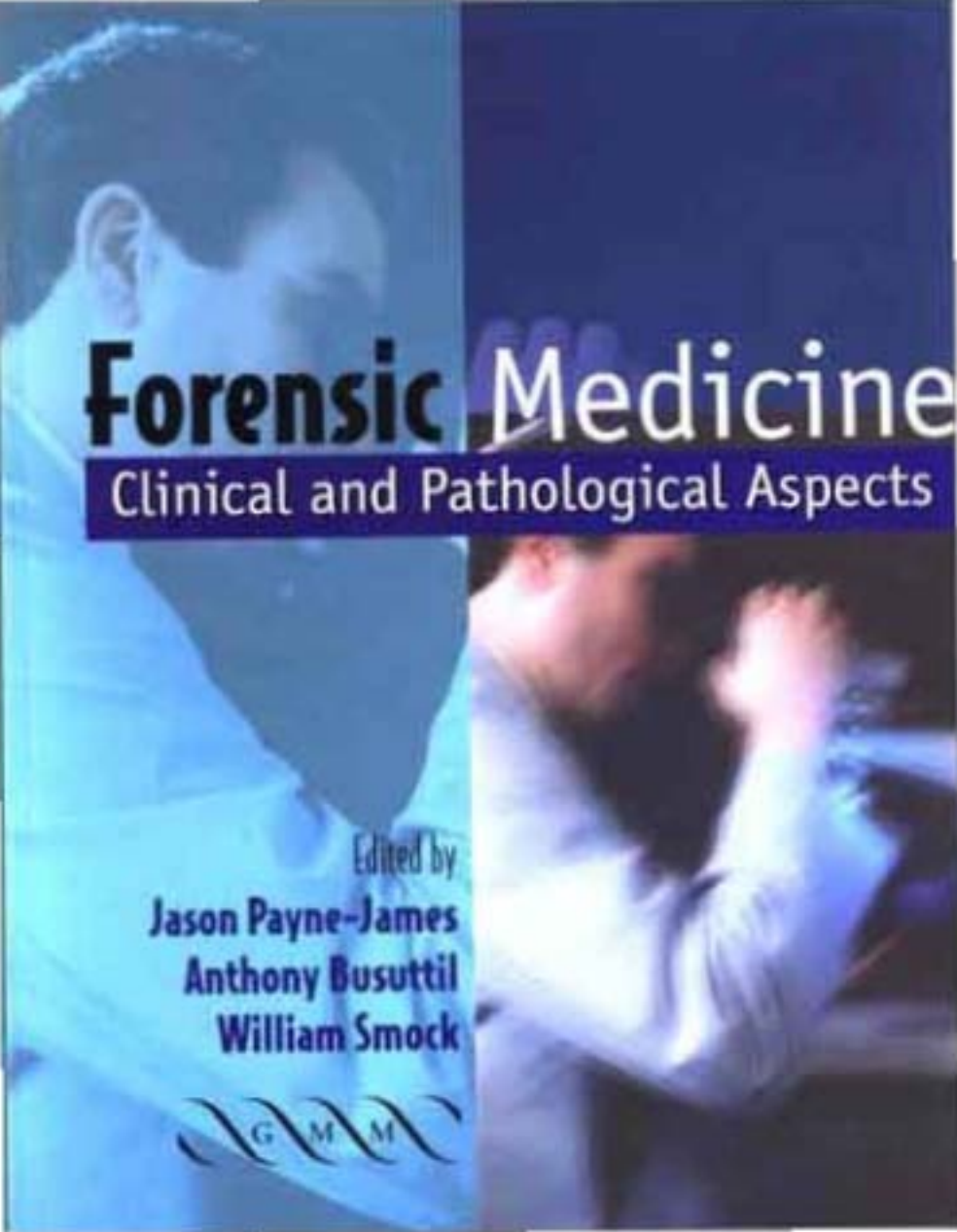
Forensic Medicine
Clinical and Pathological Aspects
Edited by
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Age estimation in the living

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Anil Aggrawal

Estimation of age is a role that a forensic practitioner often has to play, particularly in developing countries, where many births take place in rural settings, without the benefit of expert supervision by a trained obstetrician. Such births are poorly recorded or more often not recorded at all in terms of exact dates. In many other cases, records are fraudulently falsified with the prospect of financial gain, e.g. to obtain government posts or pensions. Developed countries, where ordinarily birth records are meticulously maintained, are not immune to this problem either. Estimation of the age of living individuals may be needed in the case of refugees/asylum seekers or other persons who arrive without acceptable identification papers. In other instances of genuine amnesia, age estimation may also be useful.

AGES OF MEDICOLEGAL IMPORTANCE

The ability to age an individual with a degree of objectivity and certainty is important in many medicolegal circumstances. In the author's 20 years of practice, children as young as 4 years have been brought for such age assessment with the issue in question being whether the child has attained the age of 5 years or not. This is because according to Section 6 (a) of *The Hindu Minority and Guardianship Act 1956*, a minor who has not completed the age of 5 years shall ordinarily be in the custody of the mother, and a divorced mother often wants to keep the child in her custody. At the other end of the spectrum, people as old as 75 years of age have come for a medicolegal opinion on their age. Many of them allege that they are above 70 years of age in order to be able to qualify for some State Government's pension scheme for old people. Thus virtually no age is irrelevant in its potential for an aging dispute from a medicolegal point of view. An exhaustive list of these ages is available elsewhere (Aggrawal 2000). The following list gives a glimpse of the amazing range of ages which a practising medicolegist may be asked to opine upon. This list presumably differs from country to country and even within the various states of the same country. It would be helpful for a medicolegist of a particular state or country to compile his own list in accordance with its own laws.

Medicolegal importance of 5 years of age

As mentioned above, according to Section 6 (a) of *The Hindu Minority and Guardianship Act 1956*, a minor who has not completed the age of 5 years shall ordinarily be in the custody of the mother.

Medicolegal importance of 7 years of age

According to Section 82 of the Indian Penal Code (IPC), a child less than 7 years of age cannot commit an offense.

Medicolegal importance of 10 years of age

According to Section 369 of IPC, to constitute a crime of kidnapping or abducting a child with the intention of taking dishonestly any moveable property from its person, the age of such a child should be below 10 years.

Medicolegal importance of 12 years of age

- According to Section 83 of IPC the crime committed by a child between 7 and 12 years of age is not an offense, if he has not attained sufficient maturity of understanding. The judge often decides this latter issue.
- According to Section 89 of IPC a child below 12 years cannot give valid consent to suffer any harm which may occur from an act done in good faith and for its benefit (such as a general physical examination by a doctor).
- According to Section 317 of IPC exposure or abandonment of a child less than 12 years of age by its parents or a person having care of it, may lead to punishment for 7 years and/or a fine.
- According to Section 376 of IPC, if a man rapes his own wife and her age is less than 12 years, he will receive the same punishment as if he raped any other girl (the sentence is not less than 7 years, and may extend to life). But if he raped his wife who was above 12 years of age, but below 15 years, he would get a lesser sentence of only 2 years. This clause may appear paradoxical as the minimum legal age for marriage in India is 18 years for girls. But despite this law, many marriages of young girls continue in India, and Section 376 caters to such cases.
- Under the *Children and Young Persons Act 1933 and 1952* of the UK, it is an offense for a person over 16 years to leave a child under 12 years in a room with an unguarded fire.

Medicolegal importance of 13 years of age

- According to Section 375 of IPC sexual intercourse with one's own wife, even with her consent, is rape if she was below 13 years. (This provision is for the state of Manipur only by a local amendment. For the rest of India this age is 15 years.)
- In England and Wales, under Section 5 of *The Sexual Offences Act 1956*, it is an offence for a man to have unlawful sexual intercourse with a girl under the age of 13.

Medicolegal importance of 14 years of age

- Under the law of England, a boy 14 years of age cannot commit rape.
- According to Article 24 of the Indian Constitution, a child below 14 years shall not be employed to work in any factory or mine or engaged in other hazardous employment (the same provisions are reproduced in Section 67 of *The Indian Factories Act 1948*).

- Under section 375 of the IPC, sexual intercourse with or without consent is rape if the age of the woman is less than 14 years. (This provision is for the state of Manipur only by a local amendment. For the rest of India this age is 16 years.)

Medicolegal importance of 15 years of age

- According to the *Indian Factories Act 1948*, a child above 15 years and below 18 years is an "adolescent." A "child" is a person who has not completed 15 years. A "young person" is either a child or adolescent.
- According to Section 375 of the IPC, sexual intercourse with one's own wife, even with her consent, is rape if she was below 15 years. (By a local amendment this age has been reduced to 13 years for the state of Manipur.)
- According to the *International Labor Conference (1948 session)*, young persons aged between 15 and 17 years shall not be employed in factories, mines, railways and ports for a period of at least 12 consecutive hours.
- According to Section 13 (2) (iv) of *The Hindu Marriage Act 1955*, a wife may divorce her husband if her marriage (whether consummated or not) was solemnized before she attained the age of 15 years, and she has repudiated the marriage after attaining that age but before attaining the age of 18 years.
- According to Section 160 of *The Criminal Procedure Code* a police officer has the power to require attendance of witnesses, but he can not compel a male person below 15 years (or any woman) to attend at any place other than the place in which such male person (or woman) resides.

Medicolegal importance of 16 years of age

- Under section 375 of the IPC, sexual intercourse with a woman, even with her consent, is rape if she was below 16 years of age. (By a local amendment this age has been reduced to 14 years for the state of Manipur.)
- According to the Indian law, a child under 16 years of age, who is serving a sentence for some offense, cannot be kept in a jail. He has to be confined within a Children's Home.
- According to Section 361 of IPC, whoever takes or entices any minor under 16 years of age if a male (or under 18 years of age if a female, or any person of unsound mind), out of the keeping of the lawful guardian of such minor (or person of unsound mind), without the consent of such guardian, is said to kidnap such minor (or persons) from lawful guardianship.
- According to England's *Tattooing of Minors Act 1969*, tattooing of persons under the age of 16 has been made illegal since 1969.
- According to Section 363-A of IPC, kidnapping or maiming of a minor for the purpose of begging is an offense. If the person merely kidnaps, the sentence is 10 years and a fine. If he maims, the sentence is life imprisonment and a fine. For the purposes of this section, a minor is a male below the age of 16 years, and a female below 18 years. This is an interesting section, as the prescribed ages for minors are different for males and females.
- Under the *Children and Young Persons Act 1933 and 1952* of the UK, it is an offense for a person over 16 years to leave a child under 12 years in a room with an unguarded fire.
- According to the *Juvenile Justice Act 1986*, a "Juvenile" means a *boy* who has not attained the age of 16 years. He is to be retained in a Juvenile Home till he attains an age of 18 years.

Medicolegal importance of 17 years of age

- According to the International Labor Conference (1948 session), young persons between 15 and 17 years shall not be employed in factories, mines, railways and ports for a period of at least 12 consecutive hours.
- *Indian Mines Act 1923*: No person who has not completed his seventeenth year shall be allowed to be present in any part of a mine which is below ground unless a certificate of fitness is granted.

Medicolegal importance of 18 years of age

- Under Section 5 (iii) of the *Hindu Marriage Act 1955*, the age for marriage for a girl is 18 years. If a girl marries before this age, the punishment is prescribed in Section 18 (a) of the same act. It is simple imprisonment which may extend to 15 days, or a fine which may extend to 1000 Rs, or both. The marriage is not dissolved.
- According to Section 361 of IPC, whoever takes or entices any minor under 18 years of age if a female (or under 16 years of age if a male, or any person of unsound mind), out of the keeping of the lawful guardian of such minor (or person of unsound mind), without the consent of such guardian, is said to kidnap such minor (or persons) from lawful guardianship.
- According to the *Indian Majority Act 1875* a person attains majority when he/she attains the age of 18 years.
- According to Section 366-A of IPC, whoever procures any girl under the age of 18 years for the purposes of illicit intercourse with another person, shall be punishable with imprisonment which may extend to ten years, and shall also be liable to a fine.
- According to Section 372 of IPC, whoever sells, lets to hire, or otherwise disposes of any person under the age of 18 years for the purposes of prostitution or illicit intercourse with any person or for any unlawful or immoral purpose, shall be punished with imprisonment of either description for a term which may extend to ten years and shall also be liable to a fine.

- According to the *Indian Factories Act 1948*, an "adult" is a person who has completed his eighteenth year. A person less than 18, but more than 15 years of age is adolescent.
- According to Section 305 of IPC, whoever abets the suicide of a child below 18 years is punishable with death, or imprisonment for life, and shall also be liable to a fine.
- *Children and Young Person's Act 1933 of England*: A person below 18 years can not be sentenced to death.
- According to Section 363-A of IPC, kidnapping or maiming of a minor for the purpose of begging is an offense. If the person merely kidnaps, the sentence is 10 years and a fine. If he maims, the sentence is life imprisonment and a fine. For the purposes of this section a minor is a female below 18 years (or a male below the age of 16 years). This is an interesting section, as the ages for minors are different for males and females.
- This is the age for voting in India and several countries.
- According to *Juvenile Justice Act 1986*, a "juvenile" means a *girl* who is below 18 years. She would be retained in a Juvenile Home until she attains 20 years.
- According to the *Juvenile Justice Act 1986*, a "juvenile" means a *boy* who has not attained the age of 16 years. He is to be retained in Juvenile Home until he attains an age of 18 years.
- According to section 3 (4) (a) of the *Medical Termination of Pregnancy Act 1971*, if the pregnant woman has not attained the age of 18 years, her pregnancy cannot be terminated, except with the consent in writing of her guardian.
- According to Section 13 (2) (iv) of *The Hindu Marriage Act 1955*, a wife may divorce her husband if her marriage (whether consummated or not) was solemnized before she attained the age of 15 years, and she has repudiated the marriage after attaining that age but before attaining the age of 18 years.
- According to Section 2 (f) of *The Transplantation of Human Organs Act, 1994*, a "donor" means any person not less than 18 years of age, who voluntarily authorizes the removal of any of his human organs for therapeutic purposes.

Medicolegal importance of 20 years of age

- Under Section 293 of IPC, if a person sells, lets to hire, distributes, exhibits or circulates obscene objects to any person under 20 years of age, then on first conviction he would be sentenced to an imprisonment of 3 years and a fine of 2000 Rs. On second conviction, the punishment would be 7 years and a fine of 5000 Rs.
- According to the *Juvenile Justice Act 1986*, a "juvenile" means a girl who is below 18 years, and she would be retained in Juvenile home until she attains 20 years.

Medicolegal importance of 21 years of age

- Under Section 5 (iii) of the *Hindu Marriage Act 1955*, the age for marriage for a boy is 21 years. If a boy marries before this age, the punishment is prescribed in Section 18 (a) of the same act. It is simple imprisonment which may extend to 15 days, or a fine which may extend to 1000 Rs, or both. The marriage is not dissolved.
- Under Section 366-B of IPC, whoever imports into India from any country outside India or from the State of Jammu and Kashmir any girl under the age of 21 years with intent that she may be, or knowing it to be likely that she will be, forced or seduced to illicit intercourse with another person, shall be punishable with imprisonment which may extend to 10 years and shall also be liable to a fine.
- When a minor is under the guardianship of the Court of Wards, or is under a guardian appointed by the Court, he is not deemed to attain majority until he is 21 years of age.

Medicolegal importance of 25 years of age

- According to Article 84 (b) of the Constitution of India, the minimum age for contesting the membership of Parliament is 25 years.
- According to Article 173 (b) of the Constitution of India, the minimum age for contesting the membership of any State Legislative Assembly is 25 years.
- This is the maximum age for entry into some government services.
- According to the *Punjab Excise Act 1914*, a person below this age can not buy and consume liquor.

Medicolegal importance of 30 years of age

- According to Article 84 (b) of the Constitution of India, this is the minimum age for election to the Council of States (*Rajya Sabha*).
- According to Article 173 (b) of the Constitution of India, this is the minimum age for election to the State Legislative Council.

Medicolegal importance of 35 years of age

- According to Article 58 (1) (b) of the Constitution of India, this is the minimum age for appointment as the President of India.

According to Article 66 (3) (b) of the Constitution of India, this is the minimum age for appointment as the Vice-President of India.

- According to Article 157 of the Constitution of India, this is the minimum age for appointment as the Governor of any State.

- According to Section 4 (3) (i) of *the Pre-natal Diagnostic Techniques (Regulation and Prevention of Misuse) Act 1994*, no prenatal diagnostic technique shall be used or conducted unless the age of the woman is above 35 years.

Medicolegal importance of 60 years of age

- This is the age of retirement from Government service (and Delhi University).

Medicolegal importance of 65 years of age

- According to Section 10 (2) of the *Consumer Protection Act 1986*, every member of the District Forum shall hold office for a term of five years or up to the age of 65 years, whichever is earlier, and shall not be eligible for reappointment. The District Forum is a kind of civil court which delivers judgments in cases of consumer grievances. Similarly, the State Commission and the National Commission (mentioned below) are also akin to civil courts which are higher in rank to a District Forum.

Medicolegal importance of 67 years of age

- According to Section 16 (3) of the *Consumer Protection Act 1986*, every member of the State Commission shall be below 67 years of age.

Medicolegal importance of 70 years of age

- According to Section 20 (3) of the *Consumer Protection Act 1986*, every member of the National Commission shall be below 70 years of age.
- This is the age prescribed by some State Governments to qualify a person to get a pension from the "Old Age Pension Scheme."

About 90% of a medicolegist's work falls within the age range of 10–20 years. This is fortunate, because this is the age range which can be most accurately opined upon. The more difficult cases begin after this age, when all the teeth have erupted and most of the ossification centers have united.

METHODS OF AGE ESTIMATION IN THE LIVING

The age of an individual can be determined from teeth, ossification of bones, and secondary sex characteristics (Aggrawal & Busuttil 1991). General development in the case of children may help to some extent but usually is not very useful from a medicolegal point of view. As mentioned earlier, the determination of age is much more accurate in the earlier years of life, up to around 20 years. After this, accuracy declines drastically.

Teeth

Structure of teeth

Teeth are composed of three parts: the crown, which projects above the gum margin; the root, which remains buried within the alveolar bone and gum; and the neck, which is a small part between the crown and the root. The tooth is composed mainly of dentine. It is covered on the crown by the enamel and on the root by cementum. The cementum is attached to the alveolar bone by the periodontal membrane.

Tooth development

The alveolar cavities which contain teeth are formed at approximately the fourth month of intrauterine life. Development of the tooth begins with the formation of cellular tooth germ within the alveolar bone, in the shape of the crown. The deciduous teeth commence mineralization at about 20 weeks of intrauterine life, and by 28 weeks all of the deciduous teeth have commenced mineralization (Cameron & Sims 1974). The anterior buccal cusp of the lower first permanent molar begins to mineralize a week or two before birth. Thus, at birth, the rudiments of all the temporary teeth and of the first permanent molars may be found in the jaws.

Temporary and permanent teeth

There are two sets of teeth – *temporary* (also known as deciduous or milk teeth) and *permanent*. During childhood the temporary set erupts. By the age of 2½ to 3 years, the temporary set is complete. At the age of 6, the first permanent tooth – the first molar – erupts. Gradually the permanent set replaces the temporary set. The last permanent tooth to erupt is the third molar, also known as the "wisdom tooth," which may erupt some time between 18 and 25 years.

There are 20 temporary teeth. These comprise 2 incisors, 1 canine, and 2 molars in each quadrant of the jaw. The permanent teeth are 32 in number and comprise 2 incisors, 1 canine, 2 premolars, and 3 molars.

THE DENTAL FORMULA

The dental formula is a handy and convenient way of representing the number and type of teeth in an individual. It appears as a fraction with two numerals, one appearing as a numerator and the other appearing as a denominator. Each numeral consists of four digits, the first representing the number of incisors in a quadrant, the second the number of canines, the third the number of premolars, and the fourth the number of molars. The upper numeral represents the number of teeth in the upper quadrants, and the lower represents the number in the lower quadrants. The dental formula of a baby with a full set of temporary teeth is

2102/2102. This means that a baby with a full set of temporary teeth has 2 incisors, 1 canine, no (0) premolars, and 2 molars. Both upper and lower quadrants show the same configuration. There are thus 5 teeth in each quadrant, making the total number of teeth in a baby equal to 20. The dental formula of an adult individual is 2123/2123. This means that an adult individual has 2 incisors, 1 canine, 2 premolars, and 3 molars. Both upper and lower quadrants show the same configuration. There are thus 8 teeth in each quadrant, making the total number of teeth in an adult equal to 32.

The permanent incisors, canines and premolars are also known as *successional permanent teeth*. They are called this because they come in succession to temporary teeth. They replace some of the other temporary teeth. The permanent molars are the *superadded teeth*. They are called this because they are added over and above the teeth already present. They do not replace any teeth. Thus the total number of teeth in an individual changes only with the appearance of molars. The replacement is as follows:

- The 2 permanent incisors replace the 2 temporary incisors.
- The 1 permanent canine replaces the 1 temporary canine.
- The 2 permanent premolars replace the 2 temporary molars.

The 3 permanent molars do not replace any teeth. They are the superadded teeth.

Temporary teeth

It is important to know the ages of eruption of both temporary and permanent teeth. Before proceeding further, it is important to keep in mind that, in general, the lower (mandibular) teeth appear earlier, both temporary and permanent teeth. There are some important exceptions, as we shall shortly see.

The age of eruption of temporary teeth, with the possibility of a few weeks' variation on either side, is given in Table 32.1. Unless otherwise indicated, these ages apply to the maxillary teeth. Mandibular teeth appear a few weeks earlier. The exception mentioned earlier occurs in the case of lateral incisors, which appear earlier in the upper jaw (according to the rule of thumb, lower teeth always appear first).

Permanent teeth

The order of appearance of permanent teeth, with a few months' variation on either side is given in Table 32.2. These eruption ages are true for maxillary teeth. Generally speaking, the mandibular teeth appear a few months earlier. The major exception is in the case of canines, which appear much earlier – almost 2 years earlier. Thus the lower canine would appear at 9 years.

Table 32.1 Eruption of temporary teeth

Tooth	Age of eruption
Lower central incisor	6 months
Upper central incisor	8 months
Upper lateral incisor	10 months
Lower lateral incisor	12 months
First molar	14 months
Canine	18 months
Second molar	24–30 months

Table 32.2 Eruption of permanent teeth

Tooth	Age of eruption
First molar	6 years
Central incisors	7 years
Lateral incisors	8 years
First premolar	9 years
Second premolar	10 years
Canine	11 years
Second molar	12 years
Third molar	18–24 years

Premolars are an exception in the sense that they appear earlier in the upper jaw. Thus the lower first premolar would appear at 10 years, and the lower second premolar would appear at 11 years.

The whole subject of dental eruption, especially that of the permanent dentition, may sound complex, but can thankfully be remembered by an interesting mnemonic:

Mama is in pain; papa can make medicine

The first letter of each word indicates the first letter of the maxillary tooth. The mnemonic can be decoded thus:

Mama –	first molar
is –	first incisor
in –	second incisor
pain –	first premolar
Papa –	second premolar
can –	canine
make –	second molar
medicine –	third molar

There is yet another good mnemonic for remembering the same sequence:

Mother is in bed; baby comes Monday morning

Here, the letter "b" in "bed" and "baby" should remind us of the word "bicuspid", which is sometimes used for premolars. The rest of the letters are as in the previous mnemonic.

The stage of mixed dentition

Before the age of 6 years (when the first permanent molar appears), all the teeth in a child's mouth are deciduous. After the age of 12 years (when the second permanent molar appears), all the teeth are permanent. Between the ages of 6 and 11, some teeth are deciduous and some are permanent. This is the stage of *mixed dentition*. Examining a child in this age group can be problematic as one has to differentiate between temporary and permanent teeth. A few pointers may be helpful. The deciduous teeth are usually whiter and the enamel is less transparent than that of the

permanent teeth; this is usually described by saying that "deciduous teeth are china-white in color, while temporary teeth are ivory-white in color". The deciduous teeth are in most dimensions smaller than the permanent teeth. However, deciduous molars are wider mesiodistally than the permanent premolars that will take their places (Brand & Isselhard 1986). The crowns of deciduous teeth are more bulbous and the cusps are more pointed when the teeth first erupt (Rogers 1988). Deciduous teeth have shorter crowns with respect to their roots. The crowns have a marked constriction at the neck, appearing to be squeezed as if with a rubber band (Woelfel & Scheid 1997). The enamel seems to bulge close to the cervical line, rather than gradually tapering (Osborn 1981). Usually there are no depressions or perikymata on the labial surface of the crowns of the deciduous incisors. These surfaces are smooth. The incisal edges of the deciduous teeth generally show no pits, while those of permanent teeth show these pits (mamelons).

Many other differences are described, but they can not be elicited clinically. For instance, it is suggested that the pulp chambers are relatively larger in deciduous teeth and that the pulp horns extend rather higher, placing them much closer to the enamel than in the permanent teeth (Brand & Isselhard 1986). In case of doubt, the best thing is to assess radiographically and to have a Panorex view of the teeth done (Figure 32.1). This can immediately show all the permanent and deciduous teeth, erupted or unerupted. This is a relatively new method of taking dental radiographs (Mason & Bourne 1998). Originally the technique was called the orthopantomograph, and the derivation OPG derived from this term is still in common use. However, its more modern name is a *dental panoramic tomograph* (DPT). Many specialists like to call it by a simpler name – the Panorex view. A special DPT machine is used for taking this radiograph. It takes a panoramic film by having a motor-driven x-ray tube and film cassette holder which circle round the subject's face. The subject sits or stands upright, and special supports keep the head still during an exposure time of up to 15 seconds. The cassette holds a special 13×31 cm film. This view is particularly helpful in the medicolegal examination of teeth, as it shows all the teeth along with their roots and crowns in a single view.

A Panorex view immediately enables a medicolegal specialist to tell which of the teeth are deciduous. An example is shown in Figure 32.1. This subject, whose age was later determined to be between 8 and 9 years, was brought to the author for age estimation, as he had stolen some valuables from a lady, and his lawyer had claimed that he should be remanded to a children's jail on account of his tender age. Figure 32.2 is a line diagram drawn from the same x-ray plate depicting some salient features of the teeth. In general, if one can see a tooth below another, obviously the one visible in the mouth is the deciduous tooth (the tooth below is the permanent tooth waiting to erupt). If no tooth is present below a tooth, that tooth must be the permanent tooth. On clinical examination of this child the first permanent molar was visible, but not the second permanent molar, enabling one to say that the subject was between 6 and 12 years of age. Further narrowing of the age could be done by the help of this x-ray. Both permanent incisors have erupted, but not the first premolar. These findings enabled the author to say that the child was between 8 and 9 years of age.

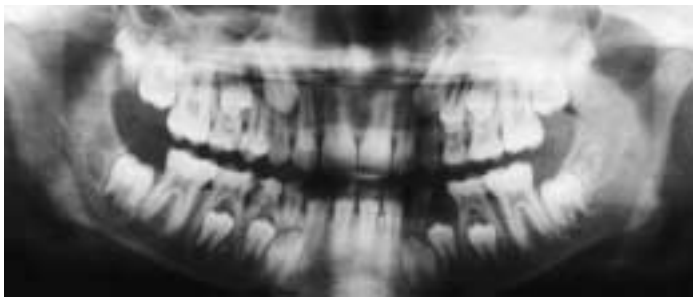

Figure 32.1 Panorex view of a child between 8 and 9 years.

An interesting fact to keep in mind is that the total number of teeth in a child's mouth only changes when the successional teeth (the molars) come. The molars arrive – in a mathematically beautiful rhythm – at 6, 12, and 18 to 24 years. Thus the total number of teeth would change only at these ages. The total number of teeth in a child's mouth is shown in Table 32.3.

During the period of mixed dentition, the age of a child may easily be calculated by the formula:

(age in years − 5) × 4 = number of permanent teeth in the mouth

Ossification of bones

Ossification of bones provides a very useful method of estimation of age in the living. Most bones develop either from cartilage or

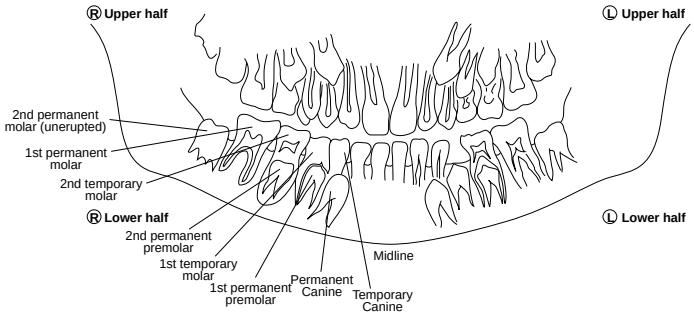

Figure 32.2 A line diagram of the x-ray in Figure 32.1. Note that permanent incisors have erupted (there are no teeth below them), but the premolars and canines have not erupted.

Table 32.3 Total number of teeth in the mouth at varying ages

Age	Total number of teeth
3–5 years	20
6–11 years	24 (addition of first molar in each quadrant
12–17 years	28 (addition of second molar in each quadrant)
Above 18 years or possibly 24	32 (addition of third molar in each quadrant)

from fibro-membranous structures. Different bones begin and complete their ossification at different, but almost fixed periods of life. These changes can be studied by x-rays and thus provide the specialist in aging with a very strong tool.

It is useful to keep in mind a few facts before proceeding further. First, the ages referred to here vary from country to country as they depend upon dietetic, hereditary and geographic factors. Second, ossification takes place slightly earlier (by about a year) in females than in males. An important exception is skull sutures, which obliterate earlier in males than in females. Last, ossification is seen earlier in tropical climates than in temperate ones. Unless otherwise stated, the ages mentioned here refer to Indian males.

The range of ages at which various bones commence and complete fusion is so complex and confusing as to deter a beginner from taking any substantial interest in this field of study. But fortunately a few "tricks of the trade" can be useful. One of the best is illustrated in Figure 32.3: imagine a person reclining on a sandy beach as shown in the diagram. His elbows are sinking in the sand somewhat. Now draw four lines parallel to the horizontal plane. The lowest one passes through the elbow, the next through the hip and ankle joints, the next through the shoulder and knee joint, and the uppermost through the wrist joint. Epiphyses falling on a particular line fuse at a particular age. Thus all epiphyses around the elbow joint complete fusion by 16 years, all epiphyses around hip and ankle joints by 17 years, all epiphyses around shoulder and knee by 18 years, and all epiphyses around the wrist by 19 years. It must, however, be stressed that this is a very general rule and probably its main utility is that it helps the mind to easily match a joint to a particular age. Several important exceptions exist which must be borne in mind.

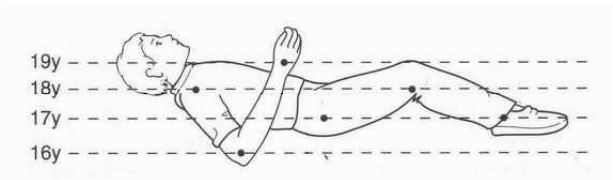

Figure 32.3 A useful way to remember ages of ossification of some major bones.

Ossification around the shoulder joint

The center for the head of the humerus appears during the first year of life, for the greater tuberosity at 3 years and for the lesser tuberosity at 5 years. The three centers unite to form a big epiphysis at around 6 years, which unites with the shaft at 18 years (refer to Figure 32.3). The coracoid and acromion both ossify from two centers, of which one each, appearing at the tip of each process, is visible easily on a radiograph. The center for the tip of the coracoid appears by about 11 years and unites by 16 years. The center at the tip of the acromion appears at 15 years and unites by 18 years.

The clavicle begins to ossify before any other bone in the body (Williams & Warwick 1980). Two centers appear in the shaft between the fifth and sixth weeks of intrauterine life, and fuse at about the forty-fifth day. The secondary center appears for the sternal end around 19 years and unites with the shaft by 21 years. These are the usual figures accepted by Indian medicolegal practitioners. However, it is useful to remember that the variation here can be quite large. Jit & Kulkarni (1976) in one of the largest studies of its kind, after having studied the sternal epiphyses in 684 Indian Punjabees (people living in the province of Punjab), came to the conclusion that the sternal end appeared from 11 to 19 years and united between 18 and 25 years.

Figure 32.4 is an anteroposterior view of the shoulder joint of the subject whose Panorex view we saw earlier. The head of the humerus, lesser tuberosity and greater tuberosity have united together (age >6 years), but have not united with the shaft (<18 years). The centers for the tip of acromion (<15 years) and the tip of coracoid (<11 years) have not appeared. The sternal end of clavicle has not appeared (<19 years). So, by examining this X-ray alone, one could confidently say that the age of the subject was between 6 and 11 years. The actual age of the subject was 8½ years.

Figure 32.4 Anteroposterior view of the right shoulder joint in a subject between 8 and 9 years old (same subject as in Figure 32.1). See text for details.

Ossification around the elbow joint

The ossification of the lower end of the humerus is more complex than that at its upper end. Four different centers of ossification appear here. The first center to appear is in the capitulum, which appears at 1 year, for the medial epicondyle between 5 and 7 years, for the trochlea at 10 years, and for the lateral epicondyle at 11 years. The centers for capitulum, trochlea and lateral condyle unite together to form a conjoint epiphysis around 14 years, which unites with the shaft at 15 years. The medial epicondyle joins the shaft separately at 16 years.

The head of the radius appears at 5 years and that of the ulna at 9 years. Both unite with the shaft at 16 years.

Figures 32.5 and 32.6 are anteroposterior and lateral views of the left elbow joint of a male who had killed a person and had applied for immunity under Section 83 of the Indian Penal Code. He sought an age less than 12 years. The x-ray shows that the medial epicondyle (>7 years) and lateral epicondyle (>11 years) have appeared. The conjoint ephiphysis has formed (>14 years) but has not united with the shaft (<15 years). The head of the ulna can not be seen clearly in Figure 32.5. The head of the radius can be seen clearly. It has not united with the shaft (<16 years).

Figure 32.6 shows the head of the ulna clearly. It has not united (<16 years). The head of radius is visible quite clearly in this view also. Thus, by examining this x-ray alone, one could say that the age of the individual was between 14 and 15 years.

Figures 32.7 and 32.8 show what happens just a year later, by which time some interesting developments have occurred. These

Figure 32.5 Anteroposterior view of the left elbow joint in a subject between 14 and 15 years of age.

Figure 32.6 Lateral view of the left elbow joint in the same subject as in Figure 32.5.

are the anteroposterior and lateral views of the left elbow joint of a male just under 16 years of age. The conjoint epiphysis has united with the shaft (>15 years), but the medial epicondyle has not yet united (<16 years). The head of the ulna has united, which might tempt one to say that the subject was above 16 years, but on careful inspection, the head of the radius has not yet united. Thus, taking into consideration all the epiphyses, one could say that the subject's age was between 15 and 16 years, and probably more towards 16 years of age.

Ossification around the wrist joint

The wrist joint presents quite a number of bones for radiologic analysis. This is one of the reasons why many workers regard it as the single most important joint in the estimation of age (Greulich & Pyle 1959). Other advantages stem from the little irradiation required to show these bones and the ease of radiographic positioning (Roche et al 1988).

Figure 32.7 Anteroposterior view of the left elbow joint in a subject approximately 16 years of age.

Figure 32.8 Lateral view of the left elbow joint in the same subject as in Figure 32.7.

The lower end of the radius appears at 2 years and that of the ulna at 6 years. Both unite with the shaft at about 19 years. The order of appearance of ossification centers in the carpal bones is: capitate 2 months; hamate 3 months; triquetral 3 years; lunate 4 years; scaphoid, trapezium and trapezoid 4–5 years; pisiform 9–12 years.

Metacarpals show more variation. A reasonable estimate can be made from the head of the first metacarpal (thumb), which unites by 16 years. The heads of other metacarpals unite by 17 years. An interesting fact is that the head of the first metacarpal is towards the wrist joint, while the heads of the other metacarpals are away from the wrist joint.

Figure 32.9 is the anteroposterior view of the left wrist joint of the same subject as in Figures 32.7 and 32.8). The lower ends of both radius and ulna have not united (<19 years). All the carpal bones have appeared (>12 years). The heads of 2-5 metacarpals have not united (<17 years), but the head of the first metacarpal has just united (around 16 years). We can see a white line at the junction of epiphysis and diaphysis, which is known as the *epiphyseal scar* and represents recent union. Thus, after examining this single x-ray, one can say that the age of the subject is between 16 and 17 years, probably more towards 16 years. A slightly lower age was estimated in the same subject by examining his elbow joint x-rays, but such variations are frequently encountered in medicolegal practice. In all such cases an overall view of all the findings is taken before giving any opinion.

Figure 32.10 shows the anteroposterior view of the wrist joint of an 8-year-old male subject who was beaten by his employer (he shows recent union of the lower ends of radius and ulna, which were fractured). The employer was booked under various offenses, one of these being that he employed a child less than 14 years of age in a hazardous profession. The employer asserted that the child was above 14 years of age, and looked younger only because he was malnourished. This was how the case was referred to the author. From the examination of the teeth of this subject, the author could almost pinpoint his age at 8 years, but the wrist joint of the same subject shows some interesting findings. The lower end of radius (>2 years) and ulna (>6 years) have appeared, but not the pisiform (<9 years). It is interesting that just by looking at this x-ray one could give the age range as 6–9 years.

Ossification in the sternum

The sternum is quite often neglected by medicolegal practitioners, but good corroborative use can be made of this bone in age estimation. The sternum consists of three parts – the manubrium sterni, the body of the sternum, and the xiphoid process. The body of the sternum has four sternebrae. The centers for the manubrium sterni and the sternebrae appear during intrauterine life and are not important from a medicolegal angle (as far as estimation of age in

Figure 32.9 Anteroposterior view of the left wrist joint in the same subject as in Figure 32.7.

the living is concerned). The center for the xiphisternum appears at 3 years of age, but can show vast variation. The union of the four sternebrae occurs from below upwards. The figures which this author has used with success are: union of third and fourth sternebrae at 15 years; that of second and third at 20 years; and that of first and second at 25 years. The xiphisternum often unites with the body at 40 years. The manubrium sterni unites with the body after 60–70 years, and quite often remains ununited.

Figure 32.10 Anteroposterior view of the left wrist joint in an 8-year-old male.

Figure 32.11A shows the lateral view of the sternum of an 18-year-old male and Figure 32.11B is an explanatory line diagram. The subject was referred to the author by a civil court for an age certificate as he wanted to marry his girlfriend in court (their parents had not consented to the marriage) and could not produce an age certificate. He asserted that he was 22 years of age (this would legally enable him to marry). A dental and radiologic examination conclusively proved that he was around 18 years of age. The lateral view of the sternum corroborates this view. The third and fourth sternebrae have united (>15 years), but not the second and third (<20 years). A large gap can be seen between the manubrium sterni and the first sternebra, as well as between the first and second sternebrae.

Ossification around the hip joint

The hip joint is probably the third most useful joint for age estimation after the wrist and elbow joints. The ischiopubic ramus unites by 7–8 years. The iliac crest ossification center appears at 14 years of age and unites with the ilium by 20 years. The center at the tip of the pubis appears at 14 years and that at the tip of ischium at 16 years. These two centers unite with the rest of the bone by 20 years. Ossification in the acetabular cup begins from two separate centers, one or other of which is often termed the *os acetabuli*. One is between the ilium and pubis, and the other is between the ilium and ischium. As bone begins to be laid from these two centers, the acetabular cup assumes the shape of a triradiate cartilage, which becomes noticeable in radiographs by 13 years. The triradiate cartilage disappears by 15 years.

The ossification center for the head of the femur appears by 1 year, the greater trochanter by 4 years, and the lesser trochanter by 14 years. All these centers unite with the shaft by 17 years.

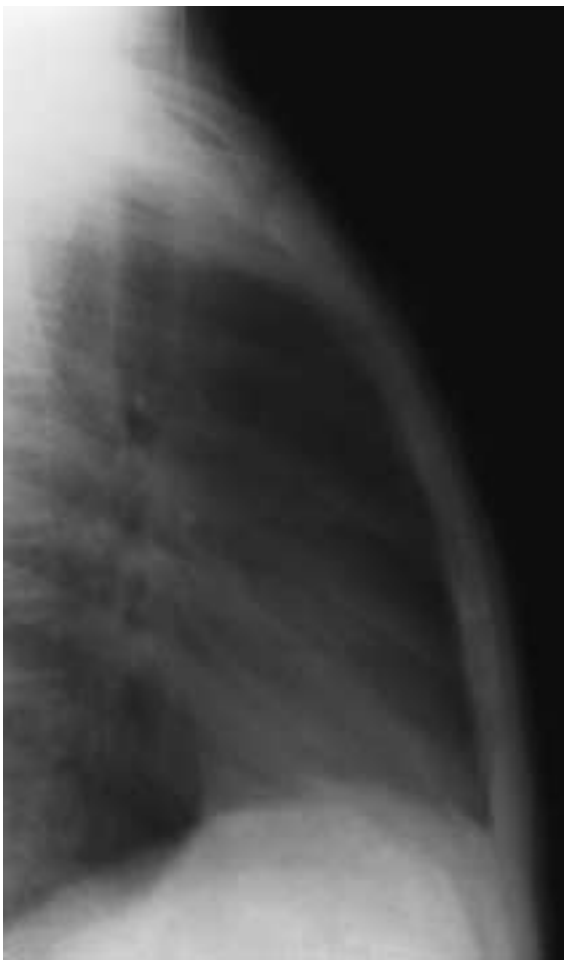

Figure 32.11 **A** Lateral view of the sternum in an 18-year-old male and **B** a line diagram of the same figure.

Figure 32.12 is an anteroposterior view of both the hip joints of a 15-year-old male, who was referred to this author as he had claimed a place in a children's home on account of his being below 16 years of age. The center for the iliac crest has appeared and is quite clearly visible on the left side (>14 years). The iliac crest has, however, not united (<20 years). The lesser trochanter has appeared (>14 years), but neither this, nor the greater trochanter, nor the head of femur has united with the shaft (<17 years). The center for the ischium has not appeared (<16 years). The triradiate cartilage could not be seen (>15 years). A combination of these findings enables the age of the subject to be determined as being between 15 and 16 years.

Ossification around the knee joint

The center for the lower end of femur appears in the ninth month of intrauterine life. The center in the upper end of the tibia appears just at birth and in the upper end of the fibula at 4 years. All these three centers unite with their respective shafts by 18 years.

Figure 32.13 is the anteroposterior view of the left knee joint of the same subject as in Figures 32.1 and 32.4. All the three centers mentioned above have appeared but none has united. This enables us to give the age range as between 4 and 18 years, admittedly too broad a range to be very useful. But this opinion can be given after examining just one joint; the joint is mostly helpful as corroborative evidence.

Ossification around the ankle joint

The centers for the lower ends of both tibia and fibula appear at 1 year of life and unite with their respective shafts at 17 years. The primary center for the calcaneum appears in the fifth month of intrauterine life, and the secondary center at 6 years. It unites by 16 years.

Figure 32.14 is an x-ray of a 12-year-old male who was caught acting as a pimp in a redlight area. The lower ends of tibia and fibula have appeared but not united. However, the interesting finding is that the secondary center for the calcaneum has

Figure 32.12 Anteroposterior view of both the hip joints of a 15-year-old male.

appeared (>6 years), but not united (<16 years). This helps to give the medicolegal practitioner the range of 6–16 years. Of course, examination of other joints would help to further narrow down this range.

Input from other specialties

Pediatricians have been using some interesting methods for calculating bone age for quite some time. They compare the bone age with chronological age of children for diagnosing several disorders that show a characteristic relationship between the two. For instance, hormonal deficiencies, notably those of thyroid and growth hormone, usually cause a bone age retardation of as much as 3 or more years. Most chronic disorders that impair growth as the consequence of metabolic causes or undernutrition will result in a bone age retardation by 2 years or so. In contrast, certain conditions can accelerate bone growth so that it exceeds chronological age. Thyrotoxicosis, sexual precocity and, to a lesser extent, simple exogenous obesity advance bone age.

Methods of comparison

As far as this author is aware, methods of comparison have not been used for medicolegal estimation of age, but there is no reason why they can not be used. A brief look at these methods would be useful for those desirous of starting such a venture.

Most of these methods can be divided into two broad groups. In one group – the atlas method – an atlas is used to compare the radiographs of various joints and, once the x-rays are exactly matched, the ages are read off directly from the atlas. In the other group – a scoring method – a scoring is done for each bone in an x-ray according to some prescribed rules, and the final age is read off tables. Leading the first group of methods is the method of Pyle et al (1971). The undoubted leader of the other group is the method of Tanner & Whitehouse, often known as the TW II method. Tanner and colleagues developed this method in 1962 (Tanner et al 1962); it was later upgraded in 1975 (Tanner et al 1975). Consequently, the first system came to be known as the TW I method and the second as TW II method (sometimes written as TW 1 and TW 2 methods). The method of de Roo & Schröder (1976) falls in the first group, while the Fels method (Roche et al 1988) falls in the second group. For details of these methods, the original publications must be consulted.

Several authors have tried to compare the accuracy and ease of these methods (Buckler 1983, Milner et al 1986, Cole et al 1988, van Lenthe et al 1998). The general consensus is that, while the atlas methods led by the method of Greulich & Pyle, are easier to perform, the results are much more accurate in scoring methods,

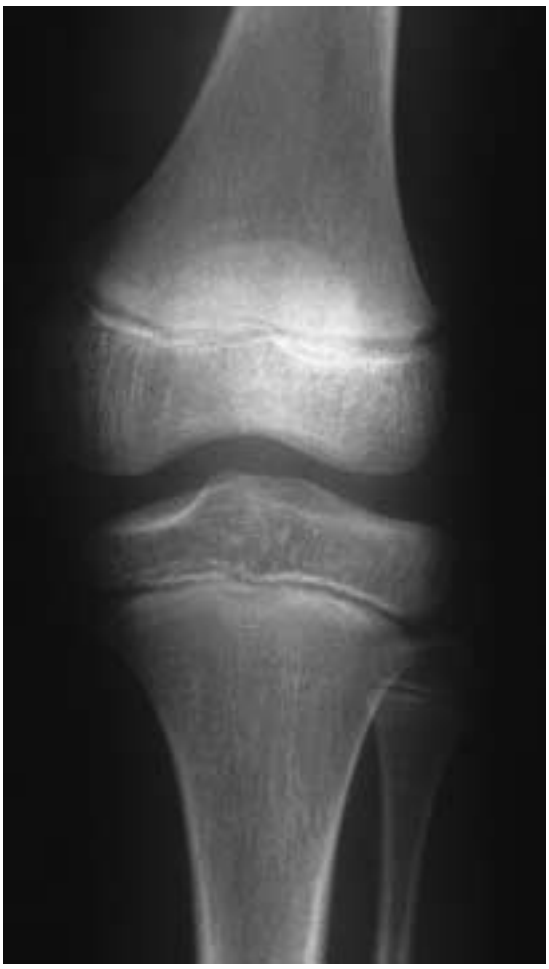

Figure 32.13 Anteroposterior view of the left knee joint of the same subject as in Figures 32.1 and 32.4.

Figure 32.14 Lateral view of the left ankle joint of a 12-year-old male.

led by the methods of Tanner & Whitehouse. Before an attempt is made to use these methods for mediolegal estimation of age, it must be remembered that the data for these methods were derived from children taken from a particular nation, so the data may not work well for other nations, or even within different areas of the same nation. The method of Pyle is based on an American population, and it is widely believed that this method does not give accurate results for British subjects. On the other hand, Tanner & Whitehouse's method is based on British children.

Some authors have made an interesting attempt to adapt these well-established methods for their own needs in intelligent ways. Cole et al (1988) thought that the atlas of Greulich & Pyle did not give accurate results for the local population of Middlesbrough, so they examined 200 hand radiographs of their own local children and after studying them thoroughly devised this interesting equation

$$\text{recalibrated GP age} = \text{nominal GP age} \times 1.065 + 0.129$$

Nominal GP age refers to the age suggested by the Greulich & Pyle atlas, and the recalibrated GP age refers to the age arrived at after recalibration. The authors are convinced that this formula gives quite accurate ages for their own population. This method can be kept in mind by prospective workers wanting to use these methods for their own population.

Secondary sexual characteristics

Secondary sexual characteristics only give a very vague idea of age and are obviously not very helpful from a medicolegal angle. Sometimes, however, sometimes they can provide good corroborative evidence. Hair first appears around the pubes, then in the axilla, and finally over the face.

In the male, fine downy hair begins to appear around the pubes by 14 years and in the axilla by 15 years, and on the chin and upper lip between 16 and 18 years. The color of the hairs becomes darker, and they become somewhat thicker in a couple of years. Hair on the inner sides of the thigh and on the scrotum may appear after 18 years. The Adam's apple becomes more prominent by 16–18 years.

In females, menstruation starts by 12–13 years. Breasts begin to develop by about 13 years. Fine downy hairs appear on the mons veneris by about 13 years. They become thicker and darker in about a couple of years.

ESTIMATION OF AGE IN OLDER PERSONS

Estimation of age after 25 years poses a real challenge, as by that time all the teeth have erupted and most bones have united. The closure of skull sutures helps to some extent here. In general, the skull sutures close in the pattern given in Table 32.4.

Table 32.4 Closure of skull sutures

Suture	Commencement	Halfway closed	Termination
Spheno-occipital synchondrosis	–	–	20
Coronal suture	25	30	40
Sagittal suture	25	30	40
Lambdoid suture	25	30	45
Pterion	40	–	65
Masto-occipital suture	45	–	80
Asterion	–	–	50

An anteroposterior (Towne) view of the skull must be carried out to visualize all major sutures. This view quite comfortably shows the sagittal, coronal and lambdoid sutures. The same sutures can also be seen in posteroanterior radiographs of the skull. Both these x-rays must be advised, as different sutures may be seen clearly in different positions.

The basisphenoid suture is visible in a submentovertical radiograph of the skull. An x-ray of the lumbar and cervical spine often shows lipping of the vertebrae and the appearance of osteophytes after the age of 40 years. A chest x-ray may show ossification of costal cartilages.

As stated earlier, x-rays of the sternum may be of some use after the age of 40 years. Radiography of the neck may be tried to visualize the ossification of the thyroid and laryngeal cartilage as well as the union of the greater cornu of the hyoid with its body. The author routinely uses these x-rays for estimating the age of middle-aged people.

Features such as an arcus senilis (>40 years), hair in the auditory meatus (>50 years), graying of hair (>40 years), loss of scalp hair (>40 years), appearance of cataract (>50 years) and loss of teeth (>60 years) are too variable to be of any specific direct use from a medicolegal angle.

Morse et al (1994) have described an interesting method for estimating the age in the older age group. They take the periapical radiographs of these subjects and derive six parameters from them (Figure 32.15):

1. coronal length (A): distance from incisal edge to top of pulp chamber
2. apical length (B): distance from root apex to apical end of root canal

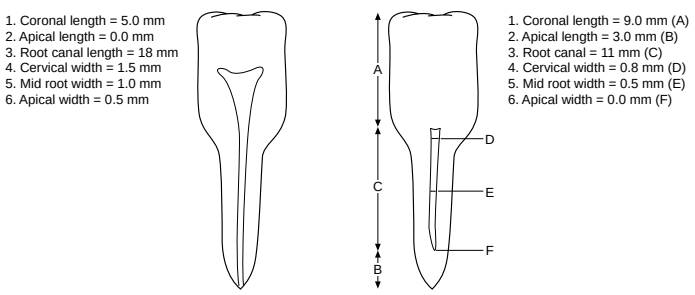

Figure 32.15 Diagramatic representation of the radiographic measurements in periapical dental radiographs of 23-year-old and 45-year-old subjects.

3. root canal length (C): tooth length minus coronal length minus apical length
4. cervical width (D): width of root canal at the cervix
5. mid root width (E): width of root canal at its halfway point
6. apical width (F): width of root canal at its most apical point.

They have found that with age these parameters change, and they have been able to find statistically significant differences between various age groups. As an illustration they give the various dimensions in the same patient at 23 and 45 years of age (Table 32.5). They have come to the conclusion that vertical root canal shrinkage occurs at the rate of 0.32 mm/year, horizontal root canal shrinkage at the rate of 0.07 mm/year, and combined root canal shrinkage at the rate of 0.39 mm/year. The method appears promising, although to the best of this author's knowledge this method has not been exploited for medicolegal purposes so far.

ESTIMATION OF AGE AS A WHOLE

Figure 32.16 is a typical age report form used by medicolegal practitioners in India. It consists of three parts – the preliminaries, the main body of the report, and the opinion. All the preliminaries are self-evident on the form. An important practical point is to obtain the consent of the individual. According to law, any physical examination of an individual without his consent may amount to assault. However, if the patient has been arrested, then consent may not be necessary (Aggrawal & Busuttil 1991).

An opinion is given only after careful consideration of all parameters – general physical development, dental eruptions, and ossification of bones. The author is tempted to say in the end that estimation of age is probably a judicious mix of fine art, rigorous

Table 32.5 Dimensions of various tooth parameters as measured radiographically in a 23-year-old and 45-year-old subject

Parameter	23 years (mm)	45 years (mm)
Coronal length (A)	5	9
Apical length (B)	0	3
Root canal length (C)	18	11
Cervical width (D)	1.5	0.8
Mid root width (E)	1	0.5
Apical width (F)	0.5	0

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DEPARTMENT OF FORENSIC MEDICINE

AGE ESTIMATION REPORT

No. FM/_____Conducted by_____
Date_____Time_____
Name_____s/o_____
R/o_____
Age (as told by patient)_____Sex_____
Onset of Menarche (Females)_____
Brought by_____
Referred by_____
Fir No/D.D.No_____
Alleged history of_____
_____
_____

Consent:
I_____S/o_____
R/o_____
give my free consent for a complete medical examination and other relevant investigations for the purpose of making an age report. The nature and consequences of such examination have been explained to me. In token thereof I subscribe my signature/thumb impression herewith.

Signature of witness Signature/thumb impression
Marks of Identification:

1.

2.

General Physical Examination:
Built-Good/Average/Poor
Height_____cms, Weight_____kg, Pulse_____
HAIR:
Pubic_____Axillary_____
Beard_____Moustache_____
Breast development_____
Genital development_____

Dental Examination:
Orodental hygiene_____
Dental formula:

_____

S indicates Space behind 2nd molar,
X indicates tooth not erupted or space not present.

Radiological Examination:
X-ray plates_____ No._____
Findings:

OPINION: In my opinion, based on physical, dental and radiological findings, when taken together, the age of the person examined is between _____and_____years.

(Dr._____)

Figure 32.16 A typical age estimation form.

science, careful judgment, and shrewd intuition. This art can only be learnt with practice. No amount of rote learning without practice is going to be of any help.

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