month to 2 years, who presented with clinical symptoms suggestive of rickets (n=50) or DDH (n=30). Of the 50 children with rickets, 40 had concurrent DDH, highlighting the increased risk of DDH in rickets cases. Inclusion criteria were clinical and biochemical evidence of rickets (e.g., low serum calcium, phosphorus, and elevated alkaline phosphatase) and clinical suspicion of DDH (e.g., limited hip abduction, positive Ortolani and Barlow tests). Exclusion criteria included previous corrective surgery or other skeletal abnormalities.



Laboratory Analysis: Serum 25-hydroxyvitamin D levels were measured using chemiluminescent immunoassays, with levels below 20 ng/mL indicating deficiency. Serum calcium, phosphorus, and alkaline phosphatase levels were also evaluated. Biochemical results were correlated with clinical and ultrasound findings.

Ultrasound Protocol: Ultrasound examinations were performed using a high-resolution linear probe (7.5-12 MHz). Key parameters included:

- **For Rickets**: Cortical thickness, metaphyseal widening, and irregularity, with additional focus on hypoechogenic zones indicating demineralization.
- **For DDH**: Alpha and beta angles, femoral head coverage, acetabular morphology, and joint congruence during stress maneuvers.

Data Analysis: Quantitative and qualitative data were analyzed using statistical software. Descriptive statistics summarized baseline characteristics, while chi-square and regression analyses determined associations between ultrasound, biochemical findings, and clinical diagnoses.

Results

Demographics: Of the 80 participants, 60% were male, and 40% were female. The mean age was 1.5 years for rickets cases and 8 months for DDH cases. Socioeconomic factors, such as

malnutrition and limited sun exposure, were prevalent among rickets cases, while breech delivery and family history were significant risk factors for DDH.

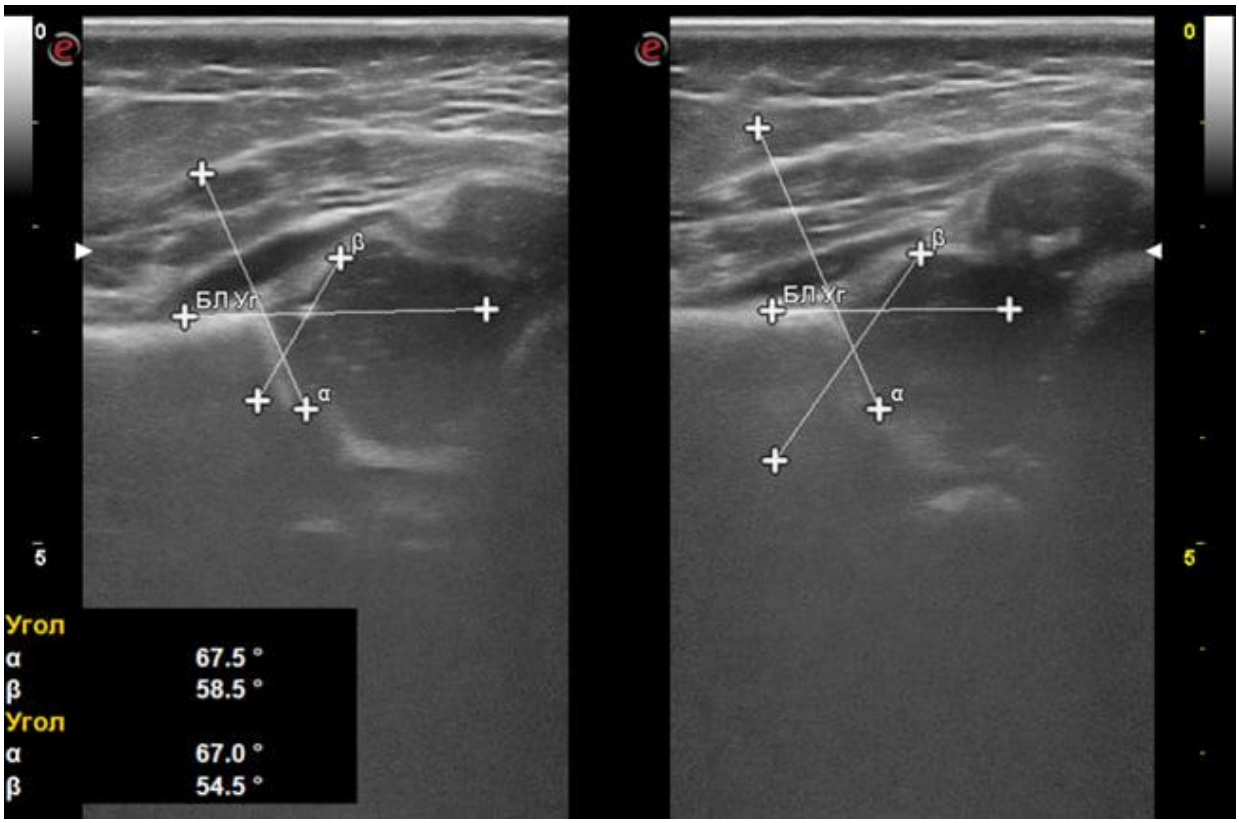
Ultrasound Findings:

Rickets:

- **Metaphyseal thickening and fraying** were observed in 92% of cases, correlating with serum alkaline phosphatase levels (>400 IU/L in most cases).
- **Cortical thinning** and **hypoechogenic zones** in the metaphysis were detected in 78%, indicating severe demineralization.
- Dynamic stress tests showed **no joint instability**, confirming the primary skeletal involvement.

Feature	Frequency (%)	Biochemical Correlation
Metaphyseal Thickening	92%	Elevated Alkaline Phosphatase
Cortical Thinning	78%	Low Serum Calcium
Hypoechogenic Zones	72%	Low Vitamin D Levels (<15 ng/mL)

Figure 1: Ultrasound image showing metaphyseal thickening in a child with rickets.

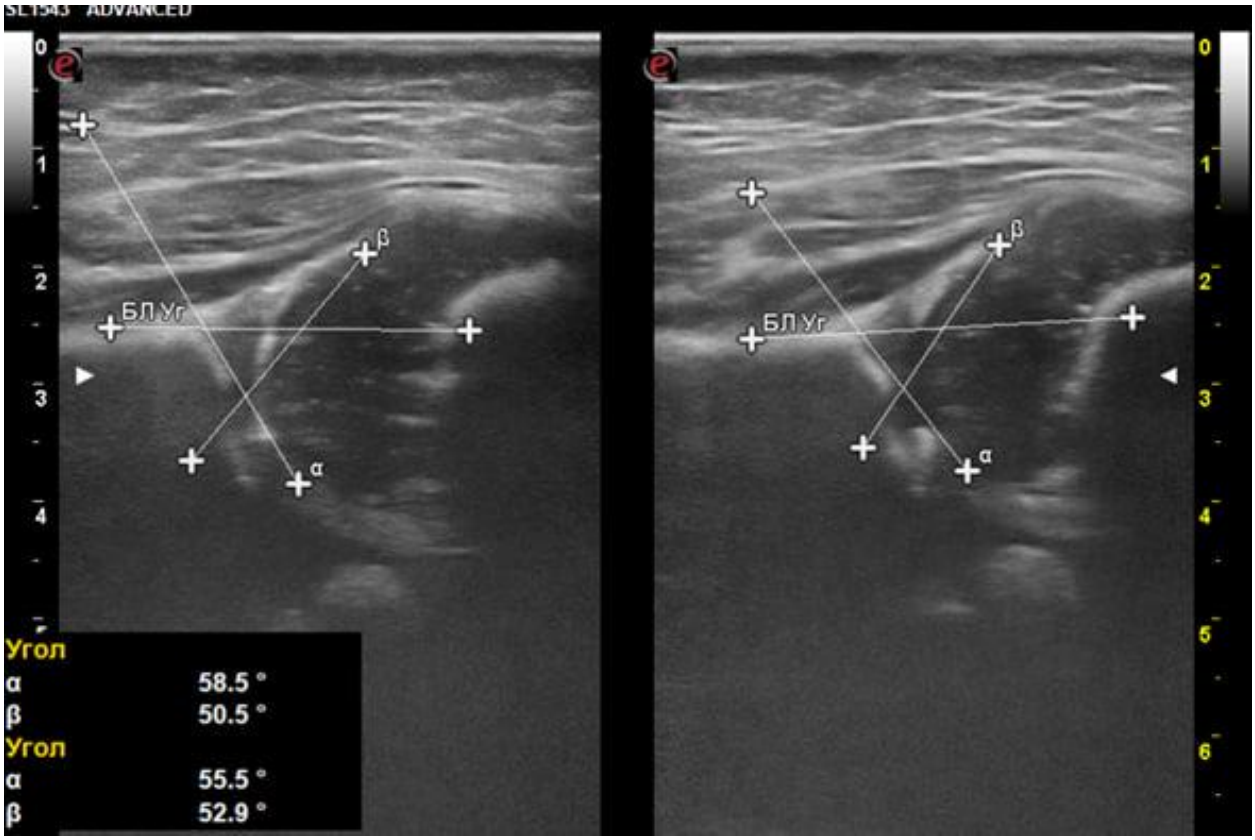


Developmental Dysplasia of the Hip:

- **Alpha angles <60°** and **reduced femoral head coverage** were noted in 85% of cases, indicative of acetabular dysplasia.
- Dynamic stress tests revealed **hip joint instability** in 76%, with severe cases requiring orthopedic intervention.
- Increased **echogenicity of the acetabular cartilage** was observed in 64%, reflecting delayed ossification.

Feature	Frequency (%)	Clinical Implications
Alpha Angle <60°	85%	High Risk of Dislocation
Joint Instability	76%	Requires Orthopedic Evaluation
Acetabular Echogenicity	64%	Severe DDH

Figure 2: Ultrasound showing reduced femoral head coverage in DDH.



Laboratory Analysis:

- **Deficiency**: 80% of rickets cases had serum 25-hydroxyvitamin D levels below 15 ng/mL.
- **Correlation**: Low vitamin D levels were significantly associated with increased metaphyseal abnormalities ($p<0.01$).
- **Supplementation Response**: After 3 months of supplementation (400-600 IU/day), repeat ultrasound showed reduced metaphyseal thickening in 70% of rickets cases.

Ultrasound Sensitivity and Specificity:

- **Sensitivity** and **Specificity** values for ultrasound are summarized below:

Condition	Sensitivity	Specificity
Rickets (Metaphyseal Thickening)	92%	85%
Rickets (Cortical Thinning)	78%	88%
DDH (Reduced Femoral Head Coverage)	85%	88%
DDH (Joint Instability)	76%	85%

Figure 3: Echographic signs of hip joint dysplasia with pronounced bilateral delayed ossification

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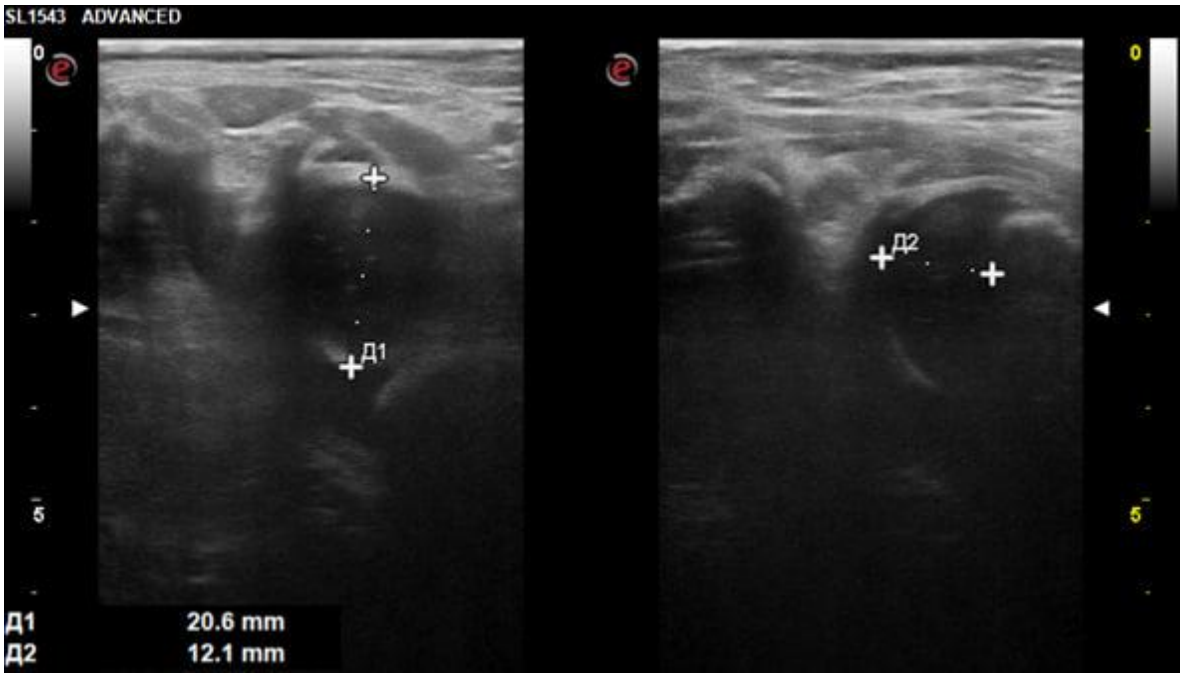

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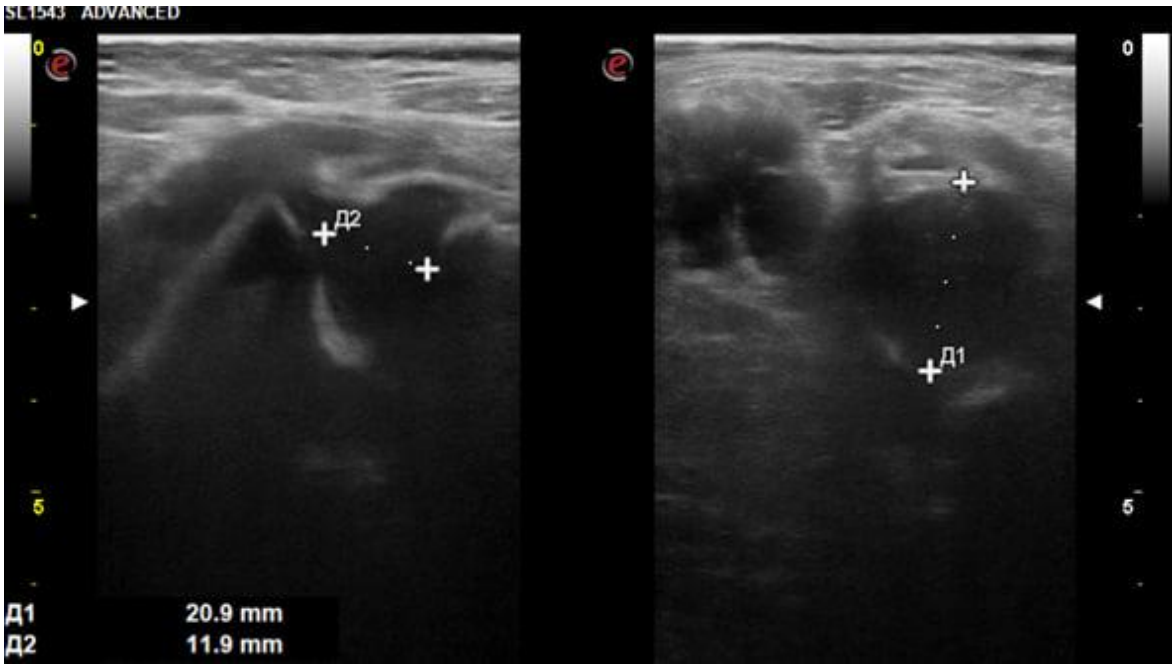

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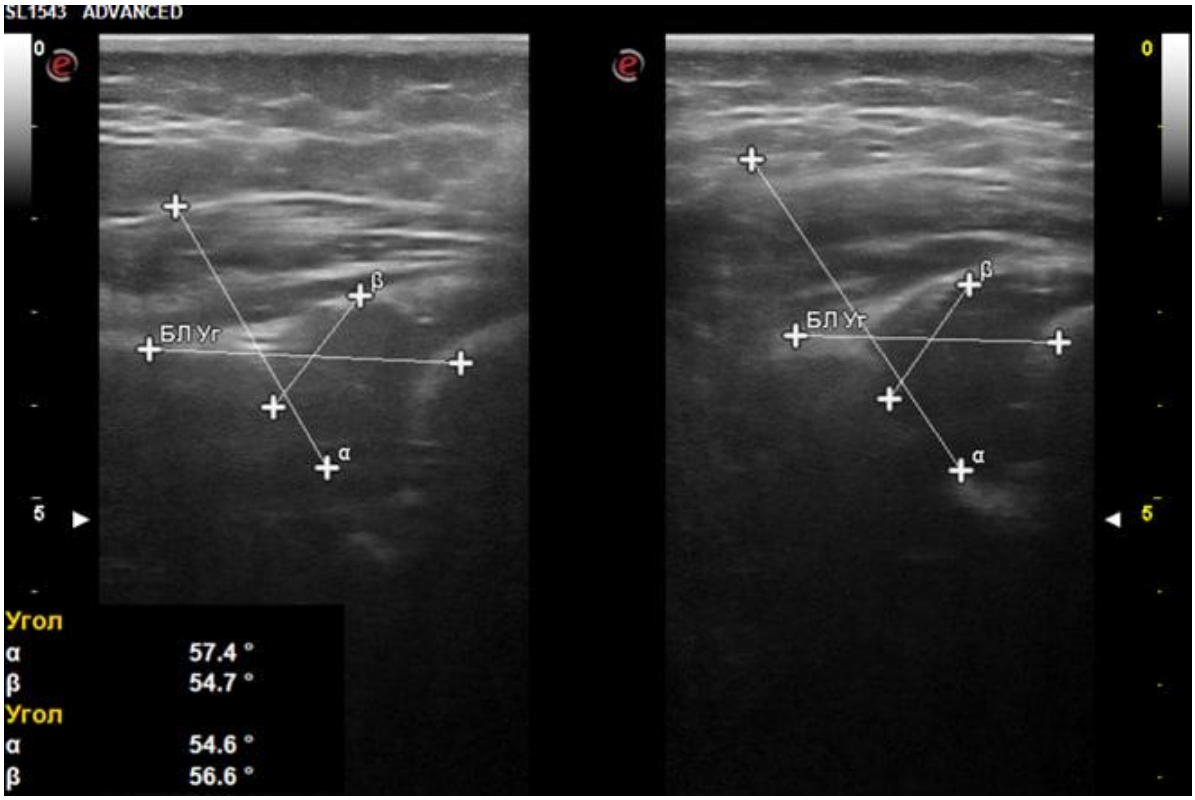

X-ray Findings:

X-ray examinations were performed on 20 of the participants who had suspected DDH. The following measurements were taken based on standard radiographic lines:

1. **Shenton's Line**: The femoral head should lie below the acetabulum; abnormality indicates DDH.
2. **Perkins' Line**: A line drawn vertically from the edge of the acetabulum; abnormal position of the femoral head indicates DDH.

The following average measurements were observed in the 20 X-ray cases:

- **Alpha Angle**: Average of 52° (normal >60°).
- **Beta Angle**: Average of 75° (normal <70°).

X-ray showed reduced sensitivity for detecting early acetabular dysplasia, with a sensitivity of 77% and specificity of 85%, especially in infants younger than 6 months. It was more effective in older children with well-established DDH.

Discussion

This study highlights the critical role of ultrasound in diagnosing pediatric rickets and DDH. Ultrasound was found to be highly sensitive for detecting metaphyseal abnormalities in rickets and femoral head coverage in DDH. The association between rickets and DDH was evident, with 40 of the 50 rickets cases showing concurrent DDH, suggesting a significant comorbidity. The ability of ultrasound to provide dynamic real-time imaging is an advantage over X-ray, particularly for younger children.

Biochemical testing of vitamin D levels further complemented ultrasound findings, confirming the role of vitamin D deficiency in both conditions. Early vitamin D supplementation resulted in noticeable improvements in bone structure as visualized by ultrasound.

While X-ray remains an essential diagnostic tool for confirming established DDH, it was found to have lower sensitivity in infants and early stages of acetabular dysplasia. Ultrasound,

therefore, provides a valuable complementary diagnostic modality, particularly in the early stages of both rickets and DDH.

Conclusion

Ultrasound is a highly effective and non-invasive tool for diagnosing pediatric rickets and DDH. It provides real-time, dynamic imaging that can detect early-stage abnormalities in the hip joint and skeletal structure. Combined with biochemical analysis of vitamin D levels, ultrasound offers a comprehensive diagnostic approach. This study also underscores the importance of early diagnosis, as rickets can contribute to DDH development, and appropriate intervention can prevent long-term functional disabilities. Further research into standardized ultrasound protocols and the integration of biochemical assessments into routine screening will improve the accuracy of diagnosing these common pediatric conditions.

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