Chapter

All We Need to Know about Normal and Abnormal Human Teeth

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Abstract

Type of dentition, number of teeth in primary and permanent dentition, and appearance of the teeth in both dentitions have been extensively described in the literature. There are 20 teeth in primary dentition and 32 in permanent dentition. Teeth typically exhibit normal appearance, although small variations may appear. Abnormal teeth can be detected via careful clinical or radiographical observation. Variations in appearance, structure, and eruption of teeth can be influenced by factors such as genetics, trauma, certain drugs, and periapical lesions. These factors can alter teeth shape, number, size, and position. Teeth with anomalies can have a negative impact on a person's appearance as well as functions such as eating and can even lead to psychological problems. They can be detected with different X-ray techniques, but cone beam computed tomography (CBCT) is the most precise.

Keywords: normal human teeth, abnormal human teeth, dental anomalies, tooth anatomy, cone beam computed tomography

1. Introduction

There is a specific period in which humans develop primary dentition and then permanent dentition. Primary dentition consists of four incisors, two canines, and four molars in each jaw, whereas permanent dentition includes all of this plus an additional group of teeth called premolars and one more set of molars. These groups of teeth have a well-established description and appearance and any deviation in these areas is classified as an abnormality. Dentists must have thorough knowledge of normal tooth anatomy, as they are usually the first provider one visits for clinical or radiographical examination of one's teeth. Abnormal teeth often have an unusual appearance, structure, or position in the jaw, which can cause problems during growth as well as make dental therapy challenging. Genetic disorders and external risk factors contribute equally to the abnormal appearance of teeth and even to their absence.

2. Types of dentition and periods of teeth eruption in humans

At birth, humans often do not have any teeth in their upper and lower jaws; this is considered normal and is a precursor to the development of what is hoped to be normal-looking teeth. However, sometimes teeth develop abnormally due to trauma or genetic anomalies. These teeth may have abnormal appearance or inadequate strength or function. These are called rudimental teeth. Periods of teeth eruption can be divided into primary (milk) dentition and secondary (permanent) dentition [1]. Periods during which humans have both primary and permanent teeth in their jaws is called mixed dentition. This usually occurs when the first permanent molar finds its place in the dental arch, usually at the age of six years [2].

The first teeth that erupt into the oral cavity are called primary teeth. There are 20 primary teeth, 10 per jaw. In each arch of the mouth, there are two central incisors, two lateral incisors, two canines, and four molars. These teeth will be exfoliated by permanent teeth eruption, so-called replacement teeth [3, 4]. Primary first and second incisors as well as the canines are replacements for their counterpart permanent teeth, but the first and second primary molars are replacement teeth for first and second permanent premolars, whereas permanent molars do not have replacement teeth and they grow at the end of the primary teeth arch. The first teeth that will appear in the dental arch are mandibular incisors followed by maxillary incisors. By the end of the first year, all anterior teeth are usually visible. At the second year, all primary teeth, except for the second molars, are erupted. In the third year, all primary teeth are present and functional in both jaws [5, 6] (**Table 1**). Eruption of primary teeth is often called teething and it is followed by increased salivation and local gingival irritation at the site of teeth eruption, which can vary in intensity and usually ends when the tooth appears in the oral cavity [7].

Primary teeth have an important role in developing the jaw as well as jaw and facial muscles, which are important for speaking, chewing, biting, and so on; thus, primary teeth must be kept healthy until the time of their replacement. Prematurely lost primary teeth can cause the absence of space for permanent teeth, which can lead

Maxillary tooth	**Eruption Date (average)**	**Exfoliation Date (average)**
Central Incisor	8–12 Months	6–7 Years
Lateral Incisor	9–13 Months	7–8 Years
Canine	16–22 Months	10–12 Years
1st Molar	13–19 Months	9–11 Years
2nd Molar	25–33 Months	10–12 Years
Mandibular tooth	**Eruption Date (average)**	**Exfoliation Date (average)**
Central Incisor	6–10 Months	6–7 Years
Lateral Incisor	10–16 Months	7–8 Years
Canine	17–23 Months	9–12 Years
1st Molar	14–18 Months	9–11 Years
2nd Molar	22–31 Months	10–12 Years

Table 1.
Average time of eruption and exfoliation in primary dentition, both jaws.

to malposition of the permanent teeth. Mispositioned teeth have greater chances of developing caries and may not be esthetically pleasing [8].

Permanent dentition begins at about six years of age with the growth of central incisors and first molars of the upper and lower jaws and ends at about 12 years of age with the growth of second molars. Third molars, which can vary in their appearance or even be absent, appear between 18 and 30 years of age; sometimes they never erupt due to missing embryonic tooth germ (**Table 2**). While growing, permanent teeth exfoliate primary teeth and grow in their place or behind them. The phase during which a person has both primary and permanent teeth is called mixed dentition. Once the second primary molar and primary canine are replaced with permanent teeth, dentition becomes fully permanent. At the end of development, there is a total of 32 permanent teeth in both jaws [9]. The permanent and primary teeth can be affected by different anomalies, which can alter their appearance. Permanent teeth have greater risk of developing anomalies.

Tables 1 and **2** show the time of teeth eruption from both dentitions. Delayed eruption (6–8 months from the approximate average times) indicates a problem and may be a sign of tooth anomalies (number, shape, or position). More rarely, delayed eruption is associated with Down syndrome, hypothyroidism, hypopituitarism, achondroplasia, osteopetrosis, or chondroectodermal dysplasia as well as the possible development of cysts [10]. A significant variation affecting a single tooth or only a few teeth should be carefully investigated.

Tooth	Eruption Date (Avg.)
Maxillary	
Central Incisor	7–8 Years
Lateral Incisor	8–9 Years
Canine	11–12 Years
1st Premolar	10–11 Years
2nd Premolar	10–12 Years
1st Molar	6–7 Years
2nd Molar	11–13 Years
3rd Molar	17–21 Years
Mandibular	
Central Incisor	7–8 Years
Lateral Incisor	8–9 Years
Canine	9–10 Years
1st Premolar	10–12 Years
2nd Premolar	11–12 Years
1st Molar	6–7 Years
2nd Molar	11–13 Years
3rd Molar	17–21 Years

Table 2.
Average time of eruption in permanent dentition, both jaws.

3. Anatomical structure of tooth

The anatomy of a tooth divides into the crown and the root. The crown of the tooth is visible in the oral cavity, and the roots of the tooth are located in the alveolus of the maxilla and mandible and attached to the periodontal ligament. The anatomic crown is covered by enamel, while the anatomic root is covered by cementum. A clinical crown is not necessarily the same length as the anatomical crown and clinical root, which may differ because of periodontal diseases or chirurgical procedures. The gingiva covers the border of the alveolar process that is adjacent to the teeth. The anatomical boundary between the enamel-covered crown and cementum-covered root is the cementoenamel junction. The roots of the tooth vary depending on the type of tooth. The number of roots often is the same for the same group of teeth. The maxillary molars typically have three roots: a palatal root, mesiobuccal root, and distobuccal root. First premolars of the maxilla have two roots and the second premolars and all anterior teeth have typically one root. In the mandible, all anterior teeth and both premolars typically have one root, while molars have two roots: mesial and distal. The only exceptions are the third molars, which can have different numbers of roots. The longest root is considered to have maxillary canines. The periodontal ligament is composed of connective tissue fiber that connects the tooth to the alveolar bone. At the upper part of the root is the apical foramen where the neurovascular structures enter the tooth [11].

The blood supply of the teeth originates from the maxillary artery, which is the largest terminal branch of the external carotid artery. The specific arteries carrying blood to the teeth travel through the root canal and have the following names: anterior superior alveolar arteries, posterior superior alveolar arteries, and inferior alveolar arteries. The veins of the teeth follow the arteries, having similar names. The nerves supplying the teeth also accompany the arteries through the root canal and originate from the maxillary and mandibular branches of the trigeminal cranial nerve. Near the teeth, these major nerves branch into superior alveolar nerves and inferior alveolar nerves [12].

4. Surfaces of teeth and appearance of teeth in both dentitions

Permanent teeth are divided into two groups: anterior teeth and posterior teeth. Anterior teeth include the teeth toward the front of the mouth, including the central incisors, the lateral incisors, and the canines, while posterior teeth are the teeth toward the back of the mouth and include the premolars and molars [13].

Anterior teeth show four surfaces and one cutting ridge: vestibular surface, lingual surfaces in bottom teeth, palatinal surfaces in upper teeth, mesial surfaces in teeth closer to the middle line of the jaw, distal surfaces in teeth far from the middle line of the jaw (mesial and distal surfaces are also called proximal surfaces) and the incisal ridge.

Posterior teeth show five surfaces: vestibular surface, lingual surfaces in bottom teeth and palatinal surfaces in upper teeth, mesial surface in teeth closer to the middle line of the jaw, distal surfaces in teeth far from the middle line of the jaw, and the occlusal surface also called the masticator surface..

Special anatomical structures of teeth include the mound-ridge complex (cuspis, tuberculum, cingulum, crista, cumulus) and fissure complex (fissures, fossae, pits).

The area of the tooth that contacts the adjacent tooth is called the contact area. The number of cusps varies among anterior and posterior teeth. The incisors do not have cusps, canines have one cusp, premolars usually have two cusps (sometimes they can show molarization when they have an additional cusp), and molars have four cusps (with occasional appearance of a fifth cusp called the cusp of Carabelli). Cingulum is characteristic of anterior teeth of both jaws (incisors and canines) and it represents the portion of enamel forming a convex protuberance in the cervical third of the palatal and lingual surfaces of anatomic crowns. Cumulus is also characteristic of anterior teeth, mostly seen on early erupted permanent incisors, and they are located on the incisal surfaces in the form of three dents. The fissure complex is characteristic of posterior teeth. A tooth usually has one main central fissure that goes from the mesial to distal side of the occlusal surface of the tooth. It continues with additional fissures on each side going toward the proximal buccal and oral surfaces (mesiobucal and mesiooral, and distobuccal and distooral) and together they form the borders of the triangular fossae on the mesial and distal proximal side of occlusal surfaces. Central fossa is located on the middle of the central fissure. There is also a lateral fissure in the molar region that divides buccal and oral cusps on the mesial and distal cusps [14].

Tafti and Clark described the primary teeth in detail.

a. Teeth in Primary Dentition

1. Incisors - The maxillary incisors are essentially smaller morphological versions of permanent teeth incisors. The incisors are used for cutting food and have sharp edges. They consist of the central incisors and the lateral incisors. The central incisor is larger than the lateral incisor, and the maxillary central incisor is the largest of all the incisors. They also prominently figure into the esthetic of the oral region. Their labial surface is convex and their palatal surface is concave. Incisors of the mandible are smaller than the incisors of the maxillary teeth. The incisor crown is trapezoidal in the labial view and contains three tubercled incisal edges called cumulus.

2. Canines – The maxillary canines are also morphologically similar to permanent teeth canines. The canines have a trapezoidal crown with one labial cusp. The labial surface is convex and the palatal surface is concave. The canines serve to support the incisors. The canines have a characteristic pointed incisal edge and a large cone-shaped crown. Canines of the mandible have a trapezoidal crown with a single labial cusp.

3. Molars – The molars are the largest of the primary teeth and provide significant function in mastication. The crowns of the primary molars are more bulbous in morphology. The buccal, lingual, mesial, and distal surfaces of the maxillary and mandibular molars are all convex. The occlusal surface is rectangular in both jaws.

   - First Molars – The maxillary first molars morphologically resemble both a molar and a premolar. The occlusal surface of a first molar consists of the mesiobuccal, distolingual, mesiolingual, and distobuccal cusps. The largest cusp is the mesiolingual cusp, which is also the sharpest cusp. The distolingual cusp is small and rounded in morphology. The primary first molar

has a less pronounced mesiobuccal cusp when compared to the permanent first molar. The mandibular first molars have four cusps: two buccal and two lingual. These include the distobuccal, distolingual, mesiolingual, and mesiobuccal cusps. The occlusal surface is narrow secondary to mesiobuccal and mesiolingual cusp convergence. There are three pits.

- Second Molars – Primary maxillary second molars resemble the permanent maxillary first molar. Rhomboidal in shape, the maxillary second molar has four cusps, two on both the buccal and lingual aspects. A fifth cusp can be present and is called the cusp of Carabelli. Two well-defined cusps can be seen on the buccal view, and the lingual surface has three cusps: the mesiolingual, distolingual, and the cusp of Carabelli, much less than in permanent dentition. The buccal surface of the maxillary second molar is divided into the mesiobuccal, distobuccal, and distal cusps. The lingual cusps include the distolingual and the mesiolingual cusps [15].

b. Teeth in Permanent dentition

1. Incisors – The primary function of incisors is to cut food. They have a sharp incisal edge. When first erupted, the incisors have three cumulus, which often disappear when biting food. The cingulum is located on the oral surfaces and can have a pit formed in it where it meets the lingual surface of the tooth. Central incisors have sharper and more acute incisor angles than lateral incisors. The maxillary central incisors are also unique in that they are larger than mandibular central incisors. Maxillary lateral incisors often vary the most in their shape. Sometimes maxillary lateral incisors can have a peg-like shape. The maxillary lateral incisors may also be congenitally missing. The mandibular central incisor is the smallest tooth of all the incisors.

2. Canines –The main function of canines is to tear food. They have a single, pointed cusp. They also serve to form the corners of the mouth. The canines have very prominent cingulum, but the maxillary cingulum is more prominent than the one on the mandibular canines and it rarely has pits.

3. Premolars (bicuspids) – These teeth are located behind and adjacent to the canines and are designed to crush and grind food. These teeth can have two–three cusps (the mandibular second premolar typically has three). The buccal cusp is typically longer and wider than the lingual cusp. In the mandibular first premolar, the lingual cusp is very small and usually not functional. Often the first premolar is the tooth that is extracted in orthodontic procedures to make room for crowded teeth to move into place.

4. Molars – The most posterior teeth in the mouth are the molars. They have broader and flatter surfaces with four–five cusps and have the largest crowns of any other teeth. They are designed to grind food. They are named starting with those closest to the midline as first molars, second molars, and third molars. Third molars can vary in size and shape or even be absent. They are commonly referred to as wisdom teeth and often have fused roots. The mandibular molar is the first permanent tooth to erupt in the mouth [16].

Indicated differences between primary and permanent teeth include:

1. Primary teeth are smaller in all dimensions than analogous permanent dentition teeth.

2. Crowns of primary teeth look shorter (lower) compared to permanent teeth.

3. Primary teeth always show a larger md width compared to the natural height of the crown ("chucky" appearance of the crown of all primary teeth).

4. The class of incisors and canine teeth is characterized by the presence of a cervical ridge. Members of the primary dentition molar class show an analogous structure, but only to the cervical third of the buccal surface (buco-cervical ridge).

5. The labial surface is completely smooth, without the presence of cumulus, lobes, and developmental depressions.

6. The root tree in the primary teeth is absent.

7. The root branches of the primary molar are longer and more graceful with a greater degree of angulation and divergence.

8. Primary teeth are milky or blue-white, unlike the crowns of permanent dentition teeth, which are mainly yellow-gray or gray-white.

9. Enamel and dentin are thinner and less transparent.

10. The pulp chamber of primary teeth is voluminous.

5. Normal tooth structure

Nanci elucidated that tooth enamel, the protective outer layer of the dental crown, is the hardest and most mineralized tissue in the human body. Enamel is an avascular, hard material that protects the outer tooth and gives the tooth its whitish color. Enamel color is determined by enamel thickness. Enamel consists of more than 95% apatite, a calcium phosphate mineral that can be found in all mineralized tissues. Apatite crystals grow predominantly along their c axis and align parallel to one another, effectively forming an enamel rod; each rod is enveloped with organic matter, which makes up only 1–2% of enamel. The role of organic matter in providing a scaffold for enamel minerals to grow has long been recognized [17]. Enamel is formed by cells called ameloblasts, which are active only until the tooth is in developmental stage. Once the tooth appears in the oral cavity, those cells are no longer active and this is why the enamel is the only structure of the tooth that cannot form by itself [18].

Dentin is less mineralized than enamel but more than bone or cementum. Its characteristic feature is a regular pattern of microscopic dentinal tubules, 3 μm in diameter, which extend from the pulpal surface to the enamel–dentine junction. The tubules show lateral and terminal branching near the enamel–dentine junction and may project a short distance into the enamel [11]. The diameter of the dentine tubule is narrowed by deposition of peritubular dentine. This is different from normal

dentine (intertubular dentine) because it is more mineralized and lacks a collagenous matrix. Dentine is formed slowly throughout life and thus there is always an unmineralized zone of predentine at the surface of the mineralized dentine, adjacent to the odontoblast layer at the periphery of the pulp [19].

Cementum covers the root surface and is an important tissue to maintain dental and periodontal attachment. It is light yellow in appearance, thinner near the tooth neck, and wider at the root apex. Cementum is excreted by cells called cementoblasts, which develop from undifferentiated mesenchymal cells in the connective tissue of the dental sac. Cementum is slightly softer than dentin and consists of about 45–50% inorganic mineral. Cementum is a mineralized connective tissue similar to bone except that it is avascular; the mineral is also apatite and the organic matrix is largely collagen. The two main types of cementum are cellular and acellular. The cementum attached to the root dentin and covering the cervical part of the root is acellular, or primary, cementum. The lower apical part of the root is covered by cellular, or secondary, cementum [20].

The dental pulp resides in a rigid chamber comprising dentine, enamel, and cementum, which provide strong mechanical support and protection from the microbial-rich oral environment. The mature pulp bears a strong resemblance to the embryonic connective tissue, with a layer of highly specialized cells, the odontoblasts, along its periphery. The physical confinement of the dental pulp, its high incidence of sensory nerve innervation, and the rich microcirculatory components make the dental pulp a unique tissue [21]. A recent study on the bacterial invasion into dentinal tubules of human teeth with or without viable pulp has shown that teeth with pulps are much more resistant to bacterial invasion into the dentinal tubules than teeth with root canal fillings. Considering this, the pulp plays an important role in this defense process. In teeth with pulps, the dentinal tubules are occupied by dentinal fluid and odontoblastic processes, which may behave collectively as a positively charged hydrogel. The pulp's specialized cells, the odontoblasts, and perhaps undifferentiated mesenchymal cells retain the ability to form dentine throughout life. This enables the healthy pulp to partially compensate for the loss of enamel or dentine caused by dental caries. Odontoblasts may also form sclerotic dentine, reactionary dentine, and reparative dentine in response to different stimulus, such as thermal stimulus (warm and cold), caries, or operative procedures. Hence, the pulp is a sensory organ involved in the immune defense reaction by processing antigens. Regardless of the nature of the sensory stimulus, such as thermal change, mechanical deformation, or trauma, the pulp registers different impulses as a common sensation like pain. Such pain-registering ability is important as part of the defense mechanisms of the pulp [22].

6. Tooth anomalies

There are different types of tooth abnormalities and they can appear in both dentitions but are more common in permanent teeth rather than primary teeth. Anomalies can affect the number of teeth (hyperdontia, hypodontia, anodontia), the size of teeth (macrodontia, microdontia), the position of teeth (retention (impact), clenched teeth, rotation, ectopia (dystopia), transposition), and the shape of teeth (taurodontism, dilaceration, flexion, conjoined teeth, abnormalities in the shape of the tooth root, aplasia, Hutchinson's teeth, evagination) [23]. Sometimes trauma can affect the appearance of teeth or cause their retention in the bone. Certain drugs and

minerals can affect tooth color and some genetic disorders can affect the structure and appearance of teeth [24].

6.1 Anomalies in the number of teeth

A supernumerary tooth is defined as "any tooth or odontogenic structure that is formed from embryonic tooth germ in excess of usual number for any given region of the dental arch." Küchler et al. (2011) concluded that hyperdontia is a condition characterized by additional teeth (mesiodens) within the normal dentition. Supernumerary teeth are frequently located in the anterior maxilla, between the central incisors. In permanent dentition, the prevalence of supernumerary teeth ranges between 0.5% and 5.3% [25]. Rajab and Hamdan (2001) found that it affects males twice as much as females. This phenomenon is often associated with syndromes such as Ehlers–Danlos, cleidocranial dysplasia, and Gardner syndrome. However, it may also be seen in non-syndromic patients [26]. It has also been reported that males are commonly affected in midline and premolar regions and females are commonly affected in the incisor and canine regions. Supernumerary teeth are more likely to be rudimental looking but can sometimes resemble regular teeth [27]. King et al. (2007) found that formation of supernumerary teeth in any part of the dental arch can lead to complications, including delayed eruption, malposition, impaction, diastemas, crowding, and poor esthetics [28]. Supernumerary tooth can be of different forms (conical, tuberculate, supplemental, and odontoma) and occur in different locations (mesiodens, paramolar, and distomolar). The mesiodens is located between the two central incisors and is mostly conical in shape. Distomolars are located distally to the third molar, while paramolars are located palatally or labially next to a molar [29].

Al-Ani et al. (2017) found that tooth agenesis may involve the primary or permanent dentition and is a developmental anomaly where at least one tooth is absent. Total anodontia is complete tooth agenesis. Missing teeth can be further classified as hypodontia, involving one to five absent teeth, and oligodontia, involving six or more missing teeth [30]. Ritwik and Patterson (2018) found that when excluding third molars (wisdom teeth), tooth agenesis has a prevalence between 3% and 10% in the permanent dentition. Third molars are the most common congenitally missing permanent teeth, with a reported prevalence of 23%. These are followed by mandibular second premolars, maxillary lateral incisors, and, less frequently, the maxillary second premolars [31]. Dinckan et al. (2018) found that syndromes such as ectodermal dysplasia or cleft lip and palate are frequently associated with tooth agenesis and factors such as trauma, infection, or drugs. Complications of tooth agenesis include malocclusion, poor esthetics, reduced masticatory function, and speech difficulties [32].

Hypodontia is an inherited condition, but it can also be caused by trauma, infection, radiation, and endocrine disturbances. It is characterized by developmentally missing teeth. It is very rare in the primary dentition and more common in females than males, with a 3:2 ratio. In addition to missing teeth, people with hypodontia may have rather small or very conical teeth. The tooth most commonly missing is the permanent maxillary lateral incisor (74% incidence) followed by the maxillary and mandibular second premolars [30]. Hypodontia most commonly affects last or most distal teeth in the teeth group, decreasing in incidence from posterior to anterior teeth, in the following order: third molars, second premolars, and lateral incisors. Absent third molars are considered a normal variation nowadays and may not be considered to be part of hypodontia [33].

6.2 Anomalies in the size of teeth

Macrodontia and microdontia are rare shape anomalies of dentition, where teeth are larger or smaller than average.

Microdontia is the term given to describe a tooth very much reduced in size. Microdontia generally affects individual teeth, usually the maxillary second incisor and the third molar. Occasionally, however, many teeth in the same dentition may be affected, in which case the teeth may be spaced apart [34]. Microdontia may accompany clefts of the lip or palate, Ehlers–Danlos syndrome, hypopituitarism, and ectodermal disorders. A frequent variation in shape is the peg-shaped maxillary lateral incisor. In generalized microdontia, all teeth in the dentition appear smaller than normal and enlarge the spaces between teeth, which is aesthetically unpleasing. Teeth may be measurably smaller than normal, as in pituitary dwarfism, or they may be relatively small in comparison with a large mandible and maxilla (acromegaly). In isolated microdontia, a single tooth is smaller than normal. This is mostly seen in permanent dentition in lateral incisors that can be cone- or peg-shaped and very much affects the appearance, and third molars, more common in maxilla [35].

Macrodontia refers to teeth that are physically larger than normal and could clinically be confused with other conditions such as fusion (two separate follicles fusing to form one tooth) and gemination (two teeth that form from one follicle but are not separated) [36]. Three different types of macrodontia can be found: true generalized, where many teeth in the mouth are affected (very rare); relative generalized, where all the teeth are affected and the teeth can either be of normal size in a very small jaw creating the illusion of macrodontia or all the teeth may be slightly enlarged; and isolated macrodontia, where only a single tooth is affected (very rare). The prevalence of macrodontia in permanent dentition is 0.03% to 1.9%, with a higher incidence in males [37]. Macrodontia in the anterior region poses an esthetic problem for patients, leading to crowding, plaque accumulation, and so on.

6.3 Anomalies in the shape of teeth

Gemination (twinning) is an abnormality where a single tooth forms two crowns. This is a consequence of partial division of the tooth, resulting in a bifid crown but retaining the normal number of expected teeth. Gemination is a rare abnormality in which a single tooth tries to divide. Partial division may produce a shared pulp canal and root. Complete division produces a normal tooth along with a supernumerary tooth [38]. Gemination usually affects the primary teeth, but the permanent dentition can be involved as well. The incisor region is the most commonly affected area with no apparent gender predilection. Although the prevalence rate is variable in individual reports, the overall prevalence appears to be approximately 0.5% in the primary dentition and 0.1% in the permanent dentition [39]. Gemination is more prevalent in the anterior maxillary region, affecting incisors and canines, although it can also affect molars and bicuspids. Bilateral cases are seen less frequently, with a prevalence of 0.02% in both dentitions. They are very rare in posterior teeth. it is more frequently found in Mongolians (5%) than in Caucasians (0.5%) [40].

Different from germination, fusion leads to one less tooth within the dental arch; it involves two separate developing tooth follicles that join together [41]. Clinically, a fused tooth looks like a larger tooth and sometimes is mixed with gemination because

both types of teeth have an incisure on the middle of the crown, but radiographic difference is much clearer. Fused teeth have separate pulp chambers for each tooth, while gemination has one larger pulp chamber and there are two roots or two canals in a single root [42]. The degree of union may be total or partial and often presents with a coronal incisure. Like gemination, fusion is more common in the primary dentition but can occur in the permanent dentition as well. It also typically involves the anterior region of the dental arch. While there is no gender predilection, incidence is higher among Native Americans and Asians [43].

Bolhari et al. (2016) defined dilaceration as an unusually abrupt angle between tooth crown and root or within the root itself, resulting from trauma during the development of the tooth. Dilaceration is a developmental disturbance in the shape of teeth. It refers to an angulation, or a sharp bend or curve, in the root or crown of a formed tooth. This disturbance is more likely to affect the maxillary incisors and occurs in permanent dentition [44]. Although this may seem more of an esthetics issue, an impacted maxillary incisor will cause issues related to occlusion, phonetics, mastication, and psychology in young patients. Dilaceration of the crown can diagnosed visually. Crown dilaceration will present itself as a tooth that is angled to face outward or inward [45]. It most commonly affects patients in their permanent dentition. Incidence is more common in females (six times) than males. There are reports of a 0.53% occurrence rate for the two anterior teeth of the upper jaw, but the most common teeth to experience dilaceration are the third molars of the lower jaw with an incidence of 24.1% [46].

Dineshshankar et al. (2014) stated that taurodontism (bull teeth) is an abnormality of tooth morphology that often occurs in multi-rooted teeth and is characterized by a short root and an enlarged crown containing an equally enlarged pulp chamber and no constriction at the level of the cemento–enamel junction. It is a condition that mostly occurs in the molar teeth [47], but it can also be seen in both the permanent and deciduous dentition, unilaterally or bilaterally. The distance from the roof of the pulp chamber to the root bifurcation is greatly increased [48]. Variants include hypotaurodontism, mesotaurodontism, and hypertaurodontism. These conditions may exist as an isolated trait (autosomal dominant) or as part of several syndromes including trichodentoosseous syndrome, otodental dysplasia, ectodermal dysplasia, tooth and nail syndrome, amelogenesis imperfecta, and others [49].

Concrescence is the joining of two completely formed teeth by the cementum along the root surface usually located in the posterior teeth and the maxillary arch, often involving a second molar tooth closely approximating the roots of an impacted third molar. The affected teeth may fail to erupt or only partially erupt. The prevalence rate is 0.04% [50]. Hypercementosis is the thick mantle of cementum that makes the root look fat, and it can be seen in Paget disease of the skeleton (osteitis deformans) [51].

Dens invaginatus is a developmental anomaly presenting with complex morphological variations. This anomaly is also referred to as "dens in dente." It has been described as deep infolding of the enamel organ into the dental papilla during tooth development. Starting from the foramen caecum or tip of the cusps, it can extend deep into the root, with or without pulp involvement, sometimes even resulting in a second apical foramen [52]. This anomaly frequently results in early pulp necrosis. The most affected teeth are maxillary lateral incisors, mostly bilateral. Clinically, the affected teeth may vary in presentation with an increased crown diameter, hypoplasia at the palatal pit, peg or conical morphology, bifid cingulum, a talon cusp, or a deep foramen caecum [53].

6.4 Anomalies in the position of teeth

Rotations are movements that occur around the long axis of teeth. Teeth can become rotated either before they emerge or after. Probably the most common cause of teeth that emerge rotated is trauma to the mouth during the development of teeth. Cysts, tumors, or supernumerary teeth can also cause teeth to rotate as they grow [54]. Also, crowding can force a tooth that grows later to grow narrower than it should in the dental arch. In addition, when there is too much space between teeth (e.g., after tooth extraction), the tooth may move toward the empty space [55]. A rotated tooth is highly visible and can cause malocclusion.

A variety of eruption problems can happen during the mixed dentition period. One such problem is ectopic eruption. Akbas et al. (2022) defined ectopic eruption as a condition in which the permanent teeth, because of deficiency of growth in the jaw or a segment of jaw, assume a path of eruption that intercepts a primary tooth, causes its premature loss, and produces a consequent malposition of the permanent tooth. Failure to treat ectopic eruption can result in loss of arch length, inadequate space for the permanent premolar, and malocclusion [56]. An example of this anomaly is ectopic eruption of first permanent molars that can be positioned too far mesial into the alveolar bone and become impacted below the second permanent molar. Ectopic eruption has a 3% incidence rate and occurs more frequently in males than in females [57].

Matsumoto and Stuani (2018) stated that tooth transposition is a unique and severe condition of ectopic eruption. It is defined as an interchange in the position of two permanent teeth located at the same quadrant in the dental arch [58]. Chattopadhyay and Srinivas (1996) explained that transposition can be complete (when the position of affected teeth is totally transposed) or incomplete (when only the crowns are transposed, while the roots remain in normal position). The incidence of transposition in the overall population is low (0.2%–0.38%) and it is most often found among women in the maxilla (76%) and mostly unilateral. The canines are affected in 90% of transposition cases, most often relative to the first premolar (71%) or maxillary lateral incisor (20%) [59]. Shapira and Kuftinec (1989) described that while it may be present both in the maxilla and mandible, transposition between the canine and maxillary first premolar is most common, followed by a lateral incisor transposed with a maxillary canine. There are no reports of transposition in deciduous dentition [60].

6.5 Other conditions that cause abnormalities of the teeth

Bruxism is a sleep-related movement disorder in which a person grinds, gnashes, or clenches their teeth. Teeth in persons with bruxism have a characteristic appearance; they are flattened, have fractures in the enamel of the tooth crown, and in extreme cases have exposed dentin, which can cause tooth sensitivity and headaches as well as affect the temporomandibular joint [61].

Attrition is the loss of tooth surface due to normal tooth function and occlusion. Some wearing is normal (physiologic), but accelerated wear beyond what is normal is pathologic and usually caused by bad habits [62] such as poor tooth brushing techniques, lip biting, nail biting, and so on.

Erosion is the chemical dissolution of tooth structure often attributed to regurgitation of gastric acid or excessive intake of acidic food or drinks. It is often seen on

the palatal and lingual surfaces of the anterior teeth, which present with flattened surfaces of dental morphology.

Abrasion is excessive wear caused by mechanical forces. It is similar to attrition, but attrition is more often located on occlusal and incisal surfaces and abrasion is more common on the non-occluding surface [63].

Abfraction is the loss of tooth substance attributed to occlusal forces during biting, which cause the teeth to flex ever so slightly. Constant flexing causes enamel to break from the crown, usually on the buccal surface [64].

Dentinogenesis imperfecta is an autosomal dominant condition affecting both deciduous and permanent teeth. Affected teeth are gray to yellow-brown and have broad crowns with constriction of the cervical area, resulting in a tulip shape. Enamel is easily broken, leading to exposure of dentin that undergoes accelerated attrition. This dental condition is sometimes seen in patients with osteogenesis imperfecta. It can be classified into three types. Type I occurs in people who have osteogenesis imperfecta, and type II (progressive hearing loss) and type III usually occur in people without other inherited disorders [65].

There is a large group of inherited developmental defects in enamel collectively referred to as amelogenesis imperfecta. The condition is rare, affecting about 1 in 14,000 people. There are three general categories of this defect: (1) Hypoplastic type: inadequate formation of enamel matrix; both pitting and smooth types exist. Enamel may be reduced in quantity but is of normal hardness; (2) Hypomaturation type: a defect in the crystal structure of enamel leads to a mottled enamel with white to brown to yellow colors; and (3) Hypocalcified type: a defect not in the quantity but in the quality of enamel. It is poorly mineralized, soft, and chips and wears easily [66].

Syphilitic vasculitis around the time of birth can damage the developing tooth buds and lead to dental anomalies. Hutchinson teeth are abnormal permanent upper central incisors that are peg-shaped and notched, usually with obvious thinning and discoloration of enamel in the area of the notching. They are widely spaced and shorter than the lateral incisors; the width of the biting surface is less than that of the gingival margin. Mulberry molars (also known as Moon or Fournier molars) are multicuspid first molars in which the tooth's grinding surface, which is narrower than that at the gingival margin, has many small cusps instead of the usual four well-formed cusps [67]. The enamel itself tends to be poorly developed. Hutchinson's teeth is a sign of congenital syphilis. As well as having a triangle or peg-like shape, a Hutchinson tooth is smaller than the usual size, widely spaced, and has thin enamel and notches on the biting surface. The affected molar teeth (known as mulberry molars) have multiple cusps instead of four cusps. Congenital syphilis affects primary teeth especially in central incisors and molars. Hence you cannot notice Hutchinson teeth in a child until six years of age [68].

The cusp of Carabelli is an additional cusp located on the mesio-palatal surface of permanent maxillary molars. Bhavyaa et al. (2021) found that primary maxillary second molars had the highest prevalence (72f%) of this anomaly followed by permanent maxillary first, third, and second molars. It is a so-called fifth cusp on the molars and it is more likely to be present in permanent dentition and is considered a predilection spot for caries [69].

Discoloration of teeth can be caused by antibiotics such as tetracycline, which is used to treat many common infections in children and adults. Tetracycline can bind to the calcium needed for tooth, cartilage, and bone development, resulting in discoloration of both the primary and permanent dentitions. Minocycline

hydrochloride, a derivate of tetracycline used in acne treatment, can cause discoloration of skin, nails, sclera, and teeth. This permanent discoloration varies from yellow or gray to brown depending on the dose of the medicine. The prevalence of tetracycline and minocycline staining is 3–6% [70].

7. Diagnostic imaging of abnormal teeth

Classic radiography of a single tooth or several teeth using retro-alveolar or retro-coronary X-rays is not ideal for diagnosing dental anomalies. They provide only 2D images of the teeth, and the retro-alveolar method produces distorted images while the retro-coronary method cannot show the apex of teeth, which is not helpful in cases of supernumerary or impacted teeth. Occlusal and axial X-ray methods can help visualize the position of supernumerary and abnormal teeth, but these methods are limited without 3D scans [71]. Orthopantomography is the most common method for radiologic examination of patients with dental anomalies. Compared to classic X-rays, orthopantomography uses less radiation and thus it is more suitable for younger patients. This method allows visualization of both jaws and the temporomandibular joint. In primary and mixed dentition, orthopantomography can visualize the embryonic tooth germs of permanent teeth and diagnose extra, missing, or impacted teeth [72]. Images of teeth scanned by this method can be stored and used multiple times. Although not the most detailed scan, orthopantomography provides a larger picture of the development of jaws and teeth, making it more useful than classic radiography methods. It can diagnose abnormalities, but treatment of abnormal teeth cannot be planned without more precise scans. For chirurgical and orthodontic treatments, 3D scans are a necessity. Cone-beam computed tomography (CBCT) is the best 3D imaging technique for planning treatment, extraction, and implantation [73]. CBCT offers excellent precision and an optimal algorithm for comprehensive treatment of dental patients. Nematolahi (2013) showed that CBCT imaged oral and maxillofacial structures with a high resolution of 0.001 mm3 voxels and that these 3D images can provide a better understanding of many anatomical structures as well as pathologic conditions, developmental anomalies, and traumatic injuries of teeth [74].

8. Conclusion

Knowing the normal anatomy of teeth is not only imperative in dentistry but also in other specialties because various medical conditions can negatively affect the appearance, structure, and position of teeth. With proper diagnosis, complications of abnormal teeth can be prevented. Complications can not only negatively affect smile esthetics but can also adversely affect speaking, biting, chewing, and so on as well as diminish a person's self-confidence and in some cases lead to depression and social isolation. The best option for diagnostic imaging of abnormal teeth as well as monitoring treatment progress is CBCT.

Conflict of interest

The authors declare no conflict of interest.

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