Development of the dentition

Humans have two dentitions, the deciduous (primary) and permanent (secondary). Each dentition is heterodont, meaning that it consists of teeth with different shapes and functions. The classes of human teeth are:

- Incisiform (incisor);
- Caniniform (canine); and
- Molariform (premolar and molar).

Deciduous teeth are progressively replaced by permanent teeth, with the addition of a molar dentition in the posterior region of the jaws.

Prenatal development of the dentition

Teeth form on the frontonasal process and on the paired maxillary and mandibular processes of the first pharyngeal arch. They are derived from two embryonic cell types:

- Oral epithelium, which gives rise to ameloblasts and enamel of the tooth crown; and
- Cranial neural crest, which contributes to formation of the dental papilla and follicle of the tooth germ and therefore, to the dentine, pulp and periodontal attachment of the fully formed tooth.

The anatomy of tooth development

In the human embryo, development of the deciduous dentition begins at around 6 weeks with the formation of a continuous horseshoe-shaped band of thickened epithelium around the lateral margins of the primitive oral cavity. The free margin of this band gives rise to two processes, which invaginate into the underlying mesenchyme:

- The outer process or vestibular lamina is initially continuous, but soon breaks down to form a vestibule that demarcates the cheeks and lips from the tooth-bearing regions.
- The inner process or dental lamina gives rise to the teeth themselves.

Discreet swellings of the dental lamina form the enamel organs of the future developing teeth. Epithelial cells of the enamel organ proliferate and progress through characteristic bud, cap and bell stages. Simultaneously, the dental papilla is formed by localized condensation of neural crest-derived ectomesenchymal cells around the epithelial invaginations. More peripherally, ectomesenchymal cells extend around the enamel organ to form the dental follicle. Together, these tissues constitute the tooth germ and will give rise to all structures that make up the mature tooth (Fig. 4.1).

The permanent dentition replaces the deciduous dentition and is composed of both successional and accessional teeth (Fig. 4.2):
Figure 4.1 Early tooth development. Localized proliferation of the oral epithelium gives rise to a thickening, which invaginates into the underlying jaw mesenchyme to form the tooth bud. Simultaneously, neural crest cells condense around the bud and these two tissues form the tooth germ. At the cap stage, the tooth bud folds to demarcate the early morphology of the crown, which is modified by further folding at the bell stage. During the bell stage, the innermost layer of cells within the epithelial component of the tooth germ, the inner enamel epithelium, induce adjacent cells of the dental papilla to differentiate into odontoblasts, responsible for the formation and mineralization of dentine. Dentine formation is preceded by the formation of predentine. The first layer of predentine acts as a signal to the overlying inner enamel epithelial cells to differentiate into ameloblasts and begin secreting the enamel matrix. At the margins of the enamel organ, cells of the inner enamel epithelium are confluent with the outer enamel epithelial cells at the cervical loop. Growth of these cells in an apical direction forms a skirt-like sheet called Hertwig's epithelial root sheath, which maps out the future root morphology of the developing tooth and induces the further differentiation of root odontoblasts. Degeneration of this root sheath leads to exposure of the cells of the dental follicle to the newly formed root dentine and differentiation into cementoblasts, which begin to deposit cementum onto the root surface. Surrounding the enamel organ, the cells of the dental follicle produce the alveolar bone and collagen fibres of the periodontium. The developing tooth remains housed in this cavity of alveolar bone until the process of eruption begins. cl, cervical loop; dp, dental papilla; df, dental follicle; dl, dental lamina; eee, external enamel epithelium; iee, internal enamel epithelium; oe, oral epithelium; sr, stellate reticulum.
- Successional teeth have deciduous predecessors and consist of the incisors, canines and premolars. Formation begins between 20 weeks in utero and 10 months of age.
- Accessional teeth have no deciduous predecessors and consist of the three permanent molars. Formation begins between the fourteenth week in utero and 5 years of age.

**The molecular control of tooth development**
The histological basis of tooth development has been understood for some time, but in recent years progress has been made in understanding molecular mechanisms that underlie the process of odontogenesis using mouse models (Box 4.1). The generation of a tooth requires coordinated molecular signalling between epithelium of the early jaws and the underlying neural crest cells that migrate into these regions (Cobourne & Sharpe, 2003; Tucker & Sharpe, 2004).

**Patterning the dentition: a molecular code for tooth shape**
The mouse jaw is demarcated into future incisor and molar-forming regions on a molecular basis before any morphological evidence of tooth development has occurred. Fgf8 is a signalling molecule belonging to the fibroblast growth factor (Fgf) family, which localizes to the future molar regions of the jaw epithelium. In contrast, Bmp4, a signalling molecule of the bone morphogenetic protein (Bmp) family, localizes to the early incisor epithelium. These signalling molecules induce the expression of a number of homeobox-containing genes that encode transcription factor proteins in the tooth-forming neural crest-derived ectomesenchyme of the early jaws.
- Fgf8 induces expression of *Barx1* and *Dlx2* in the molar regions.
- Bmp4 induces expression of *Msx1* and *Msx2* in the incisor regions.

*Figure 4.2* Successional teeth form as a result of localized proliferation within the dental lamina associated with each deciduous tooth germ (left, arrowed). In contrast, accessional teeth form as a result of backward extension of the dental lamina into the posterior region of the jaws (right, arrowed). Courtesy of Dr Barry Berkovitz.
Initially, signalling from the epithelium to neural crest cells that migrate into the jaws can induce expression of a range of genes. However, expression domains very rapidly become established and then independent of epithelial signalling. It has been suggested that the differing combinations of gene expression patterns act to specify tooth shape (Sharpe, 1995). The ‘odontogenic homeobox code’ predicts that for each tooth-forming region of the early maxilla and mandible, the morphology of the developing tooth is dictated by a specific combination of homeobox genes within the ectomesenchyme (Box 4.2). Thus, for the molar region of mouse jaws, an overlapping code of Barx1 and Dlx2 exists (Fig. 4.3). There are several important points to note with regard to the homeobox model (Sharpe, 2001):

- One specific gene is not responsible for each tooth shape;
- The absence of a gene is as important as the presence in terms of reading the code; and
- Because the code is overlapping it can specify a wide range of subtle differences in tooth shape.

This final point is important because the peripheral regions of overlap between teeth of different classes appear to be particularly vulnerable with regard to human hypodontia. In these cases, teeth at the end of a series (upper lateral incisors, lower second premolars, third molars) are those most commonly congenitally absent.

**Initiation of tooth development**

Once the ectomesenchyme within each mouse jaw has been regionalized into presumptive incisor and molar domains, tooth development is initiated within the jaw epithelium. A key player in this process is sonic hedgehog (Shh), a protein produced in localized regions of jaw epithelium where the teeth are going to form. Shh drives...
Development of the dentition

proliferation of the dental lamina within these regions, resulting in formation of the tooth buds; if Shh signalling is lost in the early dental lamina, teeth fail to develop. Restriction of Shh production is therefore important in ensuring that teeth develop in the correct regions of the jaws and this is orchestrated by molecular compartmentalization of the jaw epithelium into tooth-forming and non-tooth-forming regions.

Specifically, expression of the \textit{Shh} gene is restricted to the tooth-forming regions because it is repressed throughout the non-dental epithelium by another signalling molecule called \textit{Wnt7b}. Therefore, tooth formation in the correct regions of the jaws is established via reciprocal expression domains between two different signalling molecules within the jaw epithelium (Fig. 4.4).

Once the tooth bud has formed, a number of homeobox-encoding genes subsequently localize to the condensing dental papilla, including \textit{Msx1} and \textit{Pax9}. These genes play an important role in mediating later signalling between the underlying ectomesenchyme and the epithelial bud as tooth development progresses to the cap stage (Fig. 4.5). A loss of either gene leads to the arrest of tooth development at the bud stage in the mouse. Mutations associated with human \textit{MSX1} and \textit{PAX9} have also been implicated in hypodontia.

**Progression to the cap stage: the production of shape**

Formation of the tooth bud heralds an important transition for the tooth germ, from bud to cap stage. During the cap stage, the essential shape of the tooth crown is established by folding of the epithelial bud. Folding is mediated by a small group of

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**Box 4.2 Transformation of tooth type by manipulation of homeobox genes**

An incisor tooth germ has been converted into one demonstrating a molar crown shape by manipulating homeobox gene expression in the future incisor-forming region of the mouse jaw. \textit{Barx1} is normally expressed in molar-forming mesenchyme of the jaws, this expression being established by Fgf8 signalling from the overlying epithelium. \textit{Barx1} expression is restricted to the molar regions by antagonistic signalling from Bmp4, which is present in the incisor-forming epithelium and represses \textit{Barx1} in the underlying mesenchyme. By artificially inhibiting Bmp4 activity in the incisor region of cultured jaws, the expression of \textit{Barx1} can be extended into the incisor region. Moreover, Bmp4 normally induces \textit{Msx1} in the incisor mesenchyme; therefore a loss of Bmp4 in this region also reduces expression of \textit{Msx1}. The code of these early incisor regions is therefore altered into one resembling a molar region: a gain of \textit{Barx1} and loss of \textit{Msx1}. Transplantation of these early incisor regions into sites that allow tooth development to progress towards completion results in the formation of multicusp ed molar teeth rather than incisors. Thus, an experimental alteration of homeobox gene expression can re-specify the identity of developing teeth, which is powerful evidence in support of the ‘odontogenic homeobox code’ (Tucker et al, 1998).
non-dividing cells within the epithelium of the tooth germ, called the primary enamel knot.

Cells of the enamel knot produce a wealth of signalling molecules and transcription factors, which influence differential growth of the epithelial cap and mediate changes in its shape. The primary enamel knot disappears during the late cap stage through
Development of the dentition

Figure 4.4 Expression of Shh and Wnt7b in the early maxilla (upper panel) and mandible (lower panel). Shh signalling is restricted to the early incisor and molar teeth, whilst Wnt7b is expressed in a reciprocal manner, in the regions of the jaw epithelium that will not form teeth.

Figure 4.5 Expression of Msx1 and Pax9 in the dental mesenchyme surrounding bud stage molar teeth.

programmed cell death but in teeth with more complex crown structures, such as molars, a series of secondary enamel knots develop in the epithelium to sculpt more intricate cusp patterns (Fig. 4.6). Whilst the crown shape of a tooth is formed by cellular activity within the epithelial component of the tooth germ during the cap and bell stages, the molecular instructions for shape are established within the ectomesenchymal component much earlier in the developmental process.
Postnatal development of the dentition

When a child is born, mineralization of all the deciduous tooth crowns is well underway, with this process also beginning in the first permanent molars. The deciduous dentition will start to erupt in the first year of life and be completed by the end of the third. The permanent dentition is heralded by eruption of the first molars at around 6 years of age and completed in most cases by the appearance of third molars in the late teenage years.

The jaws at birth

At birth, the maxillary dental arch is characteristically horseshoe-shaped while the mandibular arch assumes a wider U-shape. The mucous membrane of both the maxilla and mandible is thickened in the newborn to produce gum pads, which cover the alveolar processes containing the developing deciduous teeth (Fig. 4.7). Formation of dentine and enamel begins in the deciduous tooth germs at around 4 to 6 months in utero and crown formation is completed during the first year of life. Each tooth is present within an individual segment of the gum pad, demarcated by characteristic transverse grooves within the mucous membrane. The grooves are particularly prominent distal to the deciduous canines in both arches and are known here as the lateral sulci.

The maxillary and mandibular gum pads have no fixed relationship during early life but the maxilla is usually positioned ahead of the mandible, resulting in a varying degree of increased ‘overjet’. The gum pads rarely occlude but if they do this generally occurs in the molar region, leaving a prominent anterior space for the tongue to occupy, which facilitates suckling (Fig. 4.8). The variation in gum pad relationship at birth means it cannot be used to predict the future jaw relationship.

Occasionally a child is born with teeth already present or that undergo precocious eruption within the oral cavity (Fig. 4.9):
Natal teeth are present at birth; Neonatal teeth erupt within the first month of life; and Pre-erupted teeth appear within the second and third months of life. Natal and neonatal teeth occur in around 1:3000 children and are usually mandibular deciduous incisors, although rarely they can be supernumerary teeth (Leung & Robson, 2006). They are often poorly developed, mobile and can cause ulceration of the mouth and nipple during suckling. If these teeth give rise to problems they should be removed.
The deciduous dentition

The first year of life is characterized by rapid jaw growth in both the anteroposterior and transverse planes of space. This is particularly marked transversely during the first six months due to the presence of sutures within the midpalatal seam of the maxilla and mandibular symphysis. Thereafter, most dimensional change is the result of backward and outward extension of the alveolar processes (Box 4.3). This growth usually ensures that enough space is available in both jaws for the deciduous teeth to erupt without crowding, even though the deciduous tooth germs are often quite crowded within the jaws at birth. The early ‘overjet’ associated with the gum pads usually diminishes in the first six months as a result of rapid facial growth and increasing mandibular prognathism.

Eruption of the deciduous dentition begins at approximately 6 months of age (Fig. 4.10) and is complete by around $2\frac{1}{2}$ to 3 years (Fig. 4.11). The sequence can be variable (Fig. 4.12), but is characteristically:

**Figure 4.9** Natal teeth removed from a 6-week-old baby. Courtesy of Zahra Kordi.

**Figure 4.10** A sight for every proud parent, eruption of the first deciduous teeth. Courtesy of Miles Cobourne.
Development of the dentition

Box 4.3  How much growth occurs in the dental arches during dental development?

The jaws grow considerably in size from birth to around 6 months of age (Clinch, 1934). After this time, very little increase in the dimensions of the tooth-bearing regions takes place in the deciduous dentition (Foster et al, 1972). During eruption of the permanent dentition, some transverse changes do occur in intercanine width, but the dimensions are small. A maximum increase of no more than 2 mm can be expected in the mandible and 4 mm in the maxilla, occurring up to the age of 12 years, with some of this increase being lost by the end of the second decade. This increase in the intercanine width is achieved largely through alveolar rather than skeletal change, during eruption of the permanent incisors and canines. In contrast to the maxilla, very little change occurs in the mandibular intercanine width once the incisor teeth have erupted, which is one of the reasons why mandibular incisor irregularity is so common. Some increase in the intermolar width is also seen in the mandibular and maxillary arches, and whilst this is also in the region of 2 and 4 mm respectively, this change differs from the intercanine width in that it occurs progressively from the age of 12 years through to 18 (Moyers et al, 1976). It should be remembered that wide individual variation is associated with all these dimensional changes, but generally there is more growth in boys than girls and the intermolar width will increase more than the intercanine width and over a longer period of time (Lee, 1999).

Figure 4.11  The complete deciduous dentition is usually present by around 3 years of age. Note the variation in overbite. Courtesy of Rupert Cobourne (left) and Isabelle George (right).

- Mandibular central incisors erupt first;
- Followed by the maxillary central incisors and soon after by the maxillary lateral incisors;
- Eruption of the mandibular lateral incisors completes the incisor dentition;
- First deciduous molars then erupt prior to the canines; and
- Mandibular and then maxillary second molars erupt.
The complete deciduous dentition is classically associated with a number of characteristic features:
- The arches are semi-circular in shape;
- The incisors are spaced, upright and associated with a positive overjet and overbite;
- Primate or anthropoid spaces are present, mesial to the maxillary deciduous canines and distal to the mandibular canines;
- The molar and canine relationship is class I; and
- The distal edges of the second deciduous molars are flush in the vertical plane.

However, these features are rarely all seen together and variation is very much the norm (Box 4.4).

**Figure 4.12** Eruption ages of deciduous teeth from a sample of indigenous British subjects. The mean value (in months) is indicated by the central diamond, whilst two standard deviations are shown by the horizontal bar. Redrawn from Leighton BC (1968). Eruption of deciduous teeth. *Dent Pract* 200:836–42.

**Box 4.4 Does a normal deciduous dentition exist?**

Foster and Hamilton studied the complete deciduous dentitions of 100 children aged between 2½ and 3 years. There was not a single child within this sample that had incisor spacing, primate spaces, upright incisors and flush terminal molars all present within the same dentition. Amongst these occlusal features, the presence of primate spaces was the most constant finding. Approximately one-third of the sample had spacing between all the incisor teeth, but the majority only had spacing between some of these teeth. Around half of the children had second deciduous molars that were flush in the terminal plane. The greatest variation was seen in the incisor relationship, with only a fifth of children having a normal overbite and almost three-quarters having some increase in the overjet (Foster & Hamilton, 1969).
Development of the dentition

Predicting a future malocclusion in the permanent dentition, based upon features of the deciduous dentition, is generally unreliable (Box 4.5). In addition, the deciduous dentition is not static and during the next two to three years, prior to eruption of the permanent teeth, a number of changes can occur:

- Occlusal wear of the teeth and more forward mandibular growth relative to the maxilla can produce an edge-to-edge incisor relationship and alteration of the molar relationship;
- Interproximal wear or premature loss of tooth substance due to caries can also produce an alteration of the molar relationship; and
- A prolonged digit or dummy sucking habit can induce an anterior open bite and posterior crossbites.

The mixed dentition

During the mixed dentition, both deciduous and permanent teeth are present. The permanent dentition is established in three phases:

- Eruption of first molars and incisors;
- Eruption of premolars, canines and second molars; and
- Eruption of third molars.

Eruption of first molars and incisors

Variations in the eruption sequence of the permanent teeth are common, but as a general rule the mandibular teeth erupt prior to the maxillary. Permanent teeth begin their eruption once crown formation is completed, taking between two and five years.
to reach the alveolar crest and a further one to two years to reach occlusion. Root development is usually completed within 2 years of eruption (Table 4.1).

The mixed dentition stage is heralded by eruption of the first permanent molars at around 6 years of age. This is generally followed by eruption of the first and then second permanent incisors between the ages of 7 and 8 years (Fig. 4.13), although in the mandible the first permanent incisors can erupt before or with the first molars.

During this phase of development the utilization of dental arch perimeter is crucial for establishing:

- Alignment of the permanent incisors; and
- Molar occlusion.

The collective mesiodistal dimensions of the permanent incisor tooth crowns are larger than their deciduous predecessors by approximately 5-mm in the mandible and 7-mm in the maxilla, a deficit known as the incisor liability. This increased space requirement for the permanent incisor teeth is gained from the following (Fig. 4.14):

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**Table 4.1  Chronology of permanent tooth development and eruption**

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<th>Maxillary teeth</th>
<th>Crown completion</th>
<th>Eruption</th>
<th>Root completion</th>
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<th>Mandibular teeth</th>
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All dates in years. Adapted from Berkovitz, Holland and Moxham (2009), *Oral Anatomy Histology and Embryology* (St Louis: Mosby).
Residual spacing present between the deciduous incisors;

- Permanent incisors erupting into a more labial position (particularly in the maxilla) than their deciduous predecessors and therefore occupying a greater arch perimeter;

- Deciduous canines being moved distally as the incisors erupt; and

- Transverse increase in the intercanine arch width.

The initial occlusal relationship of the first permanent molars is directly influenced by the deciduous second molar position. If these teeth are flush in the terminal plane then the first permanent molars assume a cusp-to-cusp relationship when they erupt. In order to establish a class I molar relationship, some mesial movement of the mandibular first permanent molar will be required. This is achieved by two possible mechanisms (Fig. 4.14):

- Early mesial shift where the lower primate space (distal to the mandibular canine and therefore adjacent to the deciduous molar occlusion) is closed by forward movement of the mandibular molar dentition as the first permanent molar erupts; and

- Late mesial shift where the mandibular first molar only moves in a mesial direction after loss of the second deciduous molar; because the mesiodistal length of the mandibular second deciduous molar crown is greater than the maxillary, the loss of these teeth results in greater mesial movement of the mandibular first molar.

Occasionally, a mesial step occlusion of the deciduous molars might have been established prior to eruption of the permanent molars; in these cases they will tend to erupt directly into a class III occlusal relationship. Alternatively, there may be a distal step occlusion, in which case the first molars will erupt into a class II relationship. However, it should be remembered that all of these relationships affecting the deciduous molars and therefore establishment of the molar occlusion will be significantly influenced by the relative amounts of forward maxillary and mandibular growth that occur during this time.

During this period of the mixed dentition, a number of features associated with the maxillary incisor teeth can be present prior to establishing the early permanent dentition:

- Transient anterior open bite; and

- Physiological spacing (ugly duckling) stage.

A transient anterior open bite can be associated with eruption of the incisors as they approach the occlusal plane and this invariably improves with time. The maxillary
Establishing the permanent incisor dentition

Space for permanent incisors obtained from
- residual deciduous spacing (black arrows)
- labial eruption path (green arrows)
- primate spaces (red arrows)

Establishing the permanent molar dentition

Early mechanism

Primate space

distal step

Flush terminal plane

flush terminal plane

Class I

Late mechanism

Leeway space (greater in lower)

Class I

Figure 4.14 Establishing the incisor and molar occlusions.
central incisors can also be quite distally inclined when they first erupt, which produces a midline diastema between them. This physiological spacing or ‘ugly duckling’ stage is thought to be due to the combined effect of the maxillary incisor apices being initially quite close together in the anterior maxilla as the incisors erupt and lateral pressure from the erupting maxillary lateral incisors and canines (Fig. 4.15). As these teeth erupt this pressure is transferred from the apical region of the maxillary incisors more coronally, improving their inclination and usually closing the diastema.

**Eruption of premolars, canines and second molars**
Further development of the dentition is characterized by eruption of the premolar and canine teeth, between the incisors at the front of the arch and the first molars at the back. Eruption of these teeth normally takes place between the ages of 9 and 12 years and as a general rule:
- In the mandible, the canine erupts ahead of the first premolar and this is followed by the second premolar; and
- In the maxilla, the first premolar usually erupts first, followed by the second premolar and then canine.
The consequences of these eruption patterns are that the mandibular second premolar and maxillary canine teeth are the most vulnerable for potential crowding (Fig. 4.16).

In contrast to the incisor dentition, the combined mesiodistal length of the deciduous canine and molar teeth is greater than that of the permanent canine and premolars, an excess known as the leeway space. In the maxilla, this is approximately 1.5-mm per quadrant, whilst in the mandible it is closer to 2.5-mm, because of the increased size of the lower second deciduous molar. However, successful alignment of the canine and premolar teeth within each quadrant relies upon a number of factors:

- The size of the leeway space;
- Previous encroachment by the incisors into the canine region; and
- The mechanism of molar relationship correction.

Clearly, the larger the leeway space present within each quadrant, the more potential space there will be for eruption of the permanent canine and premolar teeth. However, if earlier alignment of the permanent incisor dentition has utilized any space within the deciduous canine regions, this will now be at the expense of that available for the permanent canines. This can be particularly relevant in the maxillary arch, where the permanent canine has a long path of eruption and often appears after the premolar teeth. In addition, if substantial forward movement of the mandibular first permanent molar has occurred during establishment of the molar relationship or following the early loss of deciduous second molars, this will also leave less space for permanent canine and premolar teeth to erupt uncrowded. In this scenario it is often the mandibular second premolar that becomes crowded (Fig. 4.16).

The final part of this phase of dental development occurs with eruption of the second permanent molars, usually at around 12 years of age. Eruption of these teeth

**Figure 4.16** Crowding of the maxillary canine and mandibular second premolar. The UR3 is buccally crowded due to timing of eruption, the LL5 is crowded due to early loss of the LLE.
is often associated with some reduction in arch length, which manifests as increased crowding, particularly of the lower incisors (Lundy & Richardson, 1995). If the second permanent molars erupt precociously before the premolar dentition is established, in the lower jaw especially this can result in a considerable arch length reduction and crowding of the second premolar tooth. Occasionally, there is a lack of space in the posterior regions of the maxillary and mandibular dental arches and the second molars can become impacted (Fig. 4.17).

**Third molar eruption**
The appearance of the third molars is the final stage in establishing the permanent dentition. These teeth usually erupt between 17 and 21 years of age, but this is characteristically variable and in many cases they either remain unerupted or fail to develop completely. Controversy exists as to the effect of third molar impaction and eruption on mesial drift within the dental arches, particularly the mandibular, and the subsequent effect that this can have on the position of the incisors (Box 4.6). It is likely that third molar eruption, rather than impaction, does have an effect upon mandibular arch crowding often seen during the late teenage years, but this effect is one component of a multifactorial condition and prophylactic third molar extraction is unlikely to remove the problem (Richardson, 2002). The National Institute for Health and Clinical Excellence (NICE) in the UK has recommended that prophylactic removal of pathology-free impacted third molars, which includes removal to prevent occlusal changes in the incisor regions, be discontinued.

**Occlusal changes in the permanent dentition**
The dentition does not remain static throughout life as longitudinal studies on individuals who have not undergone orthodontic treatment have shown (Bishara et al, 1989; Moorrees et al, 1969; Sinclair & Little, 1983). Generally, the dental arches in males grow larger and for longer than in females during both the preadolescent and adolescent periods.

Apart from the effects of dental disease, which can result in major occlusal changes if teeth are lost, there is a gradual and progressive loss in arch length as age increases, particularly in the lower arch of females. The net effect of this is an increase
Crowding of the mandibular incisors is one of the most common problems encountered in the permanent dentition and lower incisor alignment is one of the most likely things to relapse after orthodontic treatment. Studies of untreated subjects followed from the mixed dentition into adulthood have shown a tendency for the width and length of the mandibular arch to decrease and for crowding of the anterior teeth to increase (Sinclair & Little, 1985).

Primary crowding refers to a discrepancy of tooth dimension and jaw size, mainly determined genetically. Secondary crowding is caused by environmental factors, including local space conditions in the dental arches and the position and function of the tongue, the lips and the buccal musculature. Tertiary crowding occurs during adolescence and post-adolescence with a predilection for the lower labial segment. Factors contributing to late lower incisor crowding may include:

- Mandibular growth rotations;
- Anterior component of occlusal force;
- Physiologic mesial drift;
- Soft tissue maturation;
- Degenerative periodontal changes allowing teeth to drift under light pressures;
- Change in diet and lack of interproximal wear;
- Tooth size and shape;
- Tooth loss and drifting leading to changes in occlusal function; and
- Mandibular third molars—presence and position.

In reality, all of these factors may contribute to the development of late lower incisor crowding but the contribution of developing third molars is regarded as being minimal as crowding can develop even in the absence of their development. The prophylactic removal of developing third molars is not recommended to prevent late lower incisor crowding.

Late lower incisor crowding in an untreated mandibular arch.
in lower incisor crowding with age, although these changes are variable and difficult to predict. It is interesting to note that the changes found in untreated individuals in general are very similar in nature to those found in patients following orthodontic treatment.

**Further reading**


**References**


