Section I
Developmental Anomalies

1 Anomalies of Number

1.1 Introduction

The human dentition may consist of fewer or more than the normal number of 20 deciduous or 32 permanent teeth. Fusion of two teeth may also give the impression of hypodontia (Section 1.2).

1.2 Hypodontia

Hypodontia is the term used for dentitions with fewer than the regular number of teeth due to *agenesis*, i.e. either absence of a tooth germ or failure of a tooth germ to develop. *Anodontia* is the congenital absence of all the teeth while the absence of many teeth is known as *oligodontia* or partial anodontia. *Isolated hypodontia* is the congenital absence of one or a few teeth. Incomplete dentitions not classified as having hypodontia by definition are those where teeth are absent due to failure of eruption, extraction due to caries or orthodontic treatment,[295] or where teeth have been lost due to trauma and other reasons.

Hypodontia is the most frequent of all congenital aberrations in humans, and also occurs in animals such as dogs.[245] The incidence of agenetic teeth in Caucasian populations seems to have increased during the twentieth century, but the available data are too limited to suggest a trend.[384]

The aetiology of hypodontia is not entirely clear, but genetic factors are most certainly involved. Because mutated genes associated with agenesis have developmental regulatory functions elsewhere in the embryo, associated defects in other tissues and organs are also possible.[591]

The skin develops from the ectoderm, one of the three primary germ layers, which is involved in the formation of the teeth. Patients with isolated dental agenesis may show unusual dermatoglyphic patterns of the palms of the hands and soles of the feet, suggesting a shared origin.[28] The combination of freckles, thin eyebrows and hypodontia[609] suggests the same. Therefore, isolated dental agenesis might be a minor manifestation of a systemic disorder.

1.2.1 *Isolated dental agenesis*

As mentioned above, isolated dental agenesis is the result of the absence of one or a few tooth germ(s). Missing teeth can lead to diastema (interdental spaces) in the dental arches. Displacement and tilting of the neighbouring teeth may close these spaces.

Epidemiology

Primary dentition

Less than 1% of children exhibit hypodontia in the deciduous dentition. The teeth most often involved are the maxillary incisors, followed by the mandibular central or lateral incisors,[112 134 220 372 394 445 469] and also the first molars.[112] When the deciduous canines are agenetic, [205 608] a syndrome (see Chapter 11) such as cleft lip is usually present.[464] Around 50% of children with hypodontia are missing one tooth, usually the maxillary lateral incisor; in the rest usually two or more teeth are missing.[134] Japanese children show agenesis more frequently (5%), which may represent an ethnic trait.[112 158]

Permanent dentition

Surveys, often retrospective, of some 160 000 children and adolescents from different countries and populations indicate that 2% to 10% of the permanent dentitions show isolated dental agenesis, third molars excepted.[1 10 31 47 55 89 94 112 129 131 159 169 170 208 210 219 231 268 279 294 352 362 371 374 388 410 414 421 423 441 469 485 488 508 541 594 595 629 638 648] One study found that 13% of orthodontic patients had hypodontia,[476] however, this sample is not representative of the population and the finding may be considered as an outlier.

The main body of data has been collected from European and American Caucasian populations, although

Pathology of the Hard Dental Tissues, First Edition. Albert Schuurs.

some studies have included different ethnic and mixed populations. European and Australian children in general lack more teeth than North American Caucasians.[446] On average two teeth, frequently homologous teeth,[31] per individual are agenetic.[160]

Girls are significantly more susceptible to agenesis than boys,[1 31 47 169 200 219 279 476 485 488 452 566 664] but not all surveys have found a difference between the sexes.[159 374 497 501 574 665] Isolated dental agenesis may, however, occur about 1.4 times more often in girls than boys,[384 446] and agenesis of several teeth is also more common in girls.[210 585 595] In one study, the prevalence of hypodontia in Jewish children did not differ by sex, but girls lacked the maxillary lateral incisors more frequently and the boys the mandibular incisors.[170]

The overall prevalence of agenesis in the maxilla is comparable with that in the mandible, but there is a marked difference in the pattern of absence of tooth type between the jaws.[446] The five teeth most prone to agenesis in order of most to least prevalent, are: third molars > mandibular second premolars > maxillary lateral incisors > maxillary second premolars > mandibular lateral incisors.

However, other rank orders of agenesis of teeth, including teeth other than the ones mentioned above, have also been reported. Specific populations and inclusion of oligodont patients may account for the differences.[446]

Third molars Wisdom teeth are most often implicated in isolated dental agenesis, but the prevalence data vary. In 10–35% of adolescent and young adult dentitions, one to four third molars are absent.[5 33 34 73 129 200 231 234 250 260 255 276 308 412 441 455 511 535 554 594 596] In studies of third molar agenesis, subjects may not be very young since the teeth develop quite late in some individuals,[61 474] and older people may not recollect whether the teeth were extracted.

Third molar agenesis seems race-related.[33 132 260 524 554] For instance, 27% of the white population in the USA versus 2% of East Africans have missing wisdom teeth,[33] and more Chinese lack all four third molars than Caucasians.[132] Women lack wisdom teeth less often than men,[444] but some researchers did not find a sex difference.[346 354]

More so than other teeth, the third molars tends to show bilateral absence.[129 354 554] Almost 10% of subjects also lack other teeth when one or more third molars are agenetic.[73]

Mandibular second premolar Of the four frequently agenetic teeth (excluding third molars), 45% or more[47 466] are second mandibular premolars; they are bilaterally missing in almost half of the population missing these teeth.[574] The reported percentages for lower second premolar agenesis vary considerably, but may be as low as 3.5%. In some studies, the maxillary lateral incisors were the most frequently agenetic,[55 170 410 501 580 638] and in one study it was the mandibular lateral incisors.[131] Such variations in findings might be due to ethnic differences.[444 524] Studies in Caucasians are more likely to show absence of the mandibular second premolar (and maxillary lateral incisor), and Asian studies of the mandibular incisors. A difference between the sexes has not been established.[574]

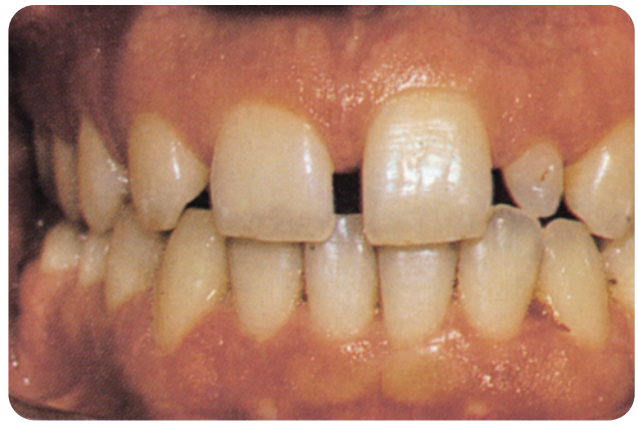


Figure 1.1 Agenetic right permanent maxillary lateral incisor; the contralateral tooth is underdeveloped.

Maxillary lateral incisor A quarter of the four most frequently agenetic teeth (excluding third molars) are the maxillary lateral incisors. In some studies these teeth are reported to be missing even more often than the second mandibular premolars. A meta-analysis showed almost equal rates of agenesis of the maxillary lateral incisors and the maxillary second premolars.[384] In about 2.2% of Caucasians and Israelis the maxillary lateral incisor is absent.[170 580] Bilateral agenesis is common,[446] and the anomaly may be more common in women.[566]

Figure 1.1 shows a congenitally missing right maxillary lateral incisor and an underdeveloped contralateral incisor, which is rarer than bilateral agenesia.[566] The reduced, often conical, morphology may represent an incomplete expression of agenesis.[444]

Maxillary second premolar This tooth accounts for some 20% of the four frequently agenetic teeth, excluding the third molars. The variations in figures may be ascribed to small sample sizes, but the large differences in reported prevalences is substantial and remains unexplained. Bilateral agenesis occurs thrice as often as unilateral agenesis.[444]

Mandibular central incisor In order of frequency of agenesis in the permanent teeth, the mandibular central incisors usually come last, but not in Chinese children in Hong Kong.[131] Occasionally, the lateral incisor has been found to be missing more often than the central. Figures 1.2 and 1.3 show two and four retained deciduous man-

dibular incisors, respectively, due to absence of their successors.

Other teeth Any other tooth may be agenetic, and this is termed "aplasia of atypical elements".[524] For instance, absence of the maxillary first premolar,[159] second molar[47 166 279 410] and the mandibular first premolar has been reported.[47 210] When the first permanent molar does not develop, other teeth tend to be missing too (oligodontia).[230 289 344] The maxillary central incisors are almost always present,[541] the canines being more often agenetic.[524] The condition in which there is presence of just one central incisor is described in Section 1.4.

Aetiology

Agenesis of teeth has been attributed to infectious diseases such as rubella, birth trauma, endocrine disorders, evolution and heredity.[268 572] For instance, one mother and her three daughters all had congenitally missing mandibular incisors, albeit different ones.[415]

Evolution

The relationship between agenesis and evolutionary processes is not clear.

Human teeth are diphyodont (two generation), except the permanent molars, which are monophyodont.[140] The last element of each tooth class (the third molars, second premolars and lateral incisors) is often agenetic or reduced in size. Bolk (1866–1930) therefore proposed the "terminal reduction theory": that is, during evolution, the *distal* element in each tooth class tends to disappear. However, of the four archetypal premolars per quadrant, the third and fourth premolars are present in the dentition of modern humans. The third molars would also have disappeared, but the primary fourth molar became the permanent first molar, accounting for the presence of three molars in modern humans.[524 628] Bolk's theory was eventually rejected but is summarised in Table 1.1, which also illustrates the current point of view.

Bolk also postulated that the teeth lost through evolution occasionally re-emerge in *Homo sapiens*. For instance, the lost lateral incisor reappears as an "additional tooth" between the central incisors (see Section 1.3).

Heredity

Hypodontia is usually a manifestation of an inherited trait (Figure 1.4) although it can occur sporadically, when it represents an acquired anomaly.[619] It is conceivable that certain mutated genes cause hypodontia.[591] Hypodontia

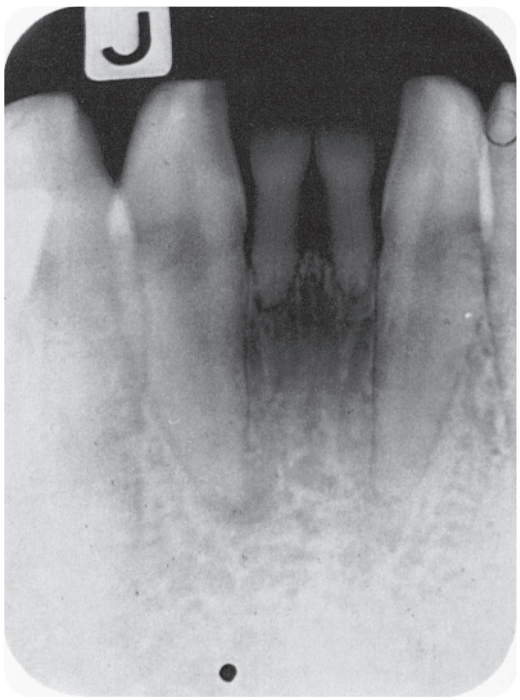


Figure 1.2 Agenetic permanent central incisors – the deciduous teeth are retained.

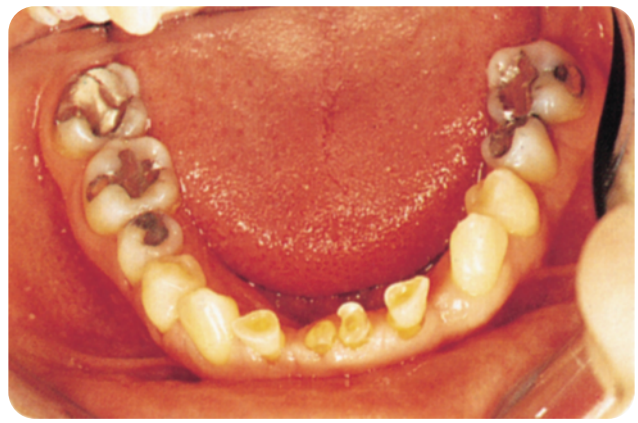
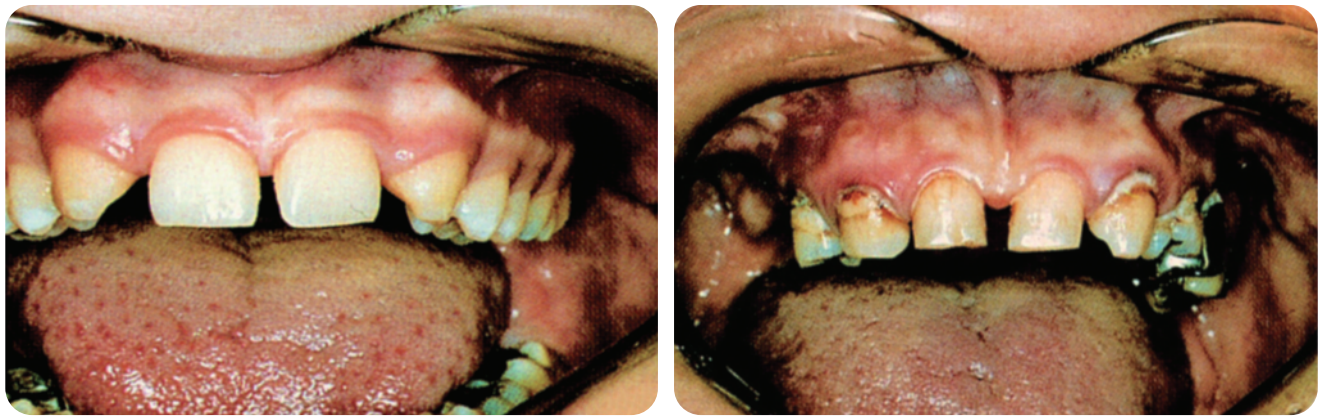


Figure 1.3 Four retained deciduous incisors in the mandible; the permanent successors are agenetic.

Table 1.1 Teeth per quadrant of the archetypal permanent dentition, the teeth remaining in modern humans according to Bolk, and present point of view[628]

Dentition	Incisors			Canines	Premolars and molars						
Archetypal	I_1	I_2	I_3	C	P_1	P_2	P_3	P_4	M_1	M_2	M_3
Human (Bolk)	–	I_2	I_3	C	P_1	P_2	–	m_4 (became M_1)	M_1	M_2	–
Human (the actual condition)	I_1	I_2	–	C	–	–	P_3	P_4	M_1	M_2	M_3



(A) (B)

Figure 1.4 Mother (A) and daughter (B) with agenetic maxillary permanent lateral incisors.

follows an autosomal dominant mode of inheritance, but incomplete penetrance suggests interference of suppressor genes with the phenotypic expression.[92] Research has focused in particular on the maxillary lateral incisors, and, to a lesser degree, the premolars.

- Agenesis of maxillary lateral incisors is an autosomal dominant trait,[19 219 376] but other modes of inheritance have also been reported.[19 284 413]
- Agenesis of premolars is an autosomal dominant trait, with a complete penetrance, but varying expression.[577]
- Agenesis in particular affects the second premolars together with the lateral maxillary incisors, called the "incisor-premolar trait", with a penetrance of 86%.[284]

One study found that mutations in the genes for growth factors, which have a regulatory role during odontogenesis, were not responsible for dental agenesis.[25] Mutations in more than one gene and possibly multiple alleles are needed to explain the variations in dental agenesis.[37 480 488] One proposition is that to become manifest, agenesis must cross a "biological threshold"[110] and penetrance would require altered expression of more than one gene. A statistical analysis[575] in 171 families[185] concluded that hypodontia must be polygenetic.

- The *homeobox genes* regulate migration of the neural crest cells and tooth morphology. Mutations of the muscle-specific homeobox gene, *MSX1*, are linked to autosomal dominant agenesis of specific teeth.[357] Inactivation of *MSX1* has a highly selective effect on the dentition, but other genes must be involved for hypodontia to occur.[516] *MSX1* encodes transcription factors expressed in several tissues including the dental mesenchyme. *MSX1* mutations might be related to agenesis of premolars and molars.[357 626] *MSX1* is located on chromosome 4; the locus of *Notch2* for third molar agenesis has been mapped to chromosome 3 in mice.[422] Multiple genes appear to contribute to interfamilial clinical variations in tooth agenesis.[619] Data on hypodontia fitted a polygenic model better than a single major gene model.[546] Several independent, defective genes acting alone or in combination, and eventually becoming antagonistic, may lead to a specific pattern of phenotypic agenesis.[625]
- Environmental factors are also implicated. Exposure in childhood to dioxin after an accident in a chemical factory (Seveso, Italy) resulted in increased incidence of hypodontia.[9] The association between different cleft types and hypodontia in twins was found to have a weak genetic component,[339] possibly because of the small sample size and the presence of environmental factors.
- Confounding factors also exist. Monozygotic twins, born from one fertilised egg, are in principle, genetically identical, but showed differential expression of hypodontia,[222 315 403] as mirrored agenesis of mandibular second premolars.[345] Regardless of tooth group concordance, mono- and dizygotic twins (born from two fertilised eggs) have similar prevalence rates of bilateral agenetic teeth.[64]

Dizygotic twins are no more similar than siblings. In the past, matched tooth anomalies were used as determinants of di- and monozygosity,[604] but cleavage of the egg can take place in the two-cell stage or later.[521] Monozygotic twins may have an abnormal number of (parts of) chromosomes.[560] Differing chromosomal compositions may exist through gene mutation or post-zygotic (partial) loss of a chromosome in one twin DNA (copy errors), while the other maintains the karyotype of the zygote. It has been established that monozygotic twins show mirror-image tooth anomalies but discordant hypodontia[222 244 312 339 345 403 604] and other dental features.[41 52 99 603 604] Moreover, lyonisation is a possibility in monozygotic female twins.

When multiple teeth are agenetic, associated deviant skeleto-dental patterns, such as a retruded maxilla,[45] have

been hypothesised to be due to environmental effects. Horizontal and vertical pressure on the dental lamina during growth supposedly suppresses or distorts the tooth buds, likely affecting the last tooth in each tooth class.[397] One study concluded that in orthodontic patients, the frequency of maxillary and mandibular third molar agenesis is related to a decreased anterior–posterior dimension of solely the maxilla.[299]

Relationships between teeth

In isolated dental agenesis, the teeth that are present show smaller crowns, a "tendency" to agenesis.[308 524] A peg maxillary lateral incisor is also associated with non-eruption and a palatally erupted canine.[439 440]

- Agenesis of the maxillary lateral incisors increases the probability of other teeth being agenetic.[349] The same applies to an increasing number of agenetic wisdom teeth.[5 201 439 511 554 574] Such relationships are not always present,[319] and the reverse has also been reported.[491 532]
- When the wisdom teeth are agenetic, the anterior teeth in particular may be relatively small, but such findings are not consistent.[38 199 497 648]
- Agenesis of the maxillary lateral incisor seems to be compensated by a larger adjacent central incisor. When the lateral incisor is undersized, this compensation is not seen; in fact the adjacent central incisor also tends to be relatively small.[550]
- Agenetic wisdom teeth (in the Inuit) were not found to be associated with a reduced occlusal pattern of the other molars.[249]
- In at least 50% of patients with a missing deciduous lateral incisor, the successor is agenetic,[72 220 290 372 469] and if bilaterally absent, more permanent teeth may be agenetic, such as the rarely involved first and second molars.[133]

A division of mandibular tooth agenesis into three groups has been suggested, based on the radiological evidence of the mandibular canal. In the anterior part of maxillary jaw, a pronounced lack of teeth was found to be associated with absence or marked reduction in the size of the incisive foramen and nasopalatine canal.[320 532]

Tooth germ-related causes

For dental agenesis, a tooth germ must be affected during its earliest developmental stages. Likely causes are failure of mesenchyme condensation during the initiation of the tooth bud stage, absence of induction of the subsequent ectodermal reactions and an inability of the ameloblasts to produce enamel following reciprocal induction by the odontoblasts. On combining these tissues *in vitro*, there was development of tooth-like structures.[543] In experimental studies, the formation of the dental papilla was induced in the mandibular epithelial lamina through its contact with non-odontogenic mesenchyme.[401]

Odontogenesis is initiated in the epithelium and is guided by interactions with the neural crest cells.[529 593] Regulation of normal tooth development requires proteins produced by a number of genes for the series of reciprocal interactions between the dental epithelium and mesenchymal condensations, which are accumulations of proliferating cells originating from the neural tube. Some of these cells are pluripotent;[77] their absence is related to non-initiation of the tooth germ.[390 542]

The specific morphology of the teeth is also influenced by the cell condenstations.[390] Butler's "field theory" states that all tooth primordia are initially equivalent and that the morphology of the teeth is determined by morphogenes in the antero–posterior axis.[93] Molecular investigations have identified single genes (such as the homeobox genes) with site-specific antero–posterior activity. A defective specific gene has been found to be associated with agenesis of specific posterior teeth, but not the anterior teeth. The developing maxillary dentition is not continuous: the upper incisors develop in the medial nasal processes of the first arch,[114] in the premaxilla.

The hypothesis that tooth agenesis is associated with prenatal brainstem anomalies has not been confirmed: the frequency of agenesis in such patients and the population was similar.[358]

Early disruption of the developmental processes is most probably a result of lack of (reciprocal) signals at the right time,[618] due to mutations in genes or an inability of the cells to respond appropriately.

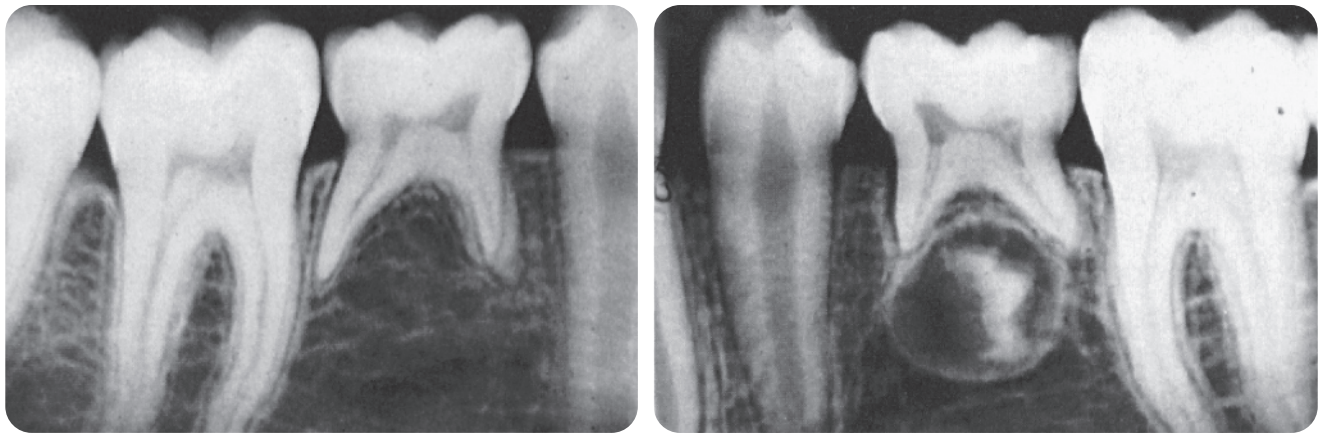
Other causes

Dental development may be interrupted by diseases such as leprosy or the presence of congenital anomalies involving atrophy or disordered development of the anterior part of the maxilla. Figure 1.5 shows absence of a mandibular second premolar and arrested development of the contralateral tooth.

Ionising radiation (radiotherapy) can cause agenesis (and morphologic changes)[161] in humans[240 217 387 505] and animals[84 85] Just one treatment with 15 Gy leads to a temporary interruption in odontogenesis.[240 565] After *chemotherapy*, children showed marked tooth agenesis.[16]

Segmental odontomaxillary dysplasia is another condition with agenesis of one or both premolars in the affected jaw segment. The disorder consists of a unilateral maxillary enlargement from the canine region to the tuberosity, accompanied by gingival hyperplasia. Superiorly the enlargement occurs at the cost of the maxillary sinus. The spaced deciduous molars may be malformed, with splayed roots and pulp stones in enlarged pulp chambers. If the skin on the affected side contains more sweat glands than normal, the anomaly is called *hemimaxillofacial dysplasia*. The cause of the disorder is not known.[42 123 162 433 459 622 637]

Cutaneous abnormalities, such as "hairy nevus" of the skin and hypopigmentation of the lip border, are less frequently observed.[459 637] The anomalies originate *in utero* or in early childhood. Less common features are enlarged crowns and roots.[42 433] The condition seems to remain stable without significant progression.[123]



(A) (B)

Figure 1.5 (A) Agenetic lower second premolar with retained deciduous second molar. (B) The development of the contralateral premolar is arrested.

Consequences

Consequences of isolated dental agenesis depend on the permanent tooth that is missing.

- When a permanent maxillary lateral incisor is agenetic, the predecessor will exfoliate, because the broad crown of the erupting permanent central incisor initiates and maintains the resorption of the roots of both the deciduous central and lateral incisors (Figure 1.4). The permanent canine frequently erupts partly mesially, and occasionally at the site of the lateral incisor, while the deciduous canines remain *in situ*.[138]
- If the mandibular central incisors are absent, the predecessors persist and may be functional for a long time.
- When the mandibular premolars are missing, the deciduous second molars are usually retained (Figure 1.5)[488] as root resorption is not initiated. In the maxilla, the deciduous second molar may exfoliate (due to resorption influenced by the first molar), but not as a rule.

A retained deciduous molar may function for many years, but undergoes wear and physiological changes, such as a reduction in the size of the pulp chamber and hypercementosis (Chapter 8).[506] Excessive wear or caries may lead to extraction. Another complication is infra-occlusion (Chapter 4), in which the occlusal surface of the retained tooth stays below the level of the occlusal plane, as the adjacent teeth continue to erupt. In 19–20-year-olds, more than half of the retained deciduous second molars showed 0.5–4.5 mm infra-occlusion.[53] The mesiodistal width of the retained tooth exceeds that of the missing mandibular second premolar, which causes a slight malocclusion.[53] After late extraction, there is tilting and migration of the neighbouring teeth and overeruption of the antagonist tooth, but this is minimal if the occlusion was stable to begin with.

An early diagnosis of premolar agenesis may be incorrect because these teeth may have delayed development.[12 117 393 648] In 6-year-olds, it is possible not to detect any trace of second mandibular premolar development[120] because initiation of calcification of mandibular second premolars may not start before the age of 9 years.[127]

Agenesis of wisdom teeth is often welcome, because a lack of space within the jaws may inhibit their eruption, causing secondary pathology (Chapter 4). A normal molar relationship (Class I) is observed in these cases.[151] Permanent teeth may erupt prematurely when the deciduous predecessors are agenetic.[464] Isolated dental agenesis may lead to malocclusion, but dentofacial deviations are mostly minor.[656] The alveolar process may be underdeveloped locally. In one study, patients lacking four or more teeth were found to have a smaller cranial base, a shorter maxillary length, a slightly prognathic mandible with anticlockwise rotation, and retroclination of the maxillary incisors.[172]

Prevention and treatment

Isolated agenesis in the deciduous dentition does not require treatment, but it is prudent to consider taking radiographs of the patient and their siblings, for counselling and timely treatment of agenetic permanent teeth.

Deciduous molars without successors must be extracted[214] at a young age,[395] taking into account the relationships between the maxillary and mandibular teeth. Early extraction allows the permanent first molar to move mesially spontaneously without excessive tilting, filling most of the extraction site. Spontaneous space closure occurs if the deciduous mandibular molar is extracted before the root of the mandibular first molar is completed and before the second molar erupts.[359] Deciduous second molar extraction at 10–13 years in dentitions with a normal occlusion was found to result in a diastema,

which half closed within 1 year by the tilting and migration of the adjacent premolars and canines, and, in particular, mesial tilting of the first mandibular molars. The closure was enhanced by the displacement of the maxillary first molar due to growth in a downward direction.[375 431] Two years later, 10% of maxillary and 20% of mandibular diastemata remained. In contrast with the mandible, a maxillary unilateral extraction did not result in a shift of midline.[375] The local width of the maxillary and mandibular alveolar arches decreases considerably after extraction.[431]

An unstable situation requires orthodontic closure of a diastema. Care must be taken that the anterior teeth do not tip lingually.[631] If the contralateral premolar is present, its extraction must be considered. An alternative approach is space maintenance, followed by the placement of an implant or a bridge. Long-term implant survival is around 90%, independent of its location.[167] Timing of implant placement depends on vertical alveolar growth, which continues beyond puberty: an implant-supported prosthesis inserted in adolescence will eventually become infraoccluded. Sometimes it is possible to transplant a tooth (Chapter 7) that must be extracted for orthodontic reasons into the site of an agenetic tooth.[340]

Extraction of retained deciduous molars in adulthood necessitates insertion of implants or bridges for function and aesthetics. However, deciduous second molars that are lacking successors and are retained into adulthood remain functional for a long time.[545] In one study, only a few retained second deciduous mandibular molars were lost because of caries or periodontal breakdown at the age of 48 years;[545] in a minority of cases root resorption of the deciduous molar will be a problem.[364 666]

- A patient with agenesis of the permanent maxillary lateral incisors requires orthodontic space closure. In contrast with replacement with partial dentures, moving the permanent canines into contact with the central incisors (Figures 1.6 and 1.7) resulted in a healthier periodontium 7–10 years later[424] and greater patient satisfaction.[482] Restorative reshaping of such canines with composite creates a cosmetically acceptable emergent incisor profile on the canine.[490] If not treated orthodontically, a rather wide diastema will remain. Space maintenance is required to close the diastema with an adequate implant[546] or bridge after cessation of the (rapid) alveolar growth. The use of osseointegrated implants in children is problematic for reasons of jaw growth, but is presently under consideration.[643]
- When the permanent central mandibular incisors are absent, extraction of the predecessors is not indicated. An acceptable prosthetic solution after natural loss of the long-persisting deciduous teeth will require maintenance of the diastema.[180]

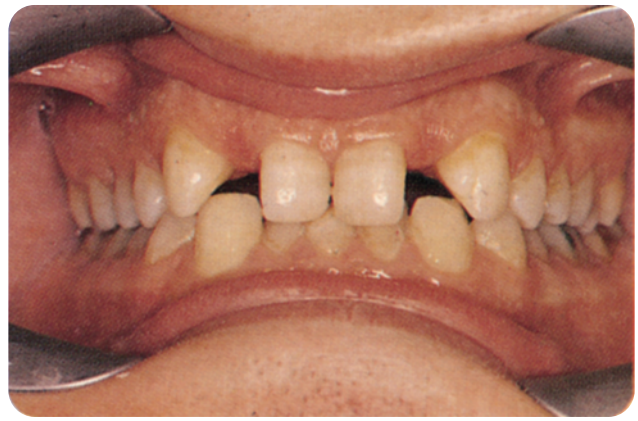


Figure 1.6 Patient with missing maxillary lateral incisors.

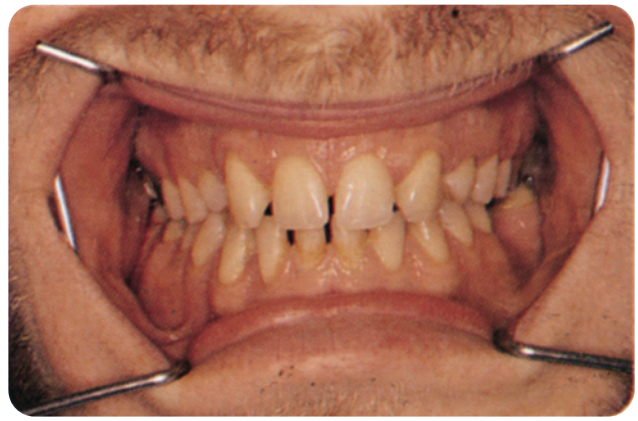


Figure 1.7 The canines of the patient in Figure 1.6 have been moved orthodontically into the locations of the agenetic maxillary lateral incisors. The morphology of the canines may be improved by grinding the cusps and building the lateral margins with composite so that the teeth resemble lateral incisors. Note the presence of only three lower incisors.

1.2.2 Oligodontia

The term *oligodontia* has been defined by various authors as the absence of either four or six and more or eight and more teeth, excluding agenesis of third molars.[263 468 648 664] Oligodontia has diverse presentations. Some patients lack many posterior teeth and others lack anterior teeth.[468] The pattern of missing teeth is often bilaterally symmetrical. The frequency of oligodontia is low: about 0.1–0.5% people have seven to eight missing teeth.[1 47 219 371 485 541 594 664]

Oligodontia occurs either sporadically in just one individual[26 559] or it may be inherited without other anomalies.[583] It commonly occurs in association with Down's syndrome (trisomy 21[116]) and syndromes in which the epithelium or its derivatives are involved, such as ectodermal dysplasia with abnormal hair, nails and sweat glands (Chapter 11). When a larger number of teeth are missing

or more "stable" elements, especially the maxillary central incisors,[468] are absent, the presence of a syndrome should be suspected. Conversely, three or more (inherited) skin conditions require investigating for dental agenesis,[517 518] but absence of "stable" teeth is not inevitably a sign of a general disorder.[572]

In *cherubism*, a hereditary (autosomal recessive?) painless disorder with oligodontia, the middle and lower part of the face become progressively more and more rounded.[335] The cherubic appearance may be enhanced by skin stretching and downward pulling of the lower eyelids, causing an upward directed look.[153 467 616]

In *microsomia I*, agenesis and delayed maturation of teeth is related to the severity of the disorder. It affects the face unilaterally, with underdevelopment of the mandibular ramus and adjacent soft tissues, possibly caused by a vascular lesion of the first and second branchial arches.[113 175]

Hall (1983) mentions 34 syndromes and a number of clefts with isolated dental agenesis or oligodontia,[235] but the number is at least 120.[660]

In one study, some 60% of oligodontia patients had ectodermal dysplasia; the other 40% had intermediate severity eczema and asthma, and some experienced hyposalivation.[423] "Isolated" oligodontia patients had fewer sweat glands than controls.[218] Oligodontia (Figure 1.8) is, moreover, characterised by reduced tooth size[423] and morphology (conical crowns, short roots), [11 317] and underdevelopment of the alveolar processes.[80 222 317 480] The face tends to resemble that of an edentulous person, with protrusion of the mandible and pouting lower lip, and often a decrease in vertical dimension.

Heredity

Analysis of family trees suggests an autosomal dominant inheritance pattern in more than half of oligodontia patients.[187 213 517 572] Different mutations of the *PAX9* gene encoding the PAX9 protein appear to be associated with specific oligodontia patterns, but other genes are most probably involved in specific combinations of multiple missing teeth. *PAX9* is expressed in the neural-crest-derived mesenchyme of the mandibular and maxillary arches. *MSX1* has been found to be associated with agenetic second premolars and third molars, but *PAX9*, on chromosome 14,[186] was associated with missing first and second molars.[327] A mutation in *MSX1* was found to be unlikely in family members who, to various degrees, had missing first, second and third molars, premolars and mandibular incisors.[213]

A *PAX9 nonsense mutation* changes a chain-termination codon from one that specifies an amino acid into one that does not,[633] which results in incomplete protein synthesis and oligodontia.[417] A *de novo deletion* of the proximal long arm at chromosome 14 resulted in developmental defects, but oligodontia was not mentioned in the report.[522] A deletion involving the *PAX9* locus was observed in a proband with absence of most deciduous and permanent teeth. A *frame-shift mutation* in *PAX9*[126] encodes an abnormal protein or disrupts the synthesis of the protein completely.[633] Identical twins have been found to have a frame-shift mutation and a premature stop codon.[125] A *missense mutation* in the *PAX9* gene was found in a family with a distinct oligodontia type.[342] The mutation changes a codon specific for one amino acid into a codon specific for another amino acid (an arginine to tryptophan change),[342] but the new protein maintains some biological activity.[633] Another oligodontia patient had a heterozygous missense mutation in the paired domain of *PAX9*: arginine was substituted by praline;[297] other substitutions also exist. *Allelic heterogeneity* in *PAX9* was found to be responsible for the autosomal dominant molar agenesis in one kindred, but in other families with a similar pattern of missing molars *PAX9* did not appear to be mutated.[187] A *de novo* mutation in *PAX9* has been confirmed in a patient with oligodontia. Other patients with oligodontia had no mutations in the coding regions of either *PAX9* or *MSX1*, indicating different genes must be responsible.[409]

Mutations of *PAX9* are associated with varying oligodontia patterns in the deciduous and permanent dentition, and missense mutations affect only the permanent dentition.[297] *MSXI* mutations have been found to be linked to isolated hypodontia and seldom to oligodontia.[150] *MSX1*, *PAX9* and *FGFA* (expressed during craniofacial development) have been suggested to interact and to play a role in non-syndromic tooth agenesis.[626] Recently, mutations in *AXIN2* have been found to cause severe oligodontia and a predisposition to colorectal cancer.[341] It has been concluded that oligodontia and anodontia are determined polygenetically.[80]

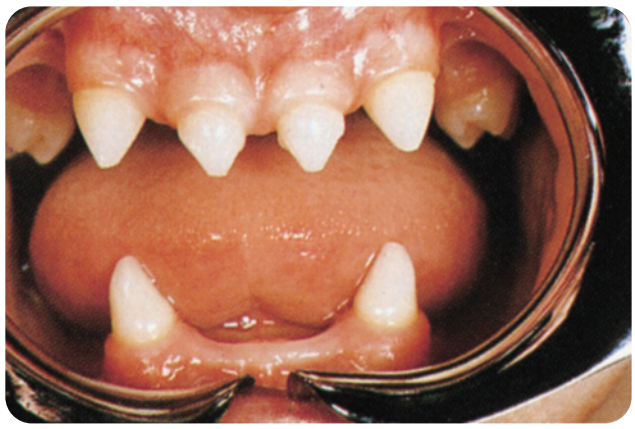


Figure 1.8 Oligodont dentition with hypoplastic and conical teeth. (Courtesy of Department of Oral Surgery, University of Groningen.)

1.2.3 Anodontia

Anodontia is the rare congenital absence of all teeth, that occurs in serious, often fatal, syndromes. Anodontia is also reported as a representation of a homozygous state (autosomal recessive) of the gene responsible for peg or missing lateral incisors in heterozygotes. The deciduous

dentition is not affected and no associated anomalies have been noted.[428]

Treatment of oligodontia and anodontia

Partial or full (over)dentures[165 460 548 644] with increase of the vertical dimension,[63] and implants and bridges are indicated for maintenance of the functional space and occlusion.[96] Because failure of an implant used as an abutment for a bridge may result in the loss of large amounts of bone, orthodontic realignment of the teeth, if present and possible, might be preferred,[630] but is troublesome.[280]

Due to psychosocial effects, anodontia and oligodontia in young children should be treated.[489 548] Extraction of retained[264 471] deciduous teeth must be delayed as long as possible.[632] Siblings must be examined for similar anomalies.[567]

1.3 Hyperdontia

Hyperdontia (or *hyperodontia*) denotes the presence of one or more extra teeth, that is a dentition with more than the 20 deciduous and/or 32 permanent teeth; the extra teeth may be morphologically similar to or dissimilar in size or shape compared with the normal teeth. The additional teeth occur singly, multiply and uni- or bilaterally. Their morphology may be similar to that of normal teeth (*eumorphic*), allowing recognition as a specific tooth. Such teeth are also called *supplemental* (or *supplementary*) teeth.[457] Other additional teeth are *atypical* or *dysmorphic*, rudimentary in size and form, with a peg-shaped crown or a reduced multi-cusp crown, and are alternatively called *supernumerary teeth*. Unerupted extra teeth within the jaws may be detected incidentally on radiographs, but a disturbed eruption pattern of the regular adjacent teeth may provide a clue.[178]

Extra teeth resemble odontomas to a certain degree. Odontomas belong to the group of benign odontogenic tumours and consist of epithelial and mesenchymal tissues. *Complex odontomes* are composed of dental hard tissues in a state of disarray and *compound odontomes* are tooth-like structures.[76 434 601]

Compound odontomes are more common than complex ones,[305] but several large studies did not find a significant difference.[579 601] Of 19 000 oral pathological conditions, 0.5% were odontomas.[432 601] and in another study, one-third of 349 odontogenic tumours were odontomas.[408]

The rare *ameloblastic fibro-odontoma* is thought to be a third type of odontoma, but may be a predecessor of the other odontomas. In *ameloblastic fibroma,* there is uncontrolled growth of epithelial and mesenchymal tissue, but without formation of real enamel. Dentine or enamel and dentine may be formed in the *ameloblastic fibro-dentinoma*.[617]

It has been questioned whether odontomes and hyperdontia are fundamentally different.[272] The term "odontoid structures" may therefore be preferrable.[257]

About half of odontomes are associated with unerupted teeth.[306] The argument that odontomes and hyperdontia are identical is weak. A relative difference is the age at which they develop. Odontomes develop at any age whereas in hyperdontia, the extra teeth rarely develop late.[210 452 456] Moreover, odontomes continuously increase in size.[368]

Teratomas are neoplasms made up of different types of tissue not belonging to the body part in which they develop. Benign tumours in the ovary contained one to nine elements resembling canines and premolars and amorphous teeth, which are randomly distributed.[155 373] As yet unexplained is why teeth developing side by side are morphologically of different tooth class/type.[123] It has been concluded that the morphology of these teeth is genetically determined independently from each other.[93]

1.3.1 Hypodontia with hyperdontia

Concomitant hypodontia and hyperdontia[31 100 159 177 206 421 501 538 561 627 638] occurs in 0.5% of the dentitions.[206] It has also been found to occur in children with conditions such as cleft lip or palate.[465]

Epidemiology

Hyperdontia is less common than hypodontia.

Primary dentition

Four radiographs are sufficient to detect hypodontia-hyperdontia in 2–6-year-olds.[495] Hyperdontia affects 0.5–1% of the deciduous dentition, but, interestingly, up to 3% are affected in many Asian populations.[60 94 158 112 169 194 257 278 283 300] The late development of additional teeth may be the reason that they do not occur in the deciduous dentition,[634] but they might not have been observed or could have been extracted prior to the patient being enrolled in a study.[278] Parents may overlook a eumorphic extra deciduous tooth, often an incisor, because the interdental spaces that are common between the deciduous anterior teeth allow good alignment teeth in spite of hyperdontia. Conical (peg-shaped) deciduous supernumeraries have also been observed.

Permanent dentition

The prevalence of extra permanent teeth is 0.5% to about 3% in different populations, with a few populations showing higher prevalence, for instance 10% in an isolated population in Alaska.[31 47 60 89 94 101 112 131 159 169 194 220 231 257 275 281 282 283 300 352 362 366 388 441 469 508 564 594 638] The varying prevalence may due to ethnic differences, age, use of radiographs, forgotten extraction of extra teeth, sample selection, etc. On average one extra tooth is present,[160] but more than one is present in a third to over 40% of patients.[174 361 379 463]

Ten per cent of dogs show hyperdontia, some breeds less frequently (huskies 2%) and others more often (spaniels 19%).[245]

Location

Extra teeth are classified based on their morphology and the tooth type which they resemble.[515] The two-digit FDI tooth identification system has been extended to a three-digit one in order to include hyperdontia.[337]

Three-quarters to more than 90% of extra teeth are found in the maxillary anterior region.[101 316 328 463] It is noteworthy that a third of the odontomes are situated in the premaxilla, twice as often in Caucasians as in people of African descent.[248 249] Another preferred region is the mandibular premolar region; only a quarter of the supernumerary premolars occur in the maxilla.[551] The third preferred region is the retromolar region. It is not clear in which of the two latter regions hyperdontia is more common.[519]

Multiple hyperdontia is rare,[149 209 302 444 353 463 496 564] unless a syndrome is present,[519] and is more likely to present in patients with relatives possessing supernumeraries. There are several reports of familial localised juvenile periodontitis occurring in association with multiple extra teeth.[426]

Sex, ethnicity

Males show hyperdontia twice as often as females[47 60 94 112 169 257 278 283 300 381 463 469 662] but a lower sex ratio has also been reported.[469] Extra premolars occur three times more commonly in males than females,[361 551] as does the maxillary mesiodens.[174] Higher sex ratios, up to 6.5:1 in children in Hong Kong[131] have been reported, as well as in some other Asian populations.[313 361 507] A difference between the sexes has not always been found,[220 366 388] and is absent in the deciduous dentition.[469] One paper reported a female predilection.[31]

Hyperdontia might be an ethnic trait, being less common in Caucasian than in Asian populations.[131 421 507] In Nigerians, extra anterior teeth are most probably rare.[484] Maxillary mesiodens are twice as common in Hispano-Mexicans than in Caucasians.[300] About 3% of Japanese and Hong Kong Chinese have mesiodens[131 421] whereas a prevalence of 0.4% was reported in a Finnish population.[290]

Syndromes

Hyperdontia is part of some syndromes (Chapter 11). Rare syndromes with hyperdontia, such as the Nance–Horan syndrome,[660] are not discussed in this book.

Non-syndromic multiple supernumeraries

Some 40 articles have reported cases with five or more non-syndromic extra teeth;[524 657] there are also a few reports of hyperdontia with up to 22 extra teeth.[478 549] Multiple hyperdontia occurs most frequently in the mandible,[656 667] predominantly in the premolar region, followed by the molar and anterior region.[657] Non-syndromic hyperdontia may be familial.[668]

Time of development

Extra incisors may develop simultaneously with the regular teeth in both dentitions,[563 651] but usually late, particularly extra premolars.[6 104 115 207 249 318 329 382 389 406 456 467 493 563 537 634 661] The development of extra premolars may lag 5–10 years behind the normal ones,[104 207 329] but they may develop more rapidly. A barely visible semicircular radiolucent band was noted to develop into an almost complete extra premolar within 9 months.[351] Five extra premolars, situated at the apices of adjacent teeth in two 13-year-olds were partially developed.[329 537] In addition, the regular first premolars may be located apically to extra ones.[302]

1.3.2 Supernumerary permanent teeth

Atypical extra teeth, sometimes called *rudimentary teeth*, are commonly peg-shaped; tuberculate (multiple cusps) forms may be barrel-shaped and invaginated. Examples are *mesiodens, distomolar* and *paramolar*. Other supernumerary teeth reported are, for instance, a rudimentary tooth germ of a lower canine in a girl with hyperdontia of the incisors.[31]

Mesiodens

The mesiodens is usually located between the maxillary central incisors; however, mandibular mesiodens also occur.[135 146 336] In cases of anterior (premaxillary) hyperdontia, the majority (75%) of teeth are conical in shape and around two-thirds are found in the central incisor region.[460] Tuberculate mesiodens are more incidentally reported.[251 379]

Mesiodens, the most common supernumerary tooth, may nor may not be conical in shape, and more than one mesiodens may occur in the same patient [184 313 413 348 396] Up to about 75% of mesiodens lie in an inverted position,[174 257 313 463 580] and a few have a transverse orientation.[463] Further, 50–75% fail to erupt,[300 460 463 662] due to their or inverted[174] position. A conical mesiodens is more likely to erupt (Table 1.2) than a tuberculate one.[185 251]

Table 1.2 Characteristics of conical and tuberculate supernumerary teeth[251]

Conical	Tuberculate
Usually erupt between the maxillary central incisors	Commonly sited palatal to the upper centrals
Erupt commonly during childhood	Erupt rarely in childhood
Roots complete before neighbouring teeth	Incomplete roots
	Develop later than conical teeth
Rarely delay the eruption of neighbouring teeth	Often delay eruption of neighbouring teeth
May displace neighbouring teeth	May displace neighbouring teeth

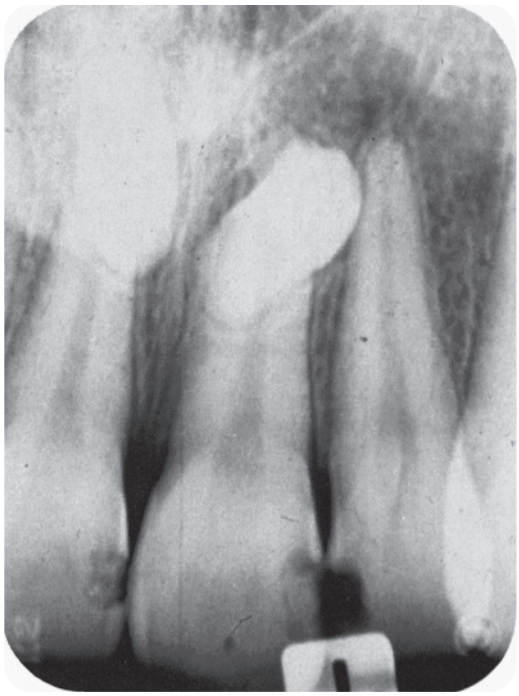


Figure 1.9 Two mesiodentes in the apical region of the permanent maxillary central incisors. They will not erupt because of their inverted direction.

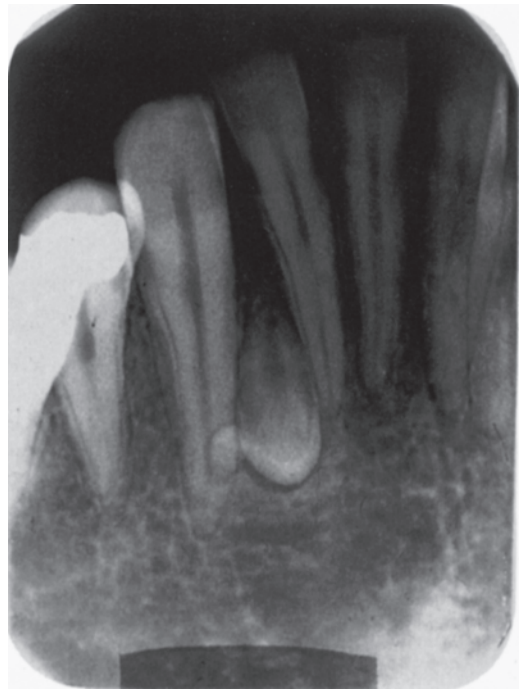


Figure 1.11 Inverted atypical extra tooth in the mandible. The small radiopacity visible on the root of the canine increased over time and resembled a late developing atypical extra tooth.

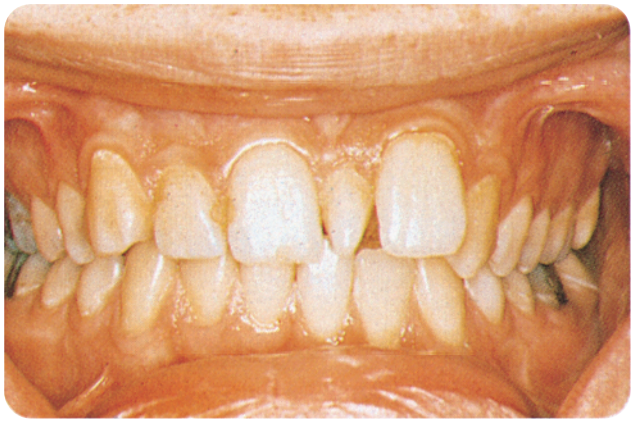


Figure 1.10 A mesiodens between the maxillary permanent central incisors.

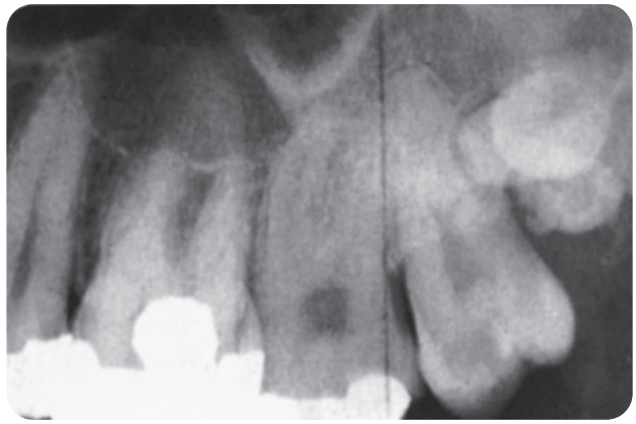


Figure 1.12 Distomolar situated behind the third maxillary molar.

Figure 1.9 shows two retained mesiodens, Figure 1.10 an erupted mesiodens, and Figure 1.11 an inverted mandibular supernumerary tooth.

Mesiodens may possess irregular enamel rods and dentinal tubules and contains more calcium and phosphate than the average tooth.[326]

Distomolar

The distomolar, typically situated distal to the third molar, is probably the second most commonly occurring atypical extra tooth (Figure 1.12). A quarter of 500 extra teeth were found to be distomolars, commonly with conical crowns. The more differentiated ones were smaller than their counterparts.[564] An atypical fifth molar with a few cusps has also been reported.[331]

Paramolar

The paramolar (*dens paramolaris*), an atypical extra tooth, may be attached (Figure 1.13) to the mesio-buccal surface of the second or third molar and sometimes the

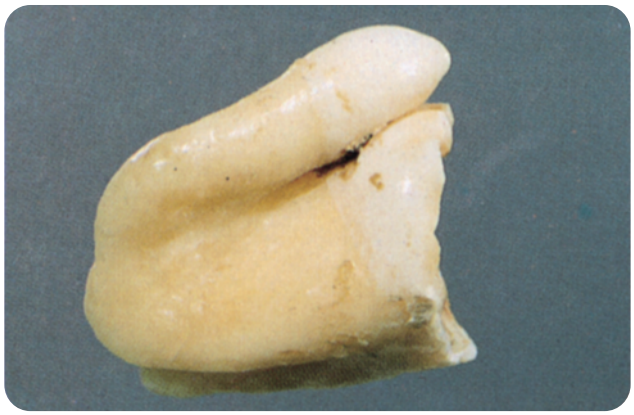


Figure 1.13 Paramolar (root and crown) attached to a decayed permanent second lower molar.

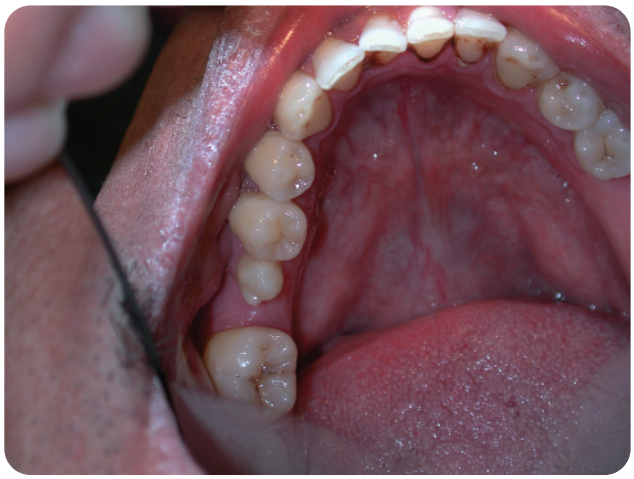


Figure 1.14 Paramolar or an atypical third premolar in the maxilla. (Courtesy of J.P. Nolte.)

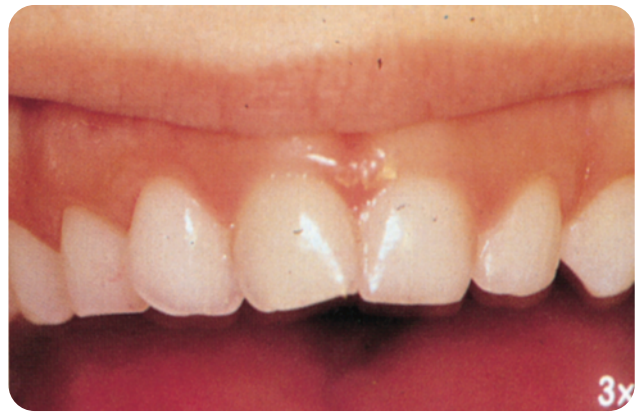


Figure 1.15 Supplemental incisor in the right upper quadrant.

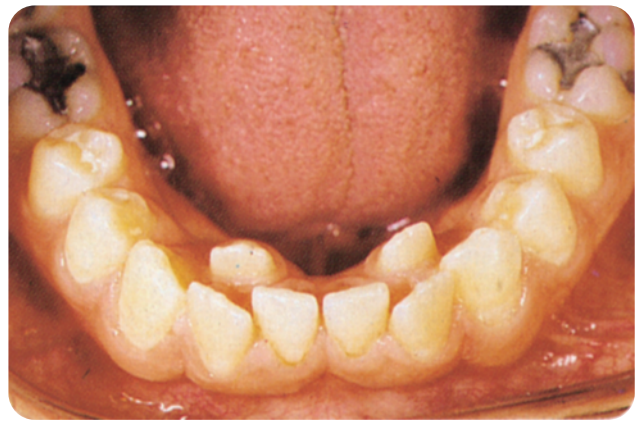


Figure 1.16 Two supplemental teeth in the mandible.

first permanent molar.[628] The tooth may manifest just as a cusp and/or a root (Chapter 2). When occurring as a separate entity, the paramolar may be situated next to, between (Figure 1.14) or possibly behind the molars. The distomolar may be a paramolar.

Among 500 extra teeth in one study, 11% were noted to be paramolars, a substantial number having multiple cusps.[564] Some 0.1% of the population possess one or more paramolars.[309 564]

1.3.3 Supplemental permanent teeth

The dentition may include extra teeth with recognisable forms: (lateral) maxillary incisors, mandibular incisors, third premolars, and fourth and sometimes fifth molars. Supplemental canines are rare.

Incisors

Among 500 extra teeth in one study, 45% were supplemental maxillary incisors,[564] commonly resembling a lateral incisor (Figure 1.15).[483 564] A minority manage to erupt.[564] Among six maxillary incisors in a patient, one was a mesiodens, the other an extra lateral incisor.[624] Supplemental maxillary "lateral incisors" might be more common than mesiodens, followed by extra central incisors and then premolars,[366] but other frequency distributions have also been reported.[537]

Supplemental mandibular incisors (Figure 1.16) are not easily identified as first or second:[17 585] they are rare, especially lateral ones.[17] In the mandibular incisor area, 2% of the extra teeth are eumorphic.[102 564]

A supernumerary maxillary lateral incisor was present in adult *Australopithecus robustus*, living 1.7 million years ago.[477] Two eumorphic extra teeth were reported in the anterior mandible.[192] Early extraction of a temporary canine next to an extra lower incisor can enable the latter to erupt.[118]

Premolars

Premolars comprise around 10% of all extra teeth (0.08% of 48 550 patients,[564] although the numbers may be much higher[493]) (Figure 1.17); the majority are mandibular and

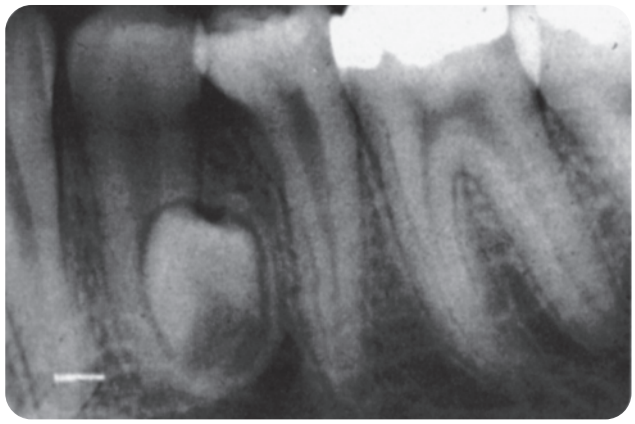


Figure 1.17 Late developing supplemental mandibular premolar.

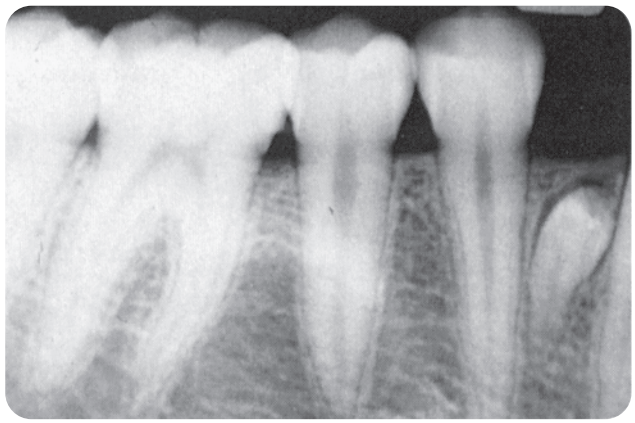


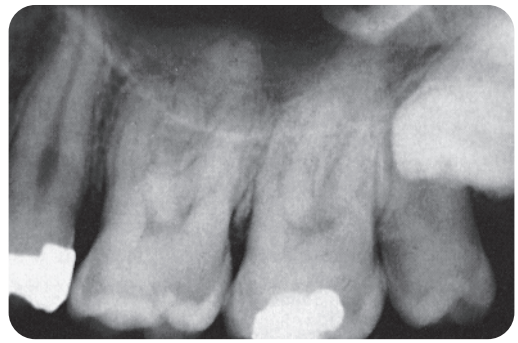
Figure 1.18 Extra premolar considered to be atypical because of its small size.

often occur bilaterally. An extra premolar present at an early age increases the probability of developing more supernumerary premolars later; in one study, after removal of the extra premolar, a new one developed in 8% of the cases.[551]

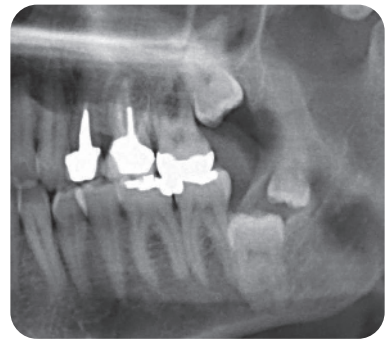
Extra premolars are commonly supplemental,[36 68 168 239 253 393 406 452 456 467 479 536 663 655] but the tooth in Figure 1.18 should be classified as atypical. They may erupt, often lingual to the dental arch, and three-quarters are retained.[406]

Fourth molars

Having a fourth molar is not uncommon and fifth molars also occur.[444] One patient had seven "third" molars.[4] Bilateral maxillary and mandibular fourth molars and one fifth molar, and even three extra molars at one site have been observed.[642] Among 500 extra teeth, 25% were supplemental maxillary fourth molars, most of them unerupted.[564] In a study of 5000 military recruits, 14 had atypical or eumorphic fourth molars.[228] Eumorphic maxillary fourth molars are often smaller than the third molars, but the one seen in Figure 1.19A was larger than the accompanying third molar. In the mandible, fourth and third molars are of equal size (Figure 1.19B).



(A)



(B)

Figure 1.19 (A) A supplemental (fourth) molar. (B) Inverted eumorphic fourth molar in the ramus of the mandible.

Canines

Additional permanent canines have been described a few times,[24 293 513 564 570] but extra deciduous canines seem rare.[413]

Eruption issues related to hyperdontia

in some patients with hyperdontia, the teeth erupt far from the dental arch, such as within the maxillary sinus.[215] Extra teeth may also migrate to a different location after development (such as the fourth molar in Figure 1.19B?).

Aetiology

Various hypotheses have been proposed to explain the aetiology of hyperdontia. As yet, nothing can be concluded with certainty. Of patients with mesiodens, one-third showed a familial disposition. It may be worth mentioning that a permanent mesiodens has been found at the same side as a deciduous double tooth.[568]

Early splitting (dichotomisation) of the tooth germ into two buds produces two teeth (Section 1.4)[361] or a localised, independent hyperactivity of the dental lamina.[338 361 457] An extension of the dental lamina leads

to formation of a supplemental tooth, whereas proliferation of the epithelial remnants of the lamina results in a supernumerary tooth.[457]

Phylogenetically speaking (phylogenetics is the science dealing with the evolutionary development of higher classes of animals from lower classes), the theory of splitting of teeth versus fusion of several tooth generations has had its adherents (Section 1.4). Arguments against phylogenetic fusion and splitting are based on embryology, fossil studies and comparative studies of the dentitions of animals. Supernumerary teeth would not be atavisms, because such evolutionary throwbacks occur predominantly in isolation instead of bilaterally, and with ectopic eruption.[457] Trauma, such as a jaw fracture, is an unlikely cause. Observations in animals lead to the supposition that a moderate or large outgrowth of the clone mass would lead to the development of an atypical or eumorphic fourth molar, respectively. An extra tooth could develop from a mesially extended anterior mass, but lack of mitotic activity would generally suppress its development.[527]

In animal experiments, it appeared possible to grow supernumerary teeth. Transplantation of the germs of the second and third molar into the eye of homologous animals developed in some cases into three molars.[311] Embryological ectoderm from regions other than the jaws assumed a bell shape when cells from the neural tube were added.[634]

Heredity

In view of a racial predisposition,[194 275 300 523] familial tendencies,[15 194 379 395 396 494 524 530 563] and gender predilection, heredity has once again been ascribed an aetiological role. Monozygotic twins have been found to have a concordant number of supernumerary tooth buds.[343] In a family with multigenerational consanguineous (next of kin) marriages, four individuals displayed five mandibular incisors,[102] two of which where fused to other teeth (Section 1.4).

Mutant genes appear to be a highly probable cause. Several inheritance modes are mentioned in the literature.[463] Whether the trait is autosomal dominant with eventual restricted or recessive penetrance needs further clarification. The higher frequency of extra permanent teeth in males has been attributed to an autosomal recessive gene with less penetrance in females.[421] The inheritance pattern deviates from a simple Mendelian pattern.[519] Supernumerary teeth as an isolated phenomenon may have a polygenic origin.[288]

Morphology

Knowledge about the determination of morphology in hyperdontia is increasing. Factors such as the location, cells originating from the neural crest, receptors, available space etc. play a role in determining the morphology in hyperdontia.

The tooth shape in mammals is possibly dictated by (1) a continuous shape-determining gradient from anterior to posterior or (2) various locations of the jaws. Each half of the jaws contains three clone masses of mesenchymal cells: the incisors, canine and the (pre)molars. As it extends due to proliferation, a clone mass progressively loses the potency/ability to determine the tooth shape. In each tooth class the most differentiated progenitor tooth develops first, closely followed by the less differentiated ones.[94 524]

Different receptors and/or different regulatory molecules play a role in the determination of the tooth shape. The level of activation of the ectodysplasin-A receptor (EDAR) appeared to control in the early stages, the cusp number and shape in transgenic mice. Less EDAR signalling results in few teeth with reduced cusps, more EDAR signalling results in more teeth with steeper cusps, and high EDAR signalling shifts the molar field distally, resulting in ectopic distal teeth, loss of the most proximal teeth, and many small cusps in the first and second molars.[607]

The cascade of events in the tooth germ is controlled by reciprocal induction. Regulatory genes tune on and off depending on the microenvironment. The fate of cells that become ameloblasts and odontoblasts is probably determined early, although transformation into the specific ameloblast takes longer. Already in the "cap" stage, the receptor for the epidermal growth factor in the cell membrane of the ameloblast is turned off; a "turning on" follows during maturation of the ameloblast. Other receptors (among which are Notch 1, 2 and 3) are also temporarily active.[592]

Consequences

The main immediate effect of hyperdontia is lack of space, delayed eruption of the extra or adjacent normal teeth, and crowding and malalignment once eruption takes place (Figures 1.20 and 1.21).[396] Mesiodens in particular may erupt quite early.[641] In children, one-third of supernumeraries erupt.[361] Hyperdontia is the most common cause for non-eruption of the normal maxillary incisors at age 8–10 years,[48 58] especially when the supernumerary tooth is tuberculate in shape and in a palatal position.[183 381] The predecessor may also be retained.[75] Extra teeth that form later in life are likely to have multiple cusps,[402] and tend to remain unerupted within the jaws.[225] Unerupted extra teeth may be the cause of diastema

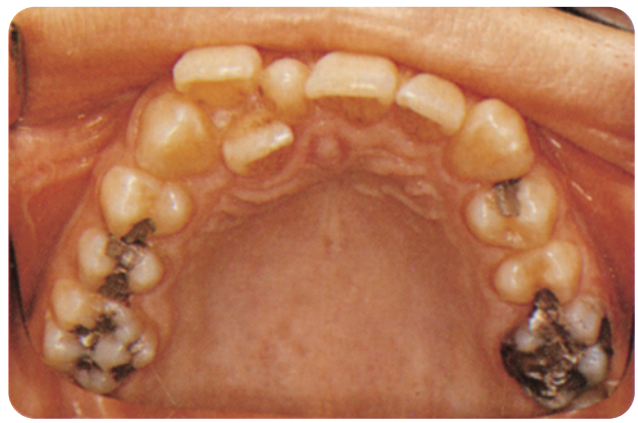


Figure 1.20 An erupted mesiodens has resulted in lack of space for the lateral incisor, which has erupted palatally.

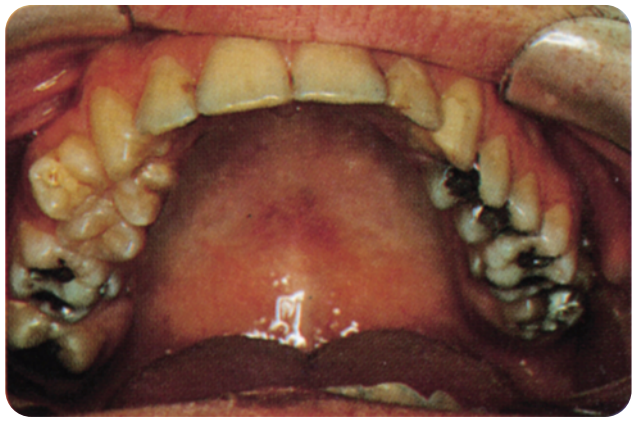


Figure 1.21 Malalignment of the teeth in the upper right quadrant as a consequence of an extra premolar.

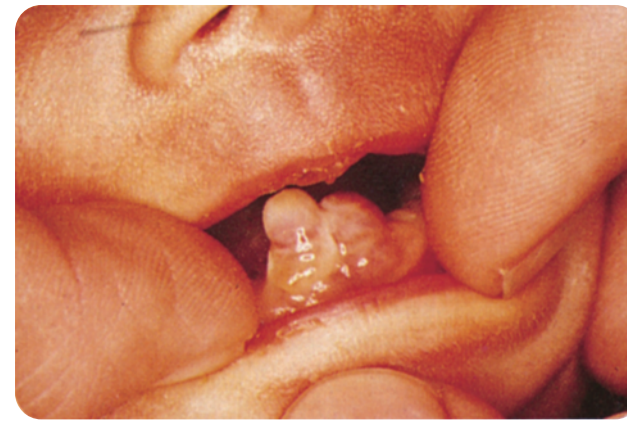


Figure 1.22 Neonatal teeth.

between the normal teeth[109] or lead to malpositions, such as rotation. They may also initiate resorption and follicular cyst formation.[382] Extra teeth may be conjoined with a regular neighbouring tooth (Section 1.4).[450]

Some evidence exists that premaxillary hyperdontia is associated with abnormalities such as dens invaginatus (Chapter 2), curved roots and delayed eruption after surgical removal of the supernumerary tooth.[241]

Treatment

Extra teeth should be extracted if (1) the eruption of the adjacent teeth is being obstructed, (2) envisaged orthodontic treatment will be compromised or (3) pathology, such as a cyst, develops. To prevent damage to the roots of the neighbouring teeth, the exact position of the extra tooth must be carefully determined. Early surgical removal could minimise interdental spacing and the need for orthodontic treatment,[661] but is not justified and is seldom indicated.[338] Complications of early removal are infrequent and minor in nature.[265 413] On one occasion an adjacent root temporarily resorbed (Chapter 7) and the situation returned to normal.[265] An extra tooth may be removed along with the deciduous predecessor when the permanent incisors roots are still incomplete.

As unerupted extra teeth may migrate,[569] it is not unwise to delay their removal until the tooth acquires a more favourable position and the roots of the adjacent teeth are fully formed. A conservative approach is warranted when the eruption of the regular teeth will not be hampered, pathology is absent, orthodontic treatment is not envisaged, and the removal of the extra tooth may compromise adjacent teeth.[202]

If the permanent incisors do not erupt into their normal position, a mesiodens is preferably removed between the ages of 8 and 9 years,[154] but pathology is extremely rare.[669] An erupted mesiodens is easily extracted, but the resulting diastema may persist.[328] A deeply situated mesiodens may be left *in situ*, but requires regular radiographic review. Retained mesiodens may be fully resorbed.[236]

After the removal of extra teeth, the normal neighbouring teeth do not necessarily erupt spontaneously.[272] A quarter of maxillary central incisors with completed roots did not erupt after the removal of the (tuberculate) supernumerary[48 183] and required surgical exposure, in many cases followed by orthodontic traction.[183] Three-quarters of the latter teeth erupted subsequently within 16–18 months, and the rest needed exposure[58 202 381 402] and orthodontic traction. Surgical movement of a maxillary incisor situated labially is considered to pose a smaller risk than orthodontic movement.[454] Multiple hyperdontia may necessitate an interdisciplinary approach.[39]

1.3.4 *"Extra dentitions"*

Some sources mention more than two dentitions in humans, i.e. including teeth erupted around birth and teeth erupting after the loss of the permanent dentition.

Natal and neonatal teeth

Natal teeth are teeth which have erupted at birth and *neonatal* teeth refers to teeth erupting within the first month after birth (Figure 1.22).[383] The terms "extra dentition" is not appropriate for these teeth because the condition involves one tooth or a few teeth, although there are some reports of 11 and even 14 natal teeth.[389 447] Probably 90%of these, often the lower incisors, belong to the regular deciduous dentition.[13 43 59 197 302 504] *Dorland's Medical Dictionary* mentions "pre-deciduous teeth", a term applied to hornified epithelial structures without roots, which are not identical to natal/neonatal teeth.

In earlier times natal teeth were viewed with superstition. These children were thought to be witches or to become vampires after death, and also thought to bring about doom or blessings.[60] To prevent doom, the Basuto

tribespeople in South Africa drowned such children or abandoned them elsewhere. Some famous people (Napoleon, Louis XIV) had neonatal teeth, which were believed to predict a glorious future.[139]

Epidemiology

Half as many natal/neonatal teeth are reported by hospital staff as by "specialised experts".[304] The teeth, the majority being natal ones,[383] are present in 1: 2000–6000 Caucasians. [8 20 43 13 121 304 598 504] Therefore, it is no surprise that in about 1000 newborns in Sweden no natal teeth were found.[182] Higher prevalence figures have been reported elsewhere: 10:1000 for Taiwanese newborns,[670] and 90:1000 for Tlingit Indians (Alaska).[386] The prevalence in children with cleft lip and palate is 50:1000.[14] The anomaly is possibly an ethnic trait.

A slight predilection for females seems likely,[6 20 219 304] but sex differences are not always reported.[43 363 523] The vast majority (59 of 62 natal/neonatal teeth in one study[23]) are mandibular central incisors. Natal/neonatal (bilateral) molars and canines have also been reported.[13 22 43 59 66 124 196 314 481 589]

Appearance

The crowns have either a normal size and shape or may be hypoplastic. In particular the lingual enamel is hypocalcified and incompletely formed,[148 250] lacking especially incisally[615] and cervically; the enamel may be thin (or absent), structurally abnormal and yellow in colour.[46 51 321 419 504 552] Amelogenesis arrests prematurely *in utero*.[51 552] There is abundant interglobular dentine (Chapter 3), irregular dentinal tubules and bone-like dentine, mainly cervically.[553] The roots may be barely formed or incomplete, covered with a thin layer of acellular cementum that is most likely not calcified.[20 111 148 196 237 304 380 447 553]

Aetiology

Reported causes include vitamin deficiency, endocrine disorders and fever. High levels of PCB (chlorinated bisphenyls) in food (Japan) may be responsible,[660] but in Finland no association was found with higher environmental levels (which have declined during recent years) of PCBs, PCDFs (dibenzofurans) and PCDDs (polychlorinated dibenzo-*p*-dioxins) in mother's milk. The prevailing levels of these substances are below the threshold reported to cause premature eruption.[8]

A hereditary,[237] superficially located tooth germ, above the alveolar bone,[419] seems more likely.[18 659] In some instances, the occurrence of the teeth is familial, both intergenerationally and in siblings, indicating a possible autosomal dominant trait.[13 18 23 43 59 237 304 383 386 540 659] Natal teeth may also occur as part of some syndromes and sequences, such as Ellis–van Creveld syndrome, Pierre Robin sequence, clefts, Wiedemann–Gautenstrauch syndrome,[120 660] in combination with a cleft tongue and deafness,[124] and the rare Pfeiffer syndrome type 3.[18]

Consequences

Natal teeth used to be removed for several reasons.

- Local mucosal infection.
- Mastitis, in a few cases, caused by nipple-biting during breast-feeding.[43 46]
- Ulceration of the underside of the child's tongue caused by contact with the natal tooth, which may lead to refusal to feed,[88 419 598] called Riga–Fedes syndrome[383] or Riga–Fedes disease.[211]

Risk of aspiration of a spontaneously shed natal tooth has been considered[252] but it has never been reported.[419] Around 30%[69] or even 60% [304] of the teeth are very mobile, being attached almost solely to gingiva,[504] which was the reason to remove half of them shortly after birth in one study.[304] Hertwig's sheath degenerates prematurely (Chapter 3),[556] but completion of the roots seems possible, at least partly. After early extraction or exfoliation, root-like structures may develop from remains of the cells of the dental papilla.[46 555 610] Such *residual natal teeth* may erupt. The root dentine is covered with an osteodentine-like substance and cementum.[610]

Left *in situ*, problems may arise in the longer term, but assumedly infrequently. One poorly developed neonatal molar became severely decayed, and impeded the eruption of the deciduous canine, disturbed the normal development and eruption of adjacent deciduous molar and caused osteomyelitis.[314]

Treatment

Natal and neonatal teeth belonging to the deciduous dentition must not be removed.[43 197 304] Curative treatment may not seem feasible,[88] but smoothing of rough incisal edges or adding composite to achieve a rounded, smoother surface has been proposed.[211] After extraction, gentle curettage is done to remove the papilla and Hertwig's epithelial root sheath.[88] No serious spatial consequences in the mandibular permanent dentition have been encountered after extraction.[304 598]

The majority of natal teeth may function well, like the other deciduous teeth,[197] but a third[54] (or two-thirds[271]) of the teeth exfoliate within the first year of life.

Third dentition

Occasionally the popular media will report a "post-permanent dentition", for example the eruption of 16 mandibular and 10 maxillary teeth in a 100-year-old Chinese person in 1983. Before 1875, reports on post-permanent dentitions were more common.[456]

The third dentition consists possibly of very late erupting regular and/or extra teeth. The eruption may be delayed considerably: in a 27-year-old woman none of the permanent teeth had erupted.[288] In cleido-cranial dysplasia, the multiple extra teeth erupt very late, because of abnormal bone remodelling owing to mutations in an

osteoblast factor (RUNX2), which controls transcription of many bone and tooth-related genes,[671] and lack of acellular root cementum. Among the "teeth" of a third dentition might also be roots left behind during extraction.

1.4 Fusion and partial schizodontia

Fusion is the union of two discrete tooth germs at an early stage of the odontogenesis,[312 430 655] in which two teeth share part of at least the enamel and/or (root) dentine. In true fusion the teeth may show confluent dentine.[50 534] Synonyms include *synodontia*[143] and *connation* (born together).[261]

Fusion is not always complete. The extent and location of the union depends on the developmental stage at the time of fusion.[534] Three types have been described: total fusion (*fusio totalis*), partial fusion of the crowns (*fusio partialis coronaris*) and partial fusion of the roots (*fusio partialis radicularis*).[50 524] Clinically, a wide tooth or a wide crown with two roots is seen, particularly in the premaxilla,[254 274 355] or a single broad root with two crowns. The broad crown may show a normal morphology, an incisal notch or an inciso-cervical groove delineating the united crowns or it may be a bifid crown.

A *megadont* tooth (a large tooth of normal morphology) represents either macrodontia (Chapter 2) or complete fusion.[385] In one dentition a megadont tooth was accompanied by a contralateral double tooth.[71 81 142 163] Deciduous double teeth may precede permanent double teeth[30 35 47 65 71 81 83 116 142 163 191 425 451 507 640] or megadont/macrodont teeth, suggestive of fusion.[81 411]

Schizodontia denotes splitting of a tooth germ. If the split is complete, two teeth are formed (*twinning*, *gemination*) and hyperdontia results.[143 355] *Partial schizodontia* during early tooth development results in two partially conjoined teeth. Alternative names are "Siamese twin teeth" and "partial gemination". The appearance of a double tooth caused by partial schizodontia depends upon the timing of the splitting. Splitting may start at the incisal edge and stop before cleavage is complete. Such a division results in a mesial and distal crown components on a single root,[534] with either one or a partly divided pulp (pulpal bifurcation)[493] space.[74 312 355] A late incomplete split produces one crown on two roots.

Figure 1.23 shows schematically the hypothetical processes[586] of partial schizodontia, complete schizodontia, fusion and *concrescence* (teeth conjoined only via the cementum). Partial schizodontia and fusion may be viewed as morphological anomalies (Chapter 2), but as they may be associated with anomalies in the number of teeth, they have been included here. The knowledge of these two phenomena is based mainly on theoretical considerations and interpretation of the clinical outcome of the processes responsible. Although the nomenclature suggests an exact knowledge of the pathogenesis, this cannot be corroborated. Only one of the two processes may occur, therefore, the preferred name is "double tooth",[312 635] which simply indicates the tooth is mesiodistally wider than normal (Figure 1.24).

In sum, a *double tooth* is wider than a normal tooth and is the clinical manifestation of either fusion or partial schizodontia.

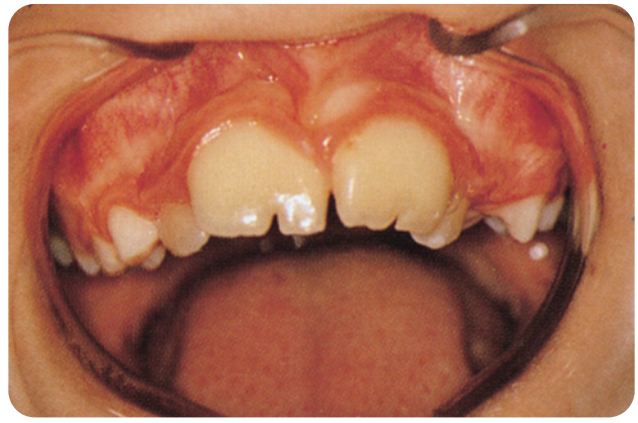


Figure 1.24 Two broad central double teeth; the incisal notches indicate existence of two components.

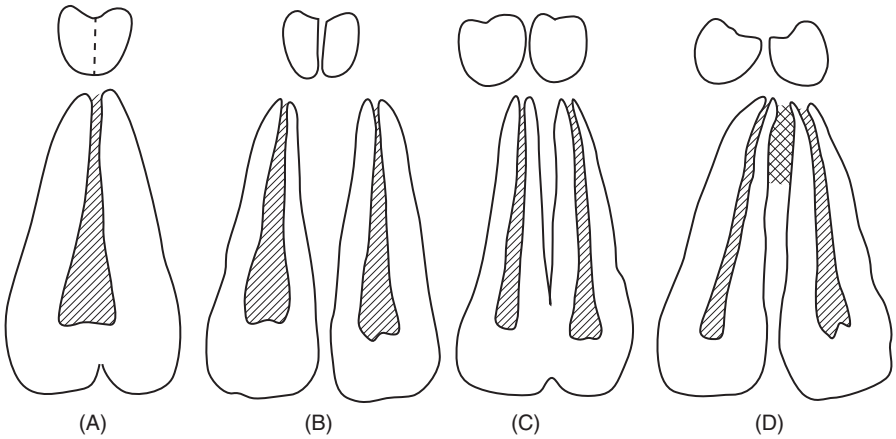


Figure 1.23 Schematic presentation (lower row) of partial schizodontia (A), complete schizodontia or twinning (B), fusion (C) and concrescence (D). The top panel shows a partially split tooth germ (A), a tooth germ split in two (B), two tooth germs pressed together, presumably resulting in fusion (C), and two tooth germs situated too close together (D).

1.4.1 Diagnosis

Diagnosis of a double tooth rarely poses a problem, but as mentioned above, there are no rigorous criteria to distinguish fusion from partial schizodontia (and hyperdontia from complete schizondontia?). Assumed fusion of a central incisor with a mesiodens (Figure 1.25) has been described a few times.[2 514 612]

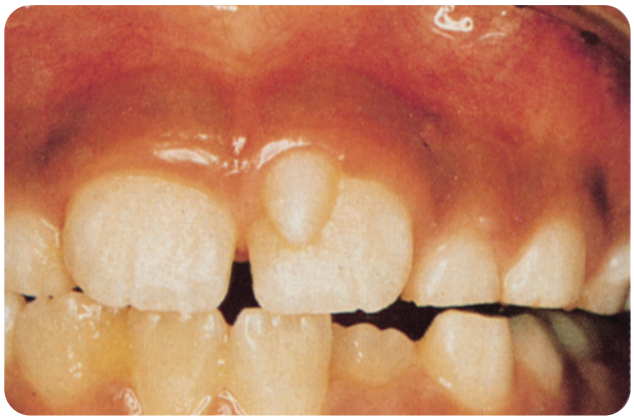


Figure 1.25 Possible fusion of a mesiodens with a regular maxillary central incisor.

Diagnostic criteria: fusion versus partial schizodontia

Many authors have diagnosed double teeth as products of fusion or partial schizodontia (correct or incorrect)[274 392] based on morphology, pulpal anatomy, location by jaw, crowding and number of teeth in the dentition.

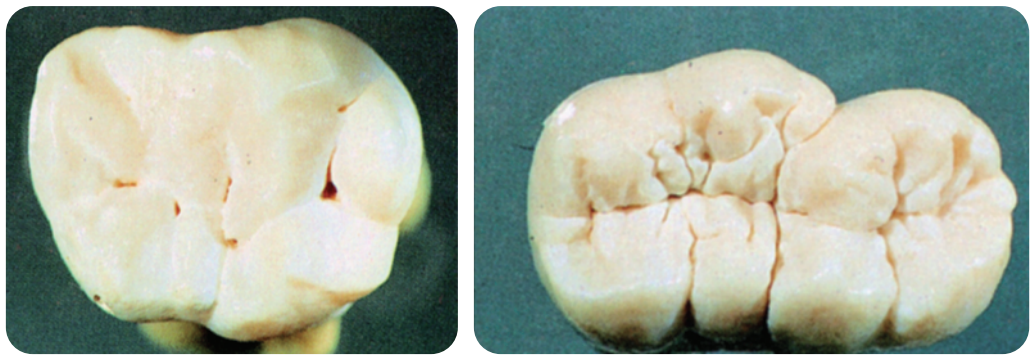
Morphology

Incomplete schizodontia (and twinning)[50 369] (Figure 1.26) creates a mirror image (Figure 1.26A) of the coronal halves.[310 586] Manipulation of mice embryos resulted in twins which showed mirror-image teeth,[498] but this does not necessarily prove twinned teeth arise in the same way.

Fusion at an angle leads to a "crooked" appearance.[369] In fusion, one coronal part may be rudimentary,[49 493] usually the mesial component,[524] but malformed crowns may not allow classification into a tooth class.[49] These morphological differences are described *after* first giving the diagnosis fusion versus partial schizodontia although as mentioned above which of the two processes is responsible may not be clinically evident.

Anatomy

The pulpal anatomy and number of roots has been used for diagnosis of fusion/schizodontia.[56 70 74 107 130 147 164 188 189 242 301 312 355 356 438 442 443 449 499 502 582 584] Fused teeth have



(A)

(B)

Figure 1.26 (A, B) Examples of permanent posterior double teeth from the upper and lower dentitions. The mirror image-like appearances of the occlusal left and right halves of the tooth (Figure 1.26A) possibly indicate partial schizodontia.

two pulp chambers and incompletely schizodont teeth have an undivided one,[355 586] whereas in fused permanent molars all root canals arise from one pulp chamber.[189] Some authors consider a vertical communication between the two pulps in double teeth as a criterion to classify these teeth as fused teeth[44 576] as well as partial schizodontia.[582] In both conditions the variability of the root canal system has been stressed,[130 189 312 355 369 586] which might preclude the diagnostic significance of anatomical[56 310] and pulpal features.

Location by jaw

Mandibular double teeth are almost exclusively considered to represent fusion but maxillary ones are occasionally thought to represent partial schizodontia.[143 164 640] Fusion with a supernumerary tooth seems to occur equally frequently in each jaw.[469] Half of the deciduous double teeth in the maxilla seemingly represent fusion between the central and lateral incisors.[655] Again, the morphological descriptions follow the diagnosis.

Crowding

Wide interdental spaces are common in deciduous dentitions with double teeth. Fused teeth require less arch length than normal teeth, leading to interdental spacing. Geminated teeth require more space, thus cause crowding,[369] as does fusion with a supernumerary tooth. Therefore, neither a diastema or crowding seems diagnostically decisive.

Number of teeth in the dentition

Two fused regular teeth counted as one unit reduces the regular number of teeth, unless there is concomitant presence of an extra tooth;[29] partial schizodontia does not affect the number of normal teeth.[312] Although fusion usually occurs as a singular anomaly,[112] the rare coexistence of hypodontia and hyperdontia (often in the same arch)[131 159 177 206 421 501 561 628 638] makes the number of teeth an invalid parameter for diagnosis. When an extra tooth is involved in fusion[67 81 469 645] the regular number of teeth is not reduced. Conversely, if a double tooth represents partial schizodontia, the number of teeth will be normal,[312] unless another tooth is agenetic.[81]

Fusion in the deciduous dentition is said to be associated with an agenetic successor,[233] but a double tooth due to partial schizodontia or fusion of a regular tooth with an extra one is not.[655] Deciduous double teeth are associated with a reduced number of teeth in both the deciduous and the permanent dentition[35 94 116 458 469 470 581 597 602 645] and with conical successor teeth.[655] In the literature, agenesis of 50–100% of permanent lateral incisors accompanied assumed fusion of the deciduous lateral incisors with the canines.[411 421 469 470 602] Assumed fusion of other deciduous teeth was less often associated with agenesis in the permanent dentition.[469 470] Hypodontia as a diagnostic criterion is further compromised because deciduous "fusion with a supernumerary tooth" has been noted to be accompanied by hyperdontia in only four of 13 permanent dentitions.[83] Other maxillary deciduous central incisors fused with extra teeth were replaced by permanent normal and extra teeth.[599]

Counting a double tooth as one unit, the number of permanent anterior teeth was unaffected in a report of six deciduous anterior teeth. However, when five primary anterior teeth, including the double teeth, were present, the permanent dentition was noted to have five or even four anterior teeth.[205] The numbers of teeth in 367 children with double teeth corroborate the above findings.[655] All kinds of combinations of fusion, partial schizodontia, agenesis and hyperdontia may result in the presence of four to eight anterior teeth. Therefore, the number of teeth merely suggests a diagnosis.[576]

Conclusion

In sum, strict diagnostic criteria to discern fusion from partial schizodontia are lacking and it is difficult,[164] if at all possible,[312] to assign aetiological labels to "double teeth", the term that is preferred to the above-mentioned aetiological terms.[81 400 461 655] Diagnosis of fusion and partial schizodontia is said to be desirable in the deciduous dentition because of the expected probability of deviations in tooth number in the permanent dentition,[34] but the aetiological terms are merely of academic interest.[2]

1.4.2 Epidemiology

Double teeth have been frequently surveyed in Caucasian and Asian populations.[30 34 47 49 50 71 78 81 83 89 100 103 112 116 122 137 181 227 269 270 283 284 286 287 288 289 290 291 292 295 296 298 300 301 302 330 372 388 394 414 424 429 445 469 488 495 499 507 508 581 587 597 602 640 654] Many samples were randomly drawn, but some studies used selected samples or retrospective data or had other flaws. For instance, the 95% confidence interval for 3.7% of cases found in 107 Amerindians[122] is 1% to 12%, but in a random sample this may be doubtful because of the rarity and possible inherited nature of double teeth.

Double teeth are more often present in the deciduous than in the permanent dentition. It seems reasonable to conclude that double teeth in Caucasians are manifest in 0.6% of deciduous dentitions and in 0.1% of mixed/permanent dentitions, which is in line with an earlier estimate.[164] In Japanese and probably Chinese and Amerindian children, the average prevalence is 2.8% in the deciduous and almost 1% in the permanent dentition. The prevalence of deciduous double teeth in (western) India is 1.5%, a figure between that of Asian and European samples.[587] Among a sample of Jordanian adults, 0.42% had double teeth.[238]

Deciduous double teeth are mostly present in the anterior mandible (Figure 1.27).[655] About 90% is suggestive

of fusion between incisor and canine.[655] Double teeth in adults may prevail in the maxillary incisor region and often concern the central incisors.[238]

Sex

Males and females might be equally affected.[81 116 291 469 507 524 602] Other studies point to a predilection in males.[49 470 654 655]

Syndromes

Double teeth are part of (or coincide with) a number of syndromes.[40 81 82 90 141 156 216 224 261 390 450 512 531 600 614 647 653]

Bilateral double teeth

Until 1987, some 30 bilateral double teeth had been reported,[164 405] but the number may have doubled since then. Around 50 (0.01%) were included in the surveys cited above. Another study estimated 0.02%.[164] In 372 double teeth cases, 1% were present in both the maxilla and mandible of the same individuals.[524] Bilateral double teeth were observed in both jaws and both dentitions of a Chinese girl.[418]

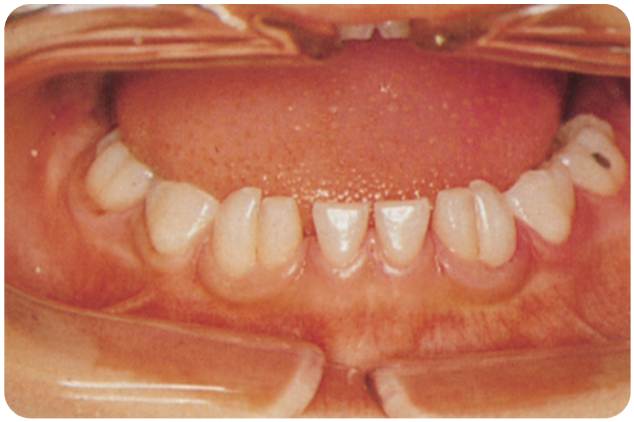


Figure 1.27 Bilateral mandibular fused anterior teeth, suggestive of fusion between the lateral incisors and canines (see text).

Posterior double teeth

In several hundred case reports reviewed,[526] 40–50 posterior double teeth (Figure 1.26) were described, mostly permanent ones.[27 44 81 105 106 109 130 136 144 145 157 179 189 204 212 221 225 229 245 256 259 266 273 298 301 400 407 461 492 503 520 523 524 525 539 558 562 573 606 620 658] Three double deciduous molars have also been reported.[3 95]

Triple and quadruple teeth

Occasionally triple teeth are encountered,[7 80 91 97 112 173 323 411 444 475 524 525 526 528 605 612] mostly deciduous ones. "Fusion" of two normal teeth with a supernumerary between them may be implicated.[7 81 91 173 323] In one report, one of two siblings had a triple and a double tooth, the other possessed two double teeth. Another patient had bilateral triple teeth. Two permanent triple teeth suggested fusion of the first, second and third molars.[524 528] A triple tooth may even consist of two deciduous teeth and one permanent tooth; the successor tooth being absent.[323] Another triple tooth was thought to represent a double tooth with a fused talon.[584] Figure 1.28 shows three triple teeth (previously unpublished).

Quadruple premolars (four conjoined teeth) have been reported twice,[523 524] but the reports may have concerned the same patient.

Solitary symmetrical median central incisor

A single maxillary symmetrical central incisor of normal size may be present across the midline (1:50 000 live births)[672] in both dentitions,[191 243 270 332 378 435 451] and less frequently in the mandible.[236] The phenomenon is linked to multiple genetic malformations, such as a short stature and midline defects (e.g. nasal defects and cyclopia, i.e.

(A) (B)

Figure 1.28 Two mandibular triple teeth (A). The maxillary triple tooth (B) was functional until its shedding. (Courtesy of M.A.C.J. Wevers.)

one eye).[82 171 193 216 243 270 378 435 510 639] The aetiology is uncertain.[672] Premature fusion of the right and left dental lamina has been assumed to prevent development of the medial halves of the central incisors, leaving the distal halves fused together.[247 378]

1.4.3 Aetiology

The manner in which and the reason why double teeth develop is still unresolved. Implicated factors are evolution, trauma, heredity and environmental factors. A multifactorial model comprising numerous genetic and environmental factors may present a unifying aetiological explanation for deviations in tooth number and size. An underlying continuous scale of the distribution of number and size with thresholds at each extreme has been proposed.[79] Double teeth may fit to such models.

Evolution Since the sixteenth century, the prevalence of both hypodontia and hyperdontia has increased distinctly, but that of fusion and partial schizodontia only slightly.[72] In Japan, the prevalence of double teeth has shown a tendency to rise.[654] An evolutionary trend might exist, which warrants a brief description of some evolutionary theories.[333 524 628]

Human (pre)molars represent fusion of haplodont (cone-like) teeth of the Mesozoical reptiles. Shortening of the jaw resulted in pressing of tooth buds of different generations together into triconodont teeth that would have separated later again into haplodont teeth when the jaw became again longer.[333 524] In evolutionary terms, both fusion and splitting would therefore be possible, but the theory seems implausible with respect to double teeth in humans.

Human teeth have also been considered to be the product of both fusion and differentiation.[62] Two triconodont teeth, like those of primitive reptiles, were "concentrated", and reduction of the triconodont character as well as differentiation and partial schizodontia may explain the morphology of the different human teeth.[333 524] This theory has become obsolete.

E.D. Cope and H.R. Osborn assumed that the (pre)molars came into being by differentiation of a haplodont tooth. Over a period spanning many centuries, a mesial and distal tuberculum conus, originating from a cervical thickening (cingulum), gradually developed into full cusps. In due time, the cusps adopted a triangular pattern. Later, the other cusps differentiated from an outgrowth of the cingulum. In spite of being criticised,[529] this (adjusted) theory is the most accepted one.[333 524]

Schizodontia has been assumed to be an evolutionary phenomenon,[214] but minor variations in tooth traits are considered of more evolutionary importance than major ones such as fusion and twinning.[529] Double teeth are viewed to lack phylogenetic significance.[333]

Trauma Development of supernumerary premolars has been ascribed to jaw fractures.[419] However, double teeth have been reported in cases with no history of trauma, which casts doubt on whether trauma may be an aetiological factor in the development of these teeth.[56 163 176 547 578]

- Trauma and (incomplete) partial schizodontia: Root duplication and hyperdontia in the permanent dentition could result from a traumatic injury to the deciduous dentition,[21] as would the duplication of a permanent incisor crown.[453] A triple tooth was attributed to a traumatically geminated permanent tooth fused with a deciduous tooth.[97] Experimentally, schizodontia appeared possible. When 20-day rabbit tooth germs were cut into two, two supernumerary teeth were formed;[400 529] tooth germs cut on day 22 did not.[529] Complete labial and lingual incisors developed 1 month after mesiodistal splitting of the odontogenic organ of rats.[659] Collectively, intrusive trauma may cause partial schizodontia.
- Trauma, crowding and fusion: Anterior deciduous tooth buds in close proximity show the highest incidence of fusion,[655] the space between them diminishing gradually on bud enlargement.[429] Forced contact between two tooth buds may cause necrosis of the intervening tissues, whereupon the enamel organs and papillae unite.[236 364 534] However, the tooth germs are neither horizontally nor vertically arranged in a straight line. Supernumeraries developing simultaneously with regular teeth lead to crowding, yet fusion rarely occurs or is not mentioned.[60 272 275 281 366 413 478 563 564 590] Fluid incompressibility may not allow the germs to merge.[430] Additionally, it has been noted that remnants of the external enamel epithelium are absent in the fused area within the teeth.[430]

Environment A relationship between double teeth and fetal alcohol exposure has been suggested.[119] Thalidomide embryopathy has also been blamed.[444] In mouse embryos hypervitaminosis A and in induced exencephaly (the brain lies outside of the skull), fusion of the enamel organs of the maxillary incisors was observed, mostly as a total fusion.[324] Administration of retinoids, the active agents of vitamin A, in 9-day mouse embryo mandibles resulted in fusion.[529] Riboflavin deficiency and triptan-blue injection had the same effect but with a lower frequency, and cyclophosphamide in extra incisors.[325 350]

Heredity Epidemiological studies do not reveal a distinct inheritance pattern with double teeth,[655] yet heredity has been implicated.[163 364 534 646] The high prevalence of double teeth in Japanese children suggests an ethnic trait. No consanguinity effect has been demonstrated in familial double teeth.[421]

An autosomal dominant and a recessive trait have been suggested.[81 116 362 377 404 437 649] The penetrance of several tooth anomalies is 90% (collectively in the deciduous and permanent dentitions), double teeth being included in this group. Based on incorrectly interpretation of family

trees,[324] a Y-linked trait has been reported.[158 507] Excluding twins, familial double teeth are cited in at least 25 case reports,[28 74 81 87 91 98 116 122 220 232 267 355 400 404 436 437 475 523 586 602 652 655] but other reports explicitly mention their absence in family members.[95 115 142 177 203 322 418 436 472 473 533 539 547 557 558 571 605 621 623] In one survey the absence of familial double teeth was highlighted,[388] and in others a familial occurrence seemed unlikely.[116 488 597] The majority of the cited epidemiological studies and case reports do not mention double teeth in parents, siblings and second- and third-degree family members. No report on heredity seems available for permanent posterior double teeth.

Relatives of Japanese children with "fusion" have been found to have a higher rate of tooth anomalies (peg-shape, hypodontia) than in the general population.[507] Among inbred dogs several tooth anomalies were present, including double teeth.[262] The presence of tooth number anomalies, such as hyperdontia, in family members of patients with double teeth[81 119] might be meaningful.

Twins The study of twins may help to disclose the relative contributions of heredity and the environment.[604] Assuming that double teeth are inherited, mirroring in a set of monozygotic twins might be explained by, for instance (1) asymmetry-determining genes, (2) late cleavage of the embryos,[560] and (3) differences due to a modestly incomplete penetrance of double teeth.[334] Monozygotic twins may differ as does a single child's left and right sides,[604] and may experience different prenatal environmental (different birth weight!) and perinatal circumstances, such as oxygen deficiency in the second-born twin.[334]

The nine reported monozygotic twins showed mirror-image and discordant double teeth.[116 334 418 420 521 526 581 559 602] In a tenth, one monozygotic twin had normal teeth, as did the relatives, and the other had a double tooth.[526]

1.4.4 Pathogenesis

Fusion takes place during the initiation-morphodifferentiation stage.[512] Inbred dogs have a variety of dental anomalies, among which are double, triple and macrodont teeth. When the interdental lamina splits near an adjacent tooth germ, a supernumerary (geminated) tooth develops from the remnants of the lamina.[263]

Hypothetically, mitotic activity in the dental lamina presses its cells together into bulging masses (primordia) within a confined space. Per quadrant, space exists for just five bulges, from which the deciduous teeth develop, leaving room for no more than the eight primordia for the permanent dentition.[462] After renewed mitotic activity in the primordial cells, epithelial strands extend into the direction of the mesenchymal cells,[492] which allows the development of enamel organs by reciprocal epithelial and mesenchymal interactions.[593]

On the anterior part of the lamina, the beginnings of an incisor and the canine appear first and, posteriorly the "cheek tooth" appears first. The development of the intervening teeth starts later.[93] In contrast with the continuous anterior–posterior field (Butler), Osborn states that the tooth primordia are preprogrammed to produce the different tooth classes.[114] Based on Osborn, Yuen *et al.* postulated that a decreased hereditary proliferation of the clone cells in the tooth class, which cluster together with an inhibitory zone around the tooth germ, is responsible for double teeth (=fusion). Such teeth are more frequently associated with agenesis of successors than double teeth resulting from partial schizodontia.[655]

In many instances the appearance of double teeth suggests that they originate from the incisor and canine tooth classes. Perhaps the tooth class boundaries in humans, like in many species,[529] are not as distinct as thought?

Speculatively, an extra bulge might develop if there is larger space and mitotic activity, leading to a double tooth or twinning. Lack of space might inhibit the formation of a regular tooth primordium, resulting in hypodontia. If in a narrow space the normal number of tooth primordia develop, the mesenchyme may not be able to condense between two of them, making fusion possible. It may be significant that two-dimensional area measurements show decreases in the size of the maxilla associated with tooth agenesis (cause or effect?), but relatively few age groups show significant changes in mandibular size.[588] Altogether, the origin and pathogenesis of double teeth remains enigmatic.

1.4.5 Consequences

Double teeth may not erupt or hinder the eruption of adjacent or successor teeth.[108] Malpositions and misalignment of the double tooth or adjacent teeth are frequent.[576] A secondary consequence is resorption of adjacent teeth.[105] Double teeth may interfere with occlusion and articulation or may show excessive wear.[248] The notch or groove in the crown may be susceptible to caries[108 307 398] or periodontal problems if it extends to the attached gingiva.[369 398]

Combinations of double incisor teeth and a protuberance on the premolars (dens evaginatus, Chapter 2)[152] and other morphological deviations may be coincidental.[399 636]

1.4.6 Treatment

Double deciduous teeth pose a transient aesthetic problem but some were treated endodontically.[32] If they are expected to affect the succeeding teeth, they must be extracted; a space maintainer is mandatory.[173] Erupted double permanent teeth are cosmetically unattractive, and together with space problems and malpositioning, demand intervention – if possible splitting, often preceded by endodontics and followed by orthodontics.[113 128 266 277 307 391 486 650] Surgical splitting of a double tooth into two teeth is an option when the degree of "fusion" is mild[287 405] and when one wide crown is present on two separate roots (Figures 1.19, 1.20, 1.21, 1.22, 1.23, 1.24, 1.25, 1.26,

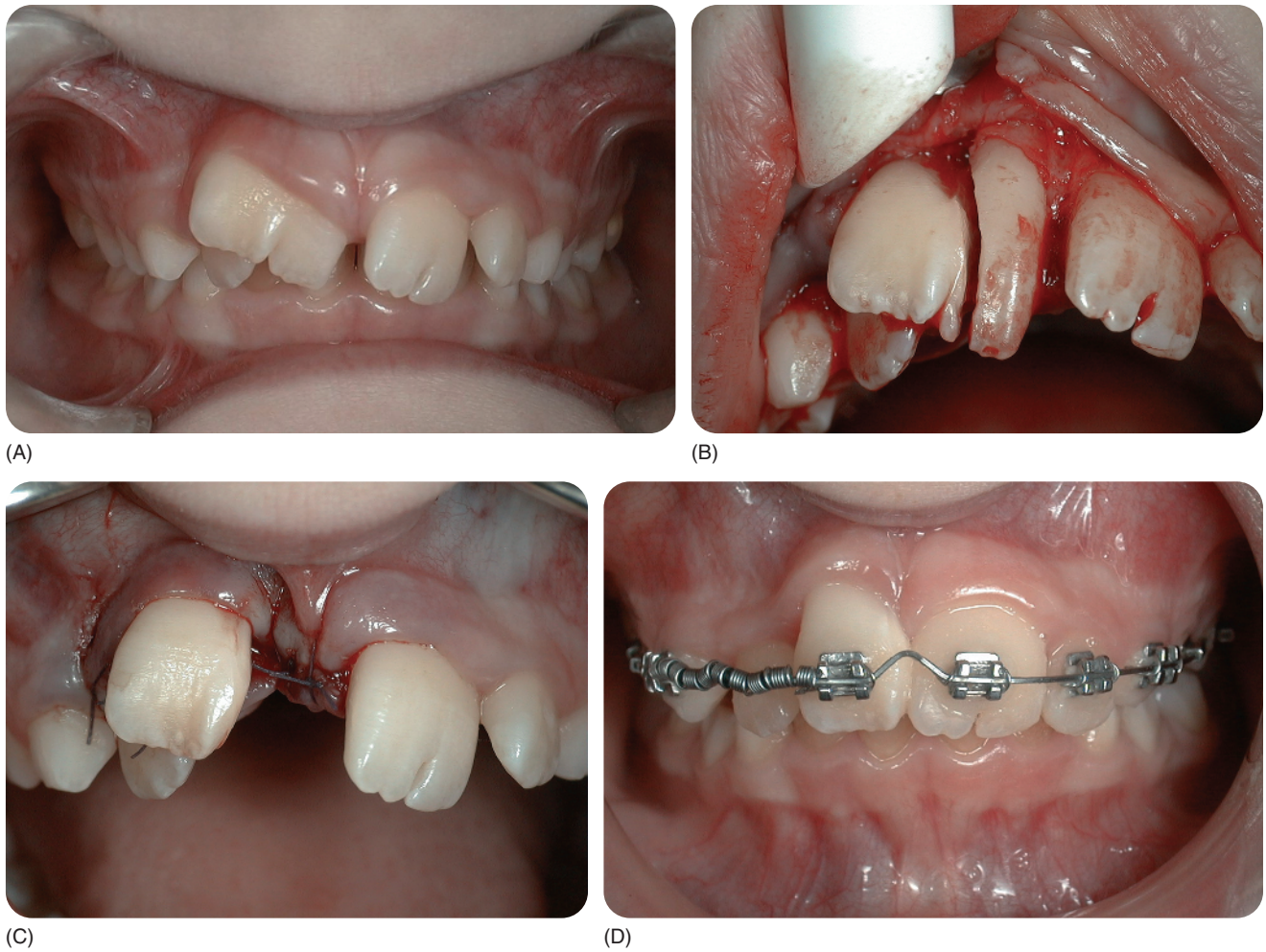


Figure 1.29 (A–D) A double tooth, consisting of conjoined crowns with a common pulp chamber. After hemisection, the mesial part of the tooth was removed and the exposed pulp was treated with direct pulp capping. The resulting diastema was closed orthodontically. (Courtesy of M.H. Ree.)

1.27, 1.28 and 1.29).[303] A double tooth was endodontically treated, extracted, split and one part was replaced.[611] A protuberance-like part of a double tooth may be reduced in size either before or after endodontics, followed by orthodontics.[303] If due to reshaping, part of the cementum is lacking, a pocket may develop or the root may resorb.[57] In the case shown in Figure 1.30, the components were separated without endodontic treatment, but the latter may be required.[247 514]

Other double teeth with a wide crown have been split and one part extracted. Treatment involving vital pulp amputation ensured completion of the root formation.[223 395] The root-to-crown ratio co-determines which part will be retained. Endodontic treatment is not required when two pulp cavities are present,[260 405] but the pulps may be horizontally connected,[557] or atubular dentine with blood vessels ("vasodentine") may connect two separate pulp chambers.[430]

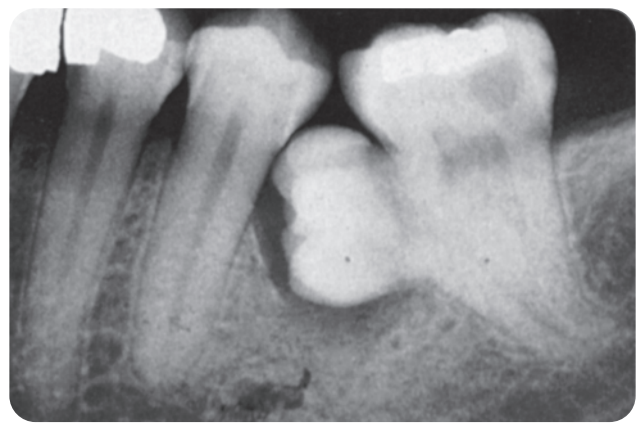


Figure 1.30 Crown of a first molar fused with a second lower molar.

The double molar crown in Figure 1.30 was removed without root canal treatment; the exposed pulp remained vital. In other cases guided tissue regeneration has been employed after splitting double teeth to promote periodontal healing.[427] Root canal treatment in permanent posterior double teeth may be complex.[606] Extraction may be required for a double tooth, but retaining the teeth seems acceptable when other treatment modalities are not suitable, as was the case with two maxillary double central incisors.[246] A multidisciplinary approach might be needed to achieve a satisfactory solution.[621]

1.5 Concrescence

Concrescence is a union of the roots of two adjacent teeth via their cementum only. Union of the cementum at the time of the odontogenesis is called *true* concrescence and that occurring post development is *false* concrescence, or alternatively "primary" and "secondary". In practice it impossible to distinguish between the two conditions.

Concrescence of two teeth (Figure 1.31) or even more has been reported.[259 312 360 370 444 534 487 534] Cementum may unite two roots when the alveolar bone between them is absent. Ectopically located tooth germs or a lack of space within the jaws seems an aetiological requirement.

Radiographs do not reveal concrescence, but it may be suspected when the roots of adjacent teeth are radiographically undistinguishable or projected on each other.[437] A consequence of this condition is that extraction, commonly of a maxillary second molar, results in removal of the conjoined tooth as well (usually the maxillary third molar). Vitality testing is difficult.[347] Prevalence data are lacking; it seems a rare phenomenon.

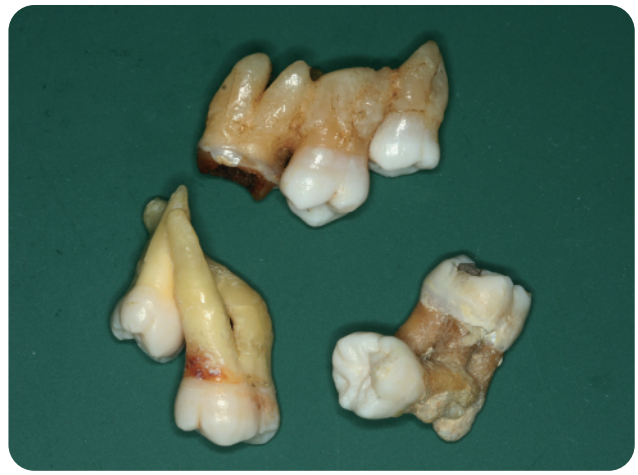


Figure 1.31 Concrescence of a second and third molar and a rare case of concrescence of three molars. The left maxillary first molar in the top panel was extracted because of extensive caries; but unexpectedly, the two other molars were extracted as well.