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Guidelines for best practice: Imaging for age estimation in the living

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Context

These standards and guidelines have been developed as a collaborative effort by members of the International Association of Forensic Radiographers [IAFR] and the International Society of Forensic Radiology and Imaging [ISFRI] in association with the International Society of Radiographers and Radiologic Technologists [ISRRT]. Experts and members of other organisations from the fields of radiography, radiology, forensic medicine, forensic odontology and forensic anthropology have contributed to these guidelines.

The aim of these guidelines is to provide guidance to Radiographers when requested to perform imaging of individuals for assessment of age. These guidelines also include an overview of the requirements from other professions (e.g. forensic physicians, anthropologists, odontologists or radiologists).

Age Assessment in this document includes the estimation of age by assessing the dentition, as well as other skeletal areas such as the hand/wrist. The following commonly used terms are differentiated as:

- **Bone age** -general degree of maturation of bone that subjects of a population reach at a certain average age. This term may be used when referring to the bone age of a specific anatomical region (i.e., bone age in the hand and wrist).
- **Dental age** -general degree of development of teeth that subjects of a population reach at a certain average age.
- **Skeletal age** -general degree of maturation of the skeleton that subjects of a population reach at a certain average age. This term may be used when talking about the entire skeleton.
- **Age assessment** -the three terms above are general in the sense of indicating the behaviour of a population in relation to skeletal and dental maturity. Age assessment is an individual concept. It is the estimation of the most probable age of an individual considering their skeletal and dental age and their specific demographic characteristics (sex, health, physical activity, intake, etc).

These guidelines have been developed to promote international 'best practice' with regards to image acquisition and to highlight established evidence-based approaches when imaging for bone age estimation. The ability to adhere to 'best practice' is dependent on local facilities and resources, as well as the expertise of the practitioner, their selection of

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appropriate age assessment methodology and the availability of child-appropriate equipment.

The European Asylum Support Office (2014, p.9) have defined age assessment as:

> "*… the process by which authorities seek to establish the chronological age, or range of age, or determine whether an individual is an adult or a child. The UN Committee on the Rights of the Child/CRC general Comment No 6 states that: the identification of a child as an unaccompanied and separated child includes age assessment, which should take into account physical appearance, but also psychological maturity. The assessment must be conducted in a scientific, safe, child and gender-sensitive and fair manner, avoiding any risk of violation of the physical integrity of the child, giving due respect to human dignity. Age assessment should only be used where there are grounds for serious doubt of an individual's age*."

Why is age assessment needed?

Age estimation of living individuals is important in its contribution to verifying in the most accurate way possible the chronological age of an individual for whom age is unknown for both civil and criminal proceedings. For example, in many jurisdictions the minimum age of criminal responsibility is 18 years. Therefore, for an undocumented individual or in cases where someone is falsifying their age, it is essential to confirm whether or not the individual has reached the age of legal liability or age of majority.

Demands for age assessments, both for civil or criminal cases, mostly relate to young adult delinquents but also include young immigrants and refugees seeking political asylum. Unaccompanied Asylum Seeking Children [UASC] and Separated Children are extremely vulnerable to global trends of criminalisation, imprisonment, exploitation, trafficking, forced marriage and violations of their rights (Brownlee and Smith, 2011; Roscam Abbing, 2011). They may have false documents or may not know their age, or they may have no documentation to prove their identity or literally may not know their date of birth (Brownlee and Smith, 2011). It is possible that some children do not know their age or their cultural background.

The reasons age assessments in the living may be requested include but are not limited to: asylum seekers who may not know their age or may attempt to falsify their age; undocumented individuals in cases of criminal prosecution, human trafficking or suspicion of underage marriage; determination of

educational and welfare support of a child; and cases regarding confirmation of pensions and other benefits (Lewis and Kasper, 2018; Lewis and Senn, 2013; Brownlees and Yazdani, 2012). Although social workers and border authorities enquire about the age of the person, scientific methods can be employed to confirm age or provide a more reliable estimate (Liversidge et al., 2015). Age assessments have even been undertaken in sporting participants (Schmidt et al., 2015; Wittschieber et al., 2014; Vietha et al., 2014)

The rights of the child

The rights of children are enshrined in the United Nations Convention on the Rights of the Child [UNCRC] (1989). This framework underpins all international guidance in relation to children. The UNCRC (1989) is a universally agreed set of non-negotiable standards and obligations which set minimum entitlements and freedoms that should be respected by governments.

Article 37 relates specifically to children who are in conflict with the law and states that they have a right to be treated "*in a manner which takes into account the needs of persons of his or her age*" (UNCRC, 1989, p.10). Therefore, a credible age assessment is crucial in safeguarding children and juveniles, ensuring appropriate treatment. Where the age of the individual is not known or uncertain, the benefit of doubt should prevail and he or she shall be presumed to be a child. The Committee on the Rights of the Child [CRC] recommends that each State party:

> "*give the benefit of the doubt in age-disputed cases of separated children seeking asylum, and seek experts' guidance on how to determine age*" (United Nations, 2008, p.17).

Who is involved in calculating age?

There may be a number of specialists involved in providing age assessments including medical practitioners and social workers. Forensic physicians, anthropologists, odontologists and radiologists are commonly asked to contribute to estimating the age of a living person for legal purposes through the analysis of images.

Role of the Forensic Radiographer

A forensic radiographer is a healthcare professional who is authorised in their jurisdiction to deliver ionising radiation for medical purposes and who has undertaken further postgraduate education in forensic radiography / forensic science and medico-legal aspects of their profession (Viner, 2008).

Following liaison with other members of the investigative team (e.g. forensic physician, anthropologist, odontologist or radiologist), the forensic

radiographer will use the most appropriate imaging modality to provide the maximum amount of diagnostic information whilst ensuring that the radiation dose is kept as low as possible in accordance with the ALARA principle (International Commission on Radiological Protection [ICRP], 2007).

The role of the Forensic Radiographer has been described by the Irish Institute of Radiography and Radiation Therapy [IIRRT], 2016, p.11-12):

- *"To produce imaging of the highest possible quality diagnostic quality using appropriate exposure factors / scan parameters and to be familiar with the most common practices in processing tools and techniques.*
- *They must understand how to acquire and post-process images in a safe and hygienic environment whilst observing the medico-legal aspects of undertaking Forensic Imaging.*
- *They should understand the importance of selecting the appropriate modality to answer the legal question(s) being asked, based on knowledge of the capabilities and limitations of the various aspects of imaging.*
- *The forensic radiographer has a responsibility to ensure the radiation safety of all staff… and is responsible for establishing and policing the "controlled area" of radiation.*
- *A forensic radiographer has a responsibility to produce a written Witness Document contemporaneously in conjunction with the Appropriate Witness in order to authenticate any images produced over the course of an examination thus ensuring that all such images are admissible as evidence if produced in court."*

The IAFR recognises that Forensic Radiography uses diagnostic imaging to answer questions of law and therefore may be performed on live individuals (The Society & College of Radiographers and The International Association of Forensic Radiographers [SCOR & IAFR], 2014). For example, the IIRRT Forensic guidelines (2016, p.13) state that under European radiation protection legislation:

> "*All forensic requests on living subjects must be treated as non-medical referrals…and as such, full informed written consent should be obtained. The referring clinician should explain the procedure and obtain consent, ideally written, from the individual, as there is increased potential for validity of consent to be questioned in forensic cases. Implied consent is never legally acceptable. For individuals who are unable to give consent, appropriate arrangements should be made to obtain consent by means of a Court Order. If no consent is given, then imaging examinations must not be performed."*

Consent will be discussed in more detail later in this document.

Role of the Forensic Physician

In some countries, the assessment of age in the forensic context is performed by forensic physicians who will examine the physical features of the individual (e.g. see Schmeling et al. 2008). Whilst radiological and odontological expertise may be sought, the global evaluation of the case is undertaken by forensic physicians who will present the report in a manner suitable for understanding by the legal system.

Role of the Forensic Radiologist

Forensic radiologists are clinically trained experts in the interpretation and reporting of radiological examinations of the body and procedures which are required for medico-legal purposes in court procedures or law enforcement. Radiological methods are widely used in identification, age estimation and establishing cause and manner of death or likely diagnosis. The role of the forensic radiologist in skeletal age estimation is to appropriately interpret high-quality images, incorporating the imprecision of current clinical practice parameters (Thali et al., 2011).

Role of the Forensic Odontologist

The forensic odontologist is a dento-legal expert in the examination and analysis of the teeth, related dental structures and associated soft tissues. One of their functions is to assess dental age through the dental examination and evaluation of tooth morphologic development, eruption sequencing, histologic examination and post-formation modifications/changes of the human dentition. A Dental Age Assessment Procedures Chart has been published by the American Board of Forensic Odontology to assist the practitioner in the best practice selection of dental age assessment methodology (American Board of Forensic Odontology [ABFO], 2018).

The forensic odontologist has the expertise to determine methodology required and thus the types and required number of dental radiographs and/or imaging modality necessary to estimate an individual's age.

Role of the Forensic Anthropologist

A forensic anthropologist is an expert in the examination and analysis of the human skeleton to address questions of medico legal importance (Black et al., 2010; Komar and Buikstra, 2008). When estimating the age of living individuals, forensic anthropologists review radiographic images (e.g. radiographs, CTs, MRIs and ultrasound) in order to assess the stage of skeletal development that an individual has reached (Márquez-Grant, 2015).

The forensic anthropologist is not involved in acquiring the images but may work in conjunction with forensic radiographers, radiologists, odontologists and physicians to advise on which area of the body to image, the type of image and imaging parameters to ensure optimal results for the individual

being age assessed. The area(s) of the body to be imaged are usually selected based on the suspected or claimed age of the individual (Franklin et al., 2015). These are usually the left hand and wrist and the sternoclavicular joints or the medial clavicular epiphysis on some occasions (Schmeling et al., 2008). The forensic anthropologist will be able to advise on the most appropriate imaging modality/modalities for each body area and the projections most valuable to them.

Methods for calculating age

A number of guidelines exist in age estimation in living individuals (Schmeling et al., 2016; Franklin et al., 2015; European Asylum Support Office, 2014; Thali et al., 2011; Black et al., 2010). Ageing can be defined as the uninterrupted process of normal development that leads to a progressive decline in physiological function and ultimately to death. However, there are different measurements of age: chronological age, measured by accepted calendar dating (number of days/years since birth); social age which reflects the normative behavior that is culturally imposed upon particular age groups (social perception of age); and physiological or biological age, a medical construct that estimates levels of functional ability or impairment (Blau and Hill, 2014).

Age estimation of a living individual involves establishing the physiological age of the skeleton, tooth emergence and dental development as well as sexual maturation determined by a medical doctor/physician and then attempting to correlate them with chronological age (Schmeling et al., 2008). Unfortunately, chronological age, dental age and skeletal (bone) age are not necessarily the same in a given individual (Introna and Campobasso, 2006). Consequently, it is acknowledged that estimating chronological age in living individuals is complex, and when possible, multiple techniques from different forensic disciplines should be used to assess age.

In addition, many established skeletal age estimation techniques require radiographic imaging. This can be problematic because many countries prohibit imaging techniques which utilise ionising radiation for medico-legal (i.e. non-medical) purposes. Some studies propose the use of MRI as a viable method of skeletal age estimation which has the advantage of not using ionising radiation (Stern et al., 2014).

Below are the most commonly used methods in assessing age from radiographs/images/skeletal images of a living individual. These are taken into consideration along with sex, ancestry, medical conditions, nutrition, etc. The age groups have been determined by those proposed by the World Health Organisation (Knoppert et al., 2007).

Individuals in whom dental development is not complete

Dental Age Assessment Methods

Atlas dental age assessment techniques utilise diagrammatic representations of the morphologic developing tooth structures with their associated emergence pattern. Atlas techniques are non-sex specific and have a limited number of population specific data sets resulting in a higher degree of variability particularly in mid-childhood through adolescence. In addition, Atlas techniques are often derived from mixed ancestral data. Atlas techniques are particularly useful in mass disaster and clustered victim situations due to their ability to rapidly segregate child, adolescent, and adult remains into age intervals.

Infant dental age assessment techniques utilise radiographic evaluation to stage the degree of morphologic development and mineralisation of the primary and/or secondary dentition as well as resorption of the primary dentition. Infant/child techniques should consider sex, ancestry, and population specificity. These techniques provide a more accurate and reliable estimate of age over emergence through soft tissues and atlas methodologies.

This interval in human dental development includes the postnatal presence of the developing and resorbing primary dentition including the period of mixed primary and secondary dentitions.

Adolescent dental age assessment techniques utilise radiographic evaluation to stage the degree of dental development toward the latter half of dental morphologic maturation. Although, the third molar exhibits the highest degree of morphologic developmental variability, it remains extremely useful in the assessment of age (Liversidge and Marsden, 2010, Harris et al., 2010). While teeth other than the third molar continue to undergo morphologic development, early adolescence age assessment methodology should be utilised. Late adolescent age assessment techniques should be used when the third molar is the only remaining tooth continuing to undergo morphologic development. These late adolescent techniques play a useful role in assisting legal authorities in determining the disposition of cases involving immigration, asylum seekers and legal age of majority. In an effort to assist authorities, late adolescent age estimations often include probability of attaining a given age in addition to estimated age and corresponding level of uncertainty.

This interval in human dental development includes the presence of the developed and developing secondary dentition. Retained primary teeth may also be present as a special circumstance during this interval.

Individuals in whom dental development is completed

Adult dental age assessment techniques may utilise radiographic morphological evaluation as well as gross and microscopic observation of

post-formation changes within the dentition following the cessation of morphologic dental development. Although others have been described, there are six traditional post-formation variables that have been used in the assessment of adult age. They are root transparency, secondary dentine deposition, periodontal attachment, cementum apposition, attrition, and root resorption.

The most useful of the criteria are root transparency and secondary dentine deposition (Lewis and Senn, 2013). The least valuable criterion is root resorption (Maples, 1978; Johanson, 1971). Ethical considerations may restrict the use of many adult age assessment methodologies due to the requirement of sacrificing tooth structure.

This interval in human dental development occurs when all teeth present have completed crown/root development and are therefore considered dentally mature.

Radiographic Assessment Methods

Mughal et al. (2014) described the most common Bone Age Assessment Methods utilised by forensic anthropologists and radiologists (European Asylum Support Office, 2014; Schmeling et al., 2011). These are summarised below.

Greulich & Pyle (GP) Atlas

This method is based on 'The *Radiographic Atlas of Skeletal Development of the Hand and Wrist'*, by Dr William Walter Greulich and Dr Sarah Idell Pyle (1959). Whilst the last edition may have been published in 1959, it is still one of the most commonly used atlases for skeletal age measurement by radiologists (Gaskin et al., 2011; Zafar et al., 2010). It contains reference images of the left hand/wrist for male and female standards from birth till 18 years of age for females and 19 years of age for males. Also, written explanations regarding the gradual age-related changes observed in the bone structure is provided with each standard image. Bone age is calculated by comparing a non-dominant wrist radiograph of the subject with the nearest matching reference radiographs provided in the atlas to determine which most demonstrates the closest maturational state. The skeletal age is given by the age of this closest standard (Gaskin et al., 2011).

According to Mughal et al. (2014) the GP method is simpler and faster than other radiograph based methods GP atlas standards are considered applicable and reliable for children in Australia (Lin et al., 2006), the UK (Hackman and Black, 2013) and the Middle East (Soudack et al., 2012). However, disparity between the calculated bone age and chronological age is noted when this method is applied to Asian children (Zafar et al., 2010; Büken et al., 2007) and to Afro-Americans and Hispanics (Garamendi et al., 2005; Mora et al., 2001; Loder et al., 1993; Ontell et al., 1996).

It is acknowledged that the GP atlas approach has been adapted to different population samples. For example, the Hernández et al atlas (1991) is based on a sample population of the Basque Country and its results are used in Spain as a national reference for bone age in hand and wrist in Spanish children. Germany also has a population specific atlas (Thiemann et al., 2006).

Tanner Whitehouse (TW2) Method

The Tanner & Whitehouse (TW2) method, in contrast to the GP Atlas, is not based on the individual's chronological age, rather it is based on the level of maturity for 20 selected regions of interest (ROI) in specific bones of the wrist and hand in each age population. The development level of each ROI is categorised into specific stages labelled as (A, B, C, D). A numerical score is given to each stage of development for each identified bone. By summing up all these scores from the ROIs, a total maturity score is calculated. This score is correlated with the skeletal age separately for males and females. The TW2 method is comparatively more complex and requires more time; however for some populations it is more accurate and reproducible when compared to GP method (Khan and Elayappen, 2012).

Tanner Whitehouse (TW3) Method

This method updated the relationship of the skeletal maturity score (SMS) with skeletal age to address the secular trend that had occurred in skeletal maturation since the second edition of the atlas had been published (Lynn and Warner, 2007). Studies have suggested that TW3 is more accurate compared to the TW2 method because children are maturing more rapidly and therefore reaching a given skeletal maturity score more quickly and at an earlier chronological age than in the past (Vignolo et al., 1999). TW3 was acknowledged to have a slight tendency to under-estimate for girls after the age of 12 and for boys after the age of 13 years (Ortega et al., 2006, Pinchi et al., 2014). TW3 is considered to be more reliable than GP particularly in some populations because the GP method tends to over-estimate age, which may lead to legal consequences for an asylum seeker or refugee who is claiming to be a minor (Pinchi et al., 2014). It is therefore recommended that a combination of both the GP and TW3 methods should be used along with information from other examinations to assure a more accurate estimation of age (Pinchi et al., 2014).

Gilsanz & Ratib (GR) Atlas

A digital atlas originally developed in 2005 by Gilsanz and Ratib produced idealised and artificial images for specific age and sex standards of skeletal maturity by analysing in detail the size, shape, morphology and density of ossification centers in hand radiographs of healthy children, and generating images that include the typical characteristics of development for each of the ossification centres (Kaplowitz et al., 2010). The images of the new GR atlas are much more precise and have a better quality than those of the older GP atlases. The newer GR atlas standards are spaced at regular 6 monthly intervals from the ages of 2-6 years of age and at yearly intervals from age 7-17 years of age (Gilsanz and Ratib, 2012).

Software programmes

Automatic skeletal age assessment software exist and can be used to eliminate inter-observer variation (Thodberg and Sävendahl, 2010). One such as example is the 'BoneXpert' software which has obtained a CE certificate so that it can be used in the clinical setting in Europe but it is acknowledged that in the United States of America, it's use is classified as 'investigational device' (Thodberg et al., 2016; Thodberg et al., 2009).

Radiographic Techniques

An imaging protocol is essential in order to standardise practice and maintain quality. Radiographic techniques may include dental imaging, radiography or other specialist modalities such as CT or MRI. Bone age calculations should be within 10% of the chronological age for normal subjects (Gilsanz and Ratib, 2012).

Dental radiographs

Dental radiographs complement the visual examination of the dental and maxillofacial structures and usually provide significant data essential for accurate age estimation. Dental age assessment techniques that make use of radiographs often provide the most accurate assessment of chronological age (Lewis and Senn, 2015; Lewis and Senn, 2013; Taylor and Blenkin, 2010). Examples of imaging that can be used, at the discretion of the odontologist, for dental age assessments include: dental periapical radiographs, panoramic radiographs, dental Computed Tomography [CT] scans (Bassed et al., 2011) and dental Magnetic Resonance Imaging [MRI] scans (De Tobel et al., 2017; Baumann et al., 2015).

Skeletal radiographs

In clinical practice, radiography of the hand and wrist continues to be the most widely used method and is considered the gold standard for bone age estimation (Chaumoitre et al., 2017), despite recent research involving the use of computed tomography (CT), magnetic resonance imaging (MRI) and ultrasound.

Radiograph of hand/wrist

A study by Mughal et al. (2014) concluded that the most commonly used and extensively developed method for skeletal age assessment in living children under 18 years of age utilises hand/wrist radiographs. Whilst the original GP atlas uses radiographs of the left hand/wrist as reference images (Gilsanz and Ratib, 2005; Greulich and Pyle, 1959), if radiographs are already in existence for the right hand/wrist, research has demonstrated that these can be used with the same degree of accuracy for age estimation purposes without the radiographic images having to be repeated (Hackman and Black, 2012).

It is acknowledged that assessment should also be made on the ulna, radius, metacarpals and phalanges when assessing the carpal bones.

Imaging of the clavicle

The German study group on Forensic Age Diagnostics [AGFAD] agree that if the skeletal development of the hand has been completed, an additional examination is required of the medial clavicles (Schmeling et al., 2008). This should be done, preferably by CT scan and a systematic procedure to assess age using CT images of the medial end of the clavicle have been proposed (Wittschieber et al., 2017).

Research in the use of the medial clavicle for age estimation purposes has increased in the last decade. The medial epiphysis of the clavicle fuses around the age of 22 years (dependent on the biological sex of the individual) although this varies (Schmeling et al., 2004; Scheuer et al., 2000). Mughal et al. (2014) state that CT of the medial end of the clavicle is the most commonly used and extensively developed modality for assessing individuals aged 18-22 years, as hand ossification, 3rd molar mineralisation and sexual maturation are usually completed by the age of 18 years.

The literature demonstrates that of the imaging modalities available, however, the use of radiographs is the least effective for imaging the medial clavicles and since a number of views are required, is most likely to expose the individual to ionising radiation but still leave the practitioner with an image that is not useful (Wittschieber et al., 2015).

The use of MRI and CT imaging have both been demonstrated to provide the practitioner with the ability to visualise and assess the maturation of this area of the skeleton. The improvement in visualisation has been augmented by the development of a scoring method which allows the stage of maturation to be assessed and related to a chronological age range (Kellinghaus et al., 2010; Schulz et al., 2005). Research has, however, demonstrated that image parameters such as slice thickness can greatly influence the accuracy of the assessment. Consequently, slice thickness should always be taken into account when undertaking imaging of this skeletal area (Mühler et al., 2006).

Imaging of other skeletal areas

Reference datasets and atlases exist for other areas of the skeleton such as the knee (Pyle and Hoerr, 1955), foot/ankle (Hoerr, 1962), elbow (Brodeur et al., 1981) and iliac crest (Schmidt et al., 2011). If images are already in existence for any of these areas of the body or if it is not possible to image the hand/wrist, the knee and/or the foot/ankle should be considered for imaging (Krämer et al., 2014; Hackman and Black, 2013; Hackman et al., 2013).

Maturation of the elbow occurs earlier in both males and females than at the knee or foot/ankle, so use of this area should be dependent on the suspected age of the child. Imaging of the iliac crest should only be considered using a non-ionising imaging modality due to non-medical irradiation of a child's gonads (Schmidt et al., 2011). A literature review suggests that the Risser sign (i.e. ossification of the iliac crest) is not uniform which results in discrepancies so it can't be used to replace the hand/wrist radiographs (Mughal et al., 2014).

Maggio (2017) concluded that MRI of the knee can be used to determine age of majority in males.

Imaging modalities

Ultrasound

Mughal et al. (2014) advised that further refinement of calculating skeletal age using ultrasound was required, as a few studies have shown wide discrepancies. Research with a larger sample size in a multi-ethnic population was recommended. Research is still ongoing regarding the use of ultrasound to assess the bone age of hand, wrist, clavicles and iliac crest apophysis (Benito Sánchez et al., 2016; Larsen et al., 2015). As there is limited published evidence currently available, it is unlikely that skeletal age estimation using ultrasound would be accepted as 'admissible' in court.

Computed Tomography (CT)

Further research is needed to validate the use of CT for children subject to immigration control (Ufuk et al., 2016). The use of CT is not currently recommended in children (under 18 years) for medico-legal purposes due to the higher radiation doses involved (Ramsthaler et al., 2009). Research has also shown that the imaging parameters used, e.g. slice thickness in cross-sectional imaging (e.g. CT) can have a significant effect on the ability to assign an age (Mühler et al., 2006).

Dual-energy X-ray absorptiometry (DXA/DEXA)

As DXA uses 1/10th of the radiation dose of a hand/wrist x-ray, it has been proposed that it could be used to assess bone age (Heppe et al., 2012). As there is limited published evidence currently available, it is unlikely that skeletal age would be estimated using DXA because there is insufficient detail to accurately assess the bones in the wrist.

Magnetic Resonance Imaging (MRI)

MRI does not utilise ionising radiation so it has been advocated as a modality that could be used to estimate skeletal age without an associated radiation dose. Dvorak et al. (2007a, 2007b) have concluded that MRI of the wrist can be used to estimate skeletal age in males aged 14-19 years of age. (Serinelli et al., 2015; Tomei et al., 2014) have concluded that MRI of the wrist can be used to estimate skeletal age in males aged 12-19 years of age, as skeletal age and chronological age were closely correlated. Currently there is ongoing research into the use of this imaging modality and age estimation (Saint-Martin et al., 2015; Dedouit et al., 2012).

Baumann et al. (2015, p.80) compared the mineralisation and eruption of molars on dental MRI with OPG images and concluded that "*dental MRI seems equally suited for dental age estimation*."

Responsibilities of the Forensic Practitioners

Depending on local arrangements, different professionals may perform different roles. It is acknowledged that the Age Estimation process shall involve multiple tests and tools in order for the result to be as accurate as possible. All forensic practitioners should adhere to the following principles if they perform the roles described.

Forensic Examination/Consultation

On initial consultation the forensic practitioner should perform a physical examination and then:

- Initiate accurate written records which are maintained throughout the process. These should take the form of signed and dated contemporaneous notes.
- Ensure that they request and understand the requirements of the analysis, is the request involving a claimed age or unknown age estimation.
- Gain as much information as possible about the individual (such as diet, medication, origin, medical history, etc.) and the requirements of the analysis. Based on this information, advise on the most appropriate body part and imaging modality to be used. This includes the use of images of the clavicle if the bones of the hand/wrist are fused.
- Advise the investigators to look for images that might already be in existence and be appropriate for use before advising that further images are taken.
- Ensure that the individual has given consent for the images to be taken and that any risks have been understood through the medium of an interpreter if required.
- Ensure that they gain as much information as possible from the referring source on the biographical background of the individual including: country of origin, stature, medication, health status etc.
- Discuss the best options for access to/delivery of the images taking cognisance of continuity of evidence/jurisdictional requirements.
- Ensure that all written notes and images are stored securely whilst not being analysed.
- Ensure the methods are the most appropriate ones used and closest to the geographical and/or ethnic/biological affiliation of the individual.
- Take into account the limitations of the methods when forming their opinion.
- Provide a peer-reviewed written report.
- All conclusions should be based on transparent reasoning and supported by appropriate literature.

Image Acquisition

Forensic practitioners who perform imaging shall meet local legal and professional requirements regarding licensing in relation to the exposure of living individuals to ionising radiation. They are responsible for:

- Establishing and maintaining operating and safety procedures that ensure radiation exposures are as low as reasonably practicable (ALARA principle, (ICRP, 2007). This includes the individual receiving ionising radiation and any persons who are in the area.
- Providing personal protective equipment [PPE] for the individual being irradiated where appropriate. Use of lead equivalent PPE should not obscure the region of interest. Limiting the irradiated field and reducing the number of exposures is the best means for minimising radiation dose.
- Establishing and 'policing' the 'controlled area' of radiation. This includes initiating corrective actions if the Controlled Area where ionising radiation is being emitted becomes unsafe or an emergency situation arises.
- Ensuring the radiation safety of all persons accompanying the individual, especially when imaging is performed outside a dedicated lead-lined x-ray room.
- Ensuring that all images have the correct demographics and correct anatomical annotation is present on every image.
- Being appropriately trained (in both forensic practice and the imaging modality) and competent in the operation of the respective imaging modality.
- Understanding the imaging modality and selecting the appropriate modality to answer the legal question(s) posed, based on knowledge of the capabilities and limitations of the various aspects of imaging.
- Being familiar with the most common in image processing tools and techniques used.

Image Interpretation

Forensic practitioners who assess images in order to provide a professional opinion in relation to Skeletal Age Estimation are responsible for:

- Ensuring that they have the sufficient training and skills to post-process the images using the software available. To be familiar with the most common processing tools and techniques;
- Ensuring that all age estimations are given as an age interval to allow for individual variation. Consideration should be given to including Maximum and Minimum probable age and probability of a subject to be older or younger than (a stated age). In particular the Minimum Age Concept is a useful approach in the forensic setting (Schmeling et al., 2016);
- Ensuring that the scientific and statistical basis for their opinion in relation to the age of the individual is transparent and clearly stated;
- Ensuring that any consideration of a claimed age is presented with an appropriate probability statement based on transparent reasoning;

- Ensuring that they have collected all of the information that is available about the individual whose age is assessed including (but not limited to); sex, ancestry, geographical background, socio-economic status, health status, medication, diet, lifestyle habits and that these factors are taken into consideration when undertaking the Skeletal Age assessment (Cameriere et al., 2007; Meijerman et al., 2007; Schmeling et al., 2006; Olze et al., 2004; Schmeling et al., 2000).
- Ensuring that the data used to analyse the images is based on population specific, robust and valid scientific research.
- Advocating that all age assessment processes that they are involved in adhere to jurisdictional and human rights legislation including the UN Convention on the Rights of the Child (1989).
- Ensure that accurate written records are kept by the institution and that these remain confidential except in relation to disclosure requirements.

The forensic practitioner is ultimately responsible for producing a clinical or medico-legal document as instructed via the relevant medico-legal system.

Documentation

The forensic practitioner is responsible for producing an expert witness report contemporaneously in conjunction with an appropriate witness to authenticate the images to ensure the images are admissible as evidence if produced in court (SCOR and IAFR, 2014).

Education and Training

Apart from the recognised postgraduate education the forensic practitioner should obtain regular continued professional development [CPD] in the area of Forensic Science and in their area of expertise. Additionally, in order to keep up-to-date with amendments to legislation and relevant 'best practice' guidelines within their areas of expertise and legal jurisdiction, all professionals who are involved in forensic imaging shall maintain their professional competency.

In the case of radiographers, this continued professional training is outlined by the IAFR (IAFR & SCOR, 2014) and IIRRT (2016) in their published guidelines. CPD is also arranged at a national level for radiologists.

Of international recognition is the German Study Group on Forensic Age Diagnostics (AGFAD) of the German Society of Legal Medicine which offers proficiency tests on an annual basis to ensure quality (Schmeling et al., 2008). This certification ensures at a global, although especially European level, that the forensic practitioners have the skills to assess age and regularly review these skills to ensure that they up to date, valid and admissible.

In addition, students may be present to observe forensic examinations in accordance with local policies and guidelines but shall not act as an Appropriate Witness (SCOR & IAFR, 2014).

Medico-legal aspects

Medico-legal considerations for forensic imaging include Justification (risk versus benefit) in relation to "*non-medical imaging exposure*" (Council of the European Union, 2013), as well as obtaining valid consent. In particular, the associated radiation risks have been considered and discussed (Schmeling et al., 2011; Ramsthaler et al., 2009).

Forensic practitioners performing forensic imaging shall be aware of, and comply with, the local protocol for forensic imaging which should address the following specific issues as outlined by the IIRRT (2016), SCOR & IAFR (2014) and the Society of Radiographers (2005):

- Authorised referrers
- Continuity of evidence
- Confidentiality
- Health and safety, including radiation protection
- Cultural and religious sensitivities
- Privacy and dignity
- Out of hours service provision

Requests for radiography for forensic purposes

Requests should be made by recognised, approved referral sources which, in addition to normal clinical referrers, may include but are not limited to:

- Forensic physicians
- Forensic pathologists
- Forensic odontologists
- Forensic anthropologists
- Customs and excise / Border Control
- Police and security service
- Consultant Paediatrician
- Judges
- Public prosecutors

Consent

All forensic requests on living subjects should be treated as non-medical imaging referrals because there is no direct health benefit to the individual (Council of the European Union, 2013) and, as such, written consent shall be obtained. However, dental radiographs may reveal undiagnosed disease or infection. In these instances, the forensic odontologist has an obligation and responsibility to inform the individual of the need for dental/medical treatment. The referring authorities should explain the procedure and obtain consent. It

should be noted that although local law may not actually require written consent, radiography for forensic purposes is an area of practice where validity of consent may be questioned and therefore to obtain written consent is considered best practice (SCOR & IAFR, 2014).

To obtain written consent a full explanation shall be provided to the individual so that they can make an informed decision. This shall include information regarding risk benefits of having a medical radiation exposure.

The consent process will confirm that the consenting individual has been informed about and understands a range of issues that include, but are not limited to:

- Purposes of the examination
- Nature of the procedure
- Duration of the procedure
- Risk and benefits of the procedure
    - the pregnancy status of the individual may be required for certain examinations (e.g. imaging using ionising radiation performed between the diaphragm and the knees)
- Persons involved
- Withdrawal of consent
- Dignity and privacy

There are no circumstances when implied consent is acceptable. For individuals unable to give consent, appropriate arrangements should be made to obtain recognised third party authority. Examples include, but are not limited to:

- Parents
- Legal guardians
- Individuals appointed by the courts

For individuals with language or communication issues, appropriate translation services are required.

The European Asylum Support Office (2014) has specifically stated that an application for asylum cannot be denied based on refusal by the individual to consent to a medical examination.

Confidentiality

In all forensic imaging cases, the standard principles of patient confidentiality shall be maintained and adhered to, in accordance with all relevant standards of professional conduct (IIRRT, 2016).

The SCOR & IAFR guidelines (2014, p.67) explain that

> "*Forensic cases will always be regarded as sub judice (the case is currently under trial or being considered by a court of law…, and must*

> *therefore, never be discussed outside the court with any person not directly involved in the case until the investigation…has been completed*."

Furthermore, the SCOR & IAFR (2014, p.13) state that:

> "*All image data on any media should be securely stored and all appropriate measures taken to prevent unauthorised access that may compromise the evidence in a court of law*."

Whilst in the case of Ireland, the IIRRT (2016, p.2 3) indicates that:

> "*In hospital/institutions with PACS, where possible a 'limited access folder' specifically for forensic cases should be created where only nominated hospital staff have access to the contents, thus preserving confidentiality.*"

The above are good examples of guidelines to follow.

Health and Safety

The forensic radiographer is the person responsible for the 'controlled area' as well as the radiation safely of all involved in the Age Assessment imaging process (IIRRT, 2016).

Occupational radiation safety measures shall be observed.

All practitioners involved in forensic imaging should wear a radiation-monitoring badge, as occupational dose limits apply.

Welfare of the multidisciplinary team

Counselling

It is acknowledged by the IAFR and IIRRT that certain aspects of forensic imaging can be potentially distressing and may result in post-traumatic stress disorder [PTSD] (SCOR & IAFR, 2014). It is the responsibility of the employer to protect the psychological and physical well-being of their forensic practitioners.

All forensic practitioners should ensure that all those professionals involved in the delivery of a forensic service have appropriate training in relation to PTSD (recognising symptoms and common feelings experienced, basic advice on coping strategies, aetiology of PTSD and types of treatment available, availability of support mechanisms, etc.). It is important that members of the multidisciplinary team watch for the symptoms in their colleagues so that it can be addressed early and appropriate support provided.

Debrief

The IAFR recommends that operational debriefs that cover all aspects of any significant incident are undertaken and should be facilitated by qualified personnel (SCOR & IAFR, 2014).

Evidence

All medico-legal cases involve the production of evidence in the form of documents and images for presentation in court to address a question of law. Therefore, it is essential that the chain of evidence is preserved during the imaging process.

The IIRRT (2016) recognises that informal and formal reports made on images produced for living individuals, along with any comments made about the examination or the images produced, constitute evidence and should be included in a Witness Document.

Continuity of Chain of Evidence

The SCOR & IAFR (2014) and the IIRRT (2016) have published guidelines on how to ensure that any evidence produced is admissible in court. These guidelines state, for any evidence to be used during legal proceedings there shall be clear evidence that the chain of evidence has not been broken. To ensure this does not occur, the entire imaging process shall be witnessed by an appropriate third party (i.e. Appropriate Witness) and documented. The forensic imaging practitioner, supported by an Appropriate Witness, shall be able to attest that any image was produced at the date and time indicated, that the image is of the identified individual or body part and very importantly that the image has not been tampered with in any way (this includes post-processing, annotation, etc), i.e. authenticate the images.

The Appropriate Witness shall be familiar with all aspects of the imaging process. All actions and communications shall be contemporaneously documented by both the forensic imaging practitioner and the Appropriate Witness to be presented if or when necessary. The Appropriate Witness shall be present throughout the forensic imaging and accompany the forensic imaging practitioner during the production and processing of the radiographs/images, including the burning of CDs.

The identities of the forensic imaging practitioner and Appropriate Witness shall be recorded on the Radiology Information System (RIS), or paper-based equivalent, at the time of the examination. Both should initial any hardcopy images produced. It is important that the Radiographer completes a Witness

Document to support their evidence. This Witness Document is vital as cases may come to court months/years later and it will be difficult for staff to recall every detail/aspect of the forensic examination.

All documentation needs to be completed and signed before the individual being assessed leaves the Controlled Area in order to maintain the evidential chain.

If the forensic imaging practitioner is required to leave the individual being assessed at any point, e.g. in order to process images or collect supplementary radiographic equipment, the forensic imaging practitioner shall be accompanied by the Appropriate Witness and the subject, individual shall be left in the care of the Responsible Officer (e.g. police officer).

The institution that holds responsibility for the radiation licence for the imaging equipment is responsible for the security and continuity of all imaging evidence until it is formally handed over to a representative of the referring authority who shall sign to confirm that it has been received.

Identity of the individual being assessed

It is essential that all subjects of forensic examinations are correctly identified prior to commencing the imaging examination, and that this identification is consistently used. When possible a name and unique identifier should be used.

These identifiers should be recorded on the images prior to digital or photographic processing, along with accurate date and time indicators. If identifiers cannot be recorded directly on the images produced, then an appropriate method to identify them should be applied.

Anatomical side markers shall be applied within the irradiated field at the time of exposure. Repeat examinations may be necessary where the anatomical markers and all relevant information are not included on the original image.

If a repeat examination is not practicable, any patient or examination identification not included on an analogue image should be added using indelible markers, countersigned by the Appropriate Witness and reference made to this in the Witness Document. It should be noted that the addition of patient or examination identification after the original exposure should be considered atypical since good practice requires inclusion at the time of the original examination.

Digital Images

The SCOR & IAFR (2014) and IIRRT (2016) have published guidelines outlining the considerations in relation to acquisition, archiving and storage of digital images. These guidelines are available from both professional bodies on request.

As these are forensic cases, continuity of the chain of evidence is important and shall be proved. A Master Copy shall be provided to the Authorities immediately following the imaging examination.

Records

Witness Document

The Witness Document is a factual record which describes the actions of the forensic practitioner from their first involvement in an age estimation process to completion. It shall be a statement of fact and shall not include any hearsay evidence or opinion. The document forms contemporaneous notes that are recorded from the first moment of contact in relation to the age estimation that is being undertaken. These contemporaneous notes should include all of the actions, instructions, meetings and discussions that occur, including who is present on each occasion.

This is different to a statement/forensic report in which images are analysed and a professional opinion given. If requested to undertake an analysis and present an opinion of that analysis, this opinion should be fully supported by literature and the steps taken to achieve that opinion should be presented clearly and any potential areas where alternate opinions might exist or where presumptions have been made should be clarified.

The Witness Document should be a written factual statement and should follow the general layout given below. At a minimum the report should include:

- The date and time of initial contact and the identity of who requested the process, the identity of who undertook the process and the identity of the patient (if known).
- The details of any process undertaken, with full information on methods used, imaging parameters etc.
- This should include not only the final successful image but any other images that were taken to achieve this if relevant.
- Information about where the images are stored should be included.
- Once written each page of the report should be signed and dated before being stored securely for future reference or passed to the appropriate authority.

An example is reproduced with permission of the IIRRT (2016, p.34-35):

Appendix B: Template for Witness Document

Template to be amended accordingly for documenting Radiographic/Fluoroscopic/PMCT Forensic Imaging examinations.

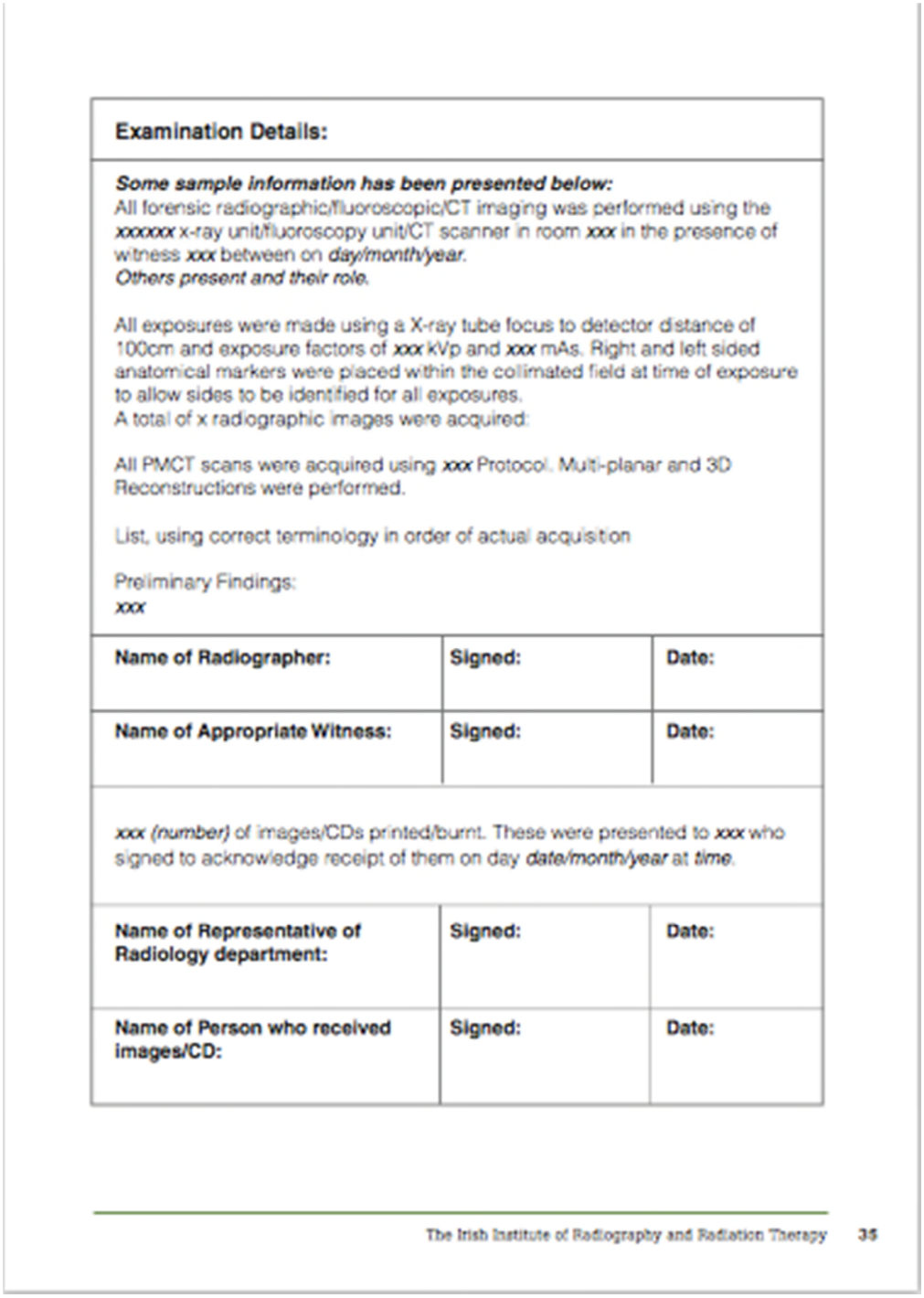
Forensic Imaging Examination

ID: *unique identifier*

Date of Examination:	*Time of Examination: Start and end time*
Name of Radiographer:	
Name of Appropriate Witness:	
Location of Examination:	*Specific location within hospital*
Modality used:	

Regions Examined: *such a diagram can be useful in identifying regions examined or pathology / evidence locations*





Examination Details:

Some sample information has been presented below:
All forensic radiographic/fluoroscopic/CT imaging was performed using the *xxxxxx* x-ray unit/fluoroscopy unit/CT scanner in room *xxx* in the presence of witness *xxx* between on *day/month/year*.
Others present and their role.

All exposures were made using a X-ray tube focus to detector distance of 100cm and exposure factors of *xxx* kVp and *xxx* mAs. Right and left sided anatomical markers were placed within the collimated field at time of exposure to allow sides to be identified for all exposures.
A total of x radiographic images were acquired.

All PMCT scans were acquired using *xxx* Protocol. Multi-planar and 3D Reconstructions were performed.

List, using correct terminology in order of actual acquisition

Preliminary Findings:
xxx

Name of Radiographer:	**Signed:**	**Date:**
Name of Appropriate Witness:	**Signed:**	**Date:**
xxx (number) of images/CDs printed/burnt. These were presented to *xxx* who signed to acknowledge receipt of them on day *date/month/year* at *time*.		
Name of Representative of Radiology department:	**Signed:**	**Date:**
Name of Person who received images/CD:	**Signed:**	**Date:**

The Irish Institute of Radiography and Radiation Therapy 35

Expert witness Statement or Report *Pro forma*

Guidelines for radiologists have been published by the American College of Radiologists (2014) and the Royal College of Radiologists (2011).

Witness Statement

A witness statement is a document usually requested by the legal authorities which records the evidence of a person and is signed by them to confirm that

the contents of the statement are true. It does not contain opinion but is a straightforward recitation of the facts and actions of the person making the statement. Occasionally the expert witness will be required to give a statement outlining actions taken during the investigation and this shall be a factual account with no hearsay or opinion included.

One important aspect is how to present the information on to law enforcement agencies/civil courts, etc.

Amongst the issues to address, the three most common are:

1. Proving if a person is the age they state
2. Estimating the age of the person when they don't know how old they are
3. Proving whether a person is under or over a certain age (e.g. 12, 14, 16, 18 years).

The first and third point above could be reported as proving or disproving a hypothesis/age they are.

Provided below are some guidelines with regard to writing an expert witness report.

Expert Witness Report

The expert witness report contains details of the examination(s), analyses, conclusions and opinions of the person writing the report. As such it also contains information including the qualifications of the individual writing the report, the work undertaken by the expert and the conclusions reached as a result of that work.

The following is a guide for the layout of an expert witness report. Some forensic providers will have their own layout and this does not replace those. The example given is also very straightforward and it may be that this has to be altered or amended for more complex cases. Each report should also take cognisance of appropriate legislation and guidance

Pro forma Expert Witness Report

Each report should include:

- Cover page
- Contents page
- Declaration of truth
- Expert's qualifications, experience and place of current employment
- Background to the case and request
- Examination and findings
- Conclusion
- Glossary
- References consulted
- Declaration
- Critical conclusions check

All pages should be sequentially numbered and should include the date of the production of the report and the signature and printed name of the expert writing the report. Each report should be peer reviewed.

Cover page
This should include:

- Name of the officer/solicitor etc. that has requested the report and the name of the force/firm that they belong to.
- The name/number of the operation as given by the requesting party.
- Personal/company reference number.
- Date report produced.
- Name of the expert writing the report including titles and postnominals.
- Number of the page in format 1 of N (where N is total number of pages of the report).

Background to the report
This should include:

- Date of initial contact, name and professional title of the person instructing the expert.
- Terms of reference-including what exactly has been asked of the expert.
- Details of the background of the case if known-the name, rank and affiliation of any information source should be included.
- Details of all of the exhibits examined-including image numbers, CD numbers, exhibit/production numbers etc.
- Details of any meetings (date, those present, any instructions/decisions which came from the meeting).
- List of those present at any examination undertaken, when and where the examination took place.
- Details of what is being requested. For example, to assess the age of someone who does not know their age, to indicate whether the individual is over or under a certain age, to indicate whether an individual is the age they state to be.

Main body
This should include details of any examination or work undertaken, methods used (including all references referred to) and the conclusions drawn from the methods used. A description of any standard deviations presented should also be included. If an image or test cannot be undertaken, this should be justified as should the tests/images used. If there are any possible issues or limitations to the conclusions which can be drawn these should also be included. If any conclusions are based on information provided by another expert this should be made clear, including who gave the information and how it added to the final conclusions.

For easy reference subheadings should be used throughout and all subheadings and/or paragraphs should be numbered.

Images
It is often helpful to include images to illustrate points made. Images should include clear labelling.

Conclusion
A final conclusion should reiterate the terms of reference and the final conclusions drawn. Any issues which are taken into consideration in relation to the final conclusions should be included as well as clear guidance on potential errors, standard deviations or the probabilistic approach etc.

Glossary
A glossary of specialist terms used (it is also good practice to offer copies of journal articles when submitting the report).

References
A list of references which have been relied on should be provided.

Critical Conclusions Check
This should include the title, name, post-nominals and qualifications of the individual undertaking the critical conclusions check. The date of the final check and the signature of the expert undertaking the check (electronic is acceptable if there is a distance involved) should be included.

These reports and the way the results are presented may vary according to the specialist (e.g. odontology, anthropology, etc.) but they should be written in a language that can be comprehended by non-medical professionals such as those working in the legal system.

For example, the Radiological Society of North America (Meyer and et al., 2009, modified 2014) have produced an online template which should be used for clinical purposes. An adapted version of their template would include headings such as:

- Clinical Indication
- Gender [Male / Female]
- Procedure – which bone examined?
- Comparison with previous radiographs?
- Findings
- Chronological age: [ ] (years + months)
- Bone age: [ ] (years + months)
- Standard deviation: [ ] months
- Impression
- Reference material used in Report

In a scientific expert witness report, the methods, their limitations and the reference studies they are based on should be outlined (Schmeling et al., 2008).

Presenting the results in the report

Reporting of skeletal age radiographs can be performed either for in-hospital medical use, or medicolegal use, and the reporting style should be appropriate. The central tenet for a forensic expert report is to give the interval of most probable ages of the examined individual, and an index of probability that the individual falls within or outside the expected range.

Schmeling et al. (2008, p.3) state that:

> "*The central forensic aspect of an expert report is to give the most probable age of the examined individual and/or the degree of probability that the stated age is the actual age or that the individual's age is above the relevant penal age limit*."

The most probable age, therefore, shall be stated and the age interval of the reference population from which the methods derive (Rösing, 2000).

Conclusion statements specific to each methodology employed should include an estimated mean age and age interval and an associated level of uncertainty. When the information is available, the level of uncertainty should statistically consider 95% of the specific population, or two standard deviations. If the peer-reviewed published scientific study(s) utilised to assess chronologic age do not provide two standard deviation statistical levels of uncertainty, then, the level of uncertainty defined by that study should be clearly stated in the forensic report. The Radiological Society of North America (Meyer et al., 2009, modified 2014), have provided some examples of reporting terminology. For instance, they indicate that the text for "*impression*" could read as one of the following:

- Normal bone age, within 2 standard deviations of chronological age.
- Advanced bone age, more than 2 standard deviations above chronological age.
- Delayed bone age, more than 2 standard deviations below chronological age.

For a medico-legal report, wording such as "*providing likely ages*" or "*consistent with*" is likely to be more helpful for the requester. Terminology such as the following can be used:

- The individual is likely to be younger than x years
- The individual is likely to be older than x years
- The individual is likely to be younger than x years
- The individual is likely to be older than x years

Variations do exist amongst practitioners and on occasions the results are expressed with the following examples:

- There is very strong support that the individual is/is not x years and x months

- There is strong support that the individual is older / younger than x years

The report therefore should include the experience/qualifications of the practitioner, the method used for age assessment, and provide an age interval from the reference population. Inter-observer variability, different racial and socioeconomic status from the reference population etc. are all likely to account for additional uncertainty but are rarely mentioned in the report.

Conclusion

It is acknowledged that each country will have access to differing levels of expertise and resources available to them. Therefore, the imaging modalities utilised should provide maximum accurate diagnostic information, with the lowest radiation dose to the individual being assessed (i.e. the ALARA Principle). The availability and expertise of local staff should also be taken into consideration. Research is on going in relation to the use of 'low dose' techniques, as well as non-ionising modalities.

Glossary

Adolescent Dental Age Interval: That interval in human dental development that includes the presence of the developed and developing secondary dentition. Retained primary teeth may also be present as a special circumstance during this interval.

Adult Dental Age Interval: That interval in human dental development where all teeth present have completed crown/root development and are therefore considered dentally mature.

Age assessment: The three terms (Bone Age, Dental Age and Skeletal Age) are general in the sense of indicating the behaviour of a population in relation to skeletal maturation. Age assessment is an individual concept. It is the estimation of the most probable age of an individual considering their skeletal age and their specific demographic characteristics (sex, health, physical activity, intake, etc).

Bone Age: The general degree of maturation of bone that the subjects of a population reach at a certain age as an average. This term may be used when referring to the bone age of a specific anatomical region (i.e., bone age in the hand and wrist).

CE standard: CE marking is a certification mark that indicates conformity with health, safety, and environmental protection standards for products sold within the European Economic Area.

Dental age: The general degree of maturation of teeth that the subjects of a population reach at a certain age as an average.

Dental Age Assessment: The processes used to produce an estimation of an individual's chronologic/biologic age using dental data.

Dental Age Estimation: The mean age, age interval, and corresponding level of the uncertainty that results from Dental Age Assessment.

Guidelines: Recommended procedures that help direct but are not required. The use of the words **"shall"**, **"should"** and **"must"** follows the 2003 American National Standards Institute (ANSI), https://www.usug.org/answg/pdf/ANSI_Style_Guidesheet_-_2003.pdf, style guidelines on the correct form of requirements and recommendations:

- **Shall** is the correct verb form for indicating a requirement. Use **shall** for indicating a mandatory aspect or an aspect on which there is no option.
- **Should** is the correct verb form for indicating a recommendation where it is considered the best among numerous options or there is insufficient scientific evidence to definitively support its mandatory use.
- Must is NOT a term recognised by ANSI and shall not be used

Infant/Child Dental Age Interval: That interval in human dental development that includes the postnatal presence of the developing and resorbing primary dentition including the period of mixed primary and secondary dentitions.

Level of Uncertainty: The statistical error rate that should minimally reflect 95% of a given population or two (2) Standard Deviations (SD). If SD is not the statistical error rate utilized by a published study, then the appropriate corresponding error rate used by that study should be reported.

Prenatal/Fetal Dental Age Interval: That interval in human dental development that occurs prior to birth.

Skeletal age: The general degree of maturation of bones that the subjects of a population reach at a certain age as an average. This term may be used when talking about all of the skeleton in general.

Standards: Established protocols that are compulsory minimal level of practice.

Study: A detailed investigation and analysis of a specific population to relate chronologic age to dental development.

Technique: A method or procedure used for age assessment.

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Guidelines for best practice: imaging for age estimation in the living

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