I.O.F.O.S. Recommendations for Quality Assurance: Bone Age Assessment in Living Individuals

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KEYWORDS

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ABSTRACT

Age assessment in living individuals is an important question of legal and humanitarian decision-making when reliable identification documents are unavailable.

In January 2026, the International Organization for Forensic Odonto-Stomatology (IOFOS) finalized, for the first time, the IOFOS Recommendations for Quality Assurance: Bone Age Assessment in Living Individuals. This document establishes a harmonized framework for the scientific, ethical, and legal application of bone age assessment in living persons.

The recommendations define minimum standards for the selection and interpretation of bone indicators addressing imaging modalities, reference population requirements, uncertainty reporting, and integration with dental age assessment. Particular emphasis is placed on transparency, protection of individual rights, and the forensic implications of legal age thresholds.

These recommendations are intended to be applied alongside IOFOS Recommendations for Quality Assurance: Dental Age Assessment in Living Individuals and to serve as an international reference framework, to be adapted and incorporated into national legal and regulatory systems according to jurisdiction-specific requirements.

1. INTRODUCTION

Estimating chronological age in living individuals plays a pivotal role in forensic, legal, and humanitarian settings, especially when reliable birth documentation is unavailable or disputed.[1] While dental age assessment has long served as a foundational method, skeletal or bone age assessment offers valuable complementary information, particularly from the hand/wrist bones, clavicular epiphyses, knee and, in some contexts, vertebral maturation. [2-8,10]

Bone age assessment is built on observing predictable ossification and epiphyseal fusion patterns over time, which are influenced by genetic, nutritional, hormonal, and environmental factors.[6-8,11] Classical techniques, such as the Greulich & Pyle atlas and the Tanner-Whitehouse scoring system applied to hand/wrist radiographs, remain central in clinical and forensic practice.[5,6,8,9] Radiographic assessments of the medial clavicular epiphysis (e.g. via CT or high-resolution imaging) are also used for later adolescent ages, since the hand bones may have already matured.[11-18] In certain approaches, vertebral maturation (especially of cervical vertebrae) is evaluated via cephalometric radiographs as a skeletal maturity marker.[19]

Because dentists are trained in interpreting radiographic anatomy and growth of craniofacial structures, they hold a potential role in bone age assessment, provided they are familiar with skeletal imaging, ossification staging, and the anatomical landmarks of the skeletal regions in question.[7,10,20] A dentist with expertise in radiographic evaluation and skeletal biology can integrate dental and skeletal data, thereby enhancing the robustness of age assessment.[2,4,21-28]

This document proposes the IOFOS Recommendations for Bone Age Assessment in Living Persons, preserving the structural framework of the dental age guideline but tailored to skeletal methods (hand/wrist, clavicle, knee, vertebrae).[29,30] It seeks to define minimum methodological standards, ethical safeguards[20], error quantification practices, and interpretative principles, so that bone age assessments in living individuals can be scientifically defensible, transparent in their limitations, and respectful of individual rights. [20,29,31,33]

2. SCOPE

This document presents the first recommendations of IOFOS for Bone Age Assessment in Living Individuals.[29,30]

3. BACKGROUND

In many forensic, clinical, and legal contexts, relying solely on dental indicators may not capture the full picture of an individual's maturational status. Integrating dental information with skeletal (bone) data offers a more complete framework for estimating chronological age.[2-4,21,22-26] This is because ossification and epiphyseal fusion in the hand/wrist, clavicle, knee and vertebral bodies follow biologically informed sequences that complement dental maturation trends.[5,6,8,12,16,17,19,34,36-38]

When skeletal development of the hand or wrist is incomplete, this usually indicates a subadult status.[5,6,8] If the hand skeleton is fully mature, an additional evaluation of the medial clavicular epiphysis may be undertaken, as this structure continues to ossify beyond adolescence.[12-18,34,35] The clavicle provides critical information in the transition between late adolescence and early adulthood, complementing dental findings in determining whether a legal age threshold (e.g., 18 years) has been surpassed. [39-49]

In clinical dentistry, particularly in orthodontics, dentists routinely interpret skeletal maturation indicators (e.g. hand/wrist radiographs, cephalometric vertical growth patterns) to guide treatment timing, predict growth spurts, or assess skeletal stage.[5,50-54] Thus, using such information for bone age assessment in living individuals does not exceed the domain of competence of a trained dentist; rather, it leverages a dimension of expertise already present in dental practice.[39,40,43-45,55-58]

This document proposes to formalize how a dentist, working within a multidisciplinary forensic or medical team, may responsibly incorporate skeletal imaging (such as hand/wrist and clavicle) alongside dental markers to arrive at a combined, justified age assessment without overstepping professional boundaries or ethical constraints. [7,10,20,27,20,59]

4. TERMS AND DEFINITIONS FOR BONE AGE ASSESSMENT

Note: For the purposes of this document, the terms and definitions given in the IOFOS Recommendation's Document for Dental Age Assessment in Living Individuals apply. The following additional terms and definitions are specific to bone age assessment:

4.1 Bone age

Is the age inferred from bone development stages or structural bone changes, through radiographic images, used to approximate chronological age.

4.2 Bone age range (interval) assessment

Processes using bone information and relating it to chronological age.

4.3 Bone age assessment technique

Method used for bone age assessment.

5. PROCEDURES AND STEPS

Note:

1. Please consult the IOFOS Recommendations for Dental Age Assessment for Living Individuals for procedures and steps already specified there; this document adds the bone estimation components not covered in the dental guidance.
2. The use of bone age markers, imaging procedures, and bone assessment methods must comply with the legal and regulatory frameworks of the jurisdiction in question, as requirements for ionizing radiation or imaging in living individuals differ between countries.

The choice of bone assessment methods (for instances such as hand/wrist, knee and clavicle) must be grounded in the dental findings: the developmental status of the dentition guides which bone regions and imaging modalities are most informative in the given case. For the hand/wrist, the Greulich & Pyle atlas approach remains a classical method to compare radiographs of carpal and phalangeal ossification with standard reference plates. [4] For the clavicle, a staging system of medial clavicular epiphyseal fusion can be applied, in CT or high-resolution imaging, to interpret ossification progression corresponding to age thresholds.[15,16] In both domains, the relevant reference studies must be carefully selected, those that document chronological ages associated with each ossification stage, in populations comparable to the subject, to calibrate the bone age assessment meaningfully in relation to the dental age results.

The use of alternative methods or bones must be supported by appropriate reference studies, establishing valid correlations between ossification or morphological markers and chronological age in the relevant population.

6. CONCLUSIONS

In forensic bone age assessment, the expert's report should integrate the findings from skeletal development (e.g., hand, wrist, and clavicle, etc) with dental markers to provide a scientifically justified estimate of chronological age. The assessment must define both the most probable age and/or a minimum age, in accordance with the forensic purpose and national legal or regulatory context.

As in dental age assessment, the minimum-age concept may be considered in some jurisdictions and case contexts; however, its use remains debated. Where applied, it ensures that the reported age does not overestimate the true biological age, thereby safeguarding the individual from being incorrectly classified as an adult. Reference studies appropriate to sex, population, and imaging modality (such as, radiograph, CT, MRI) must be used to justify stage assignment and age inference.

Finally, the interpretation of bone age must always be contextual and integrative, combining skeletal and dental markers. Where there is evidence or a reasonable basis to suspect such effects, variations attributable to population background, socioeconomic factors, or medical conditions shall be considered and documented in the interpretation. The final forensic opinion should provide a transparent statement of uncertainty, explicitly indicating whether the evidence supports or refutes that the individual has surpassed the relevant legal age threshold.

7. SUMMARY

Forensic age assessment is frequently requested by judicial or administrative bodies when an individual's actual age is unknown or disputed. Traditionally, dental age assessment has provided fundamental indicators, but skeletal maturation offers additional, complementary insights, especially through analysis of bone development such as in the hand/wrist, clavicle and knee.

This document presents the first IOFOS Recommendations for Bone Age Assessment in Living Individuals, intended to be used alongside the existing dental age assessment recommendations.

The proposed framework includes methodology for selecting imaging modalities, staging bone maturity, integrating reference studies, documenting uncertainties, and combining skeletal and dental indicators into a coherent final age assessment. Legal, ethical, and radiological constraints must be respected per jurisdiction, and all novel methods must be justified by validated reference studies.

The goal of these recommendations is to ensure bone age assessments in living persons are transparent, scientifically defensible, and compatible with individual rights and legal rigor.

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