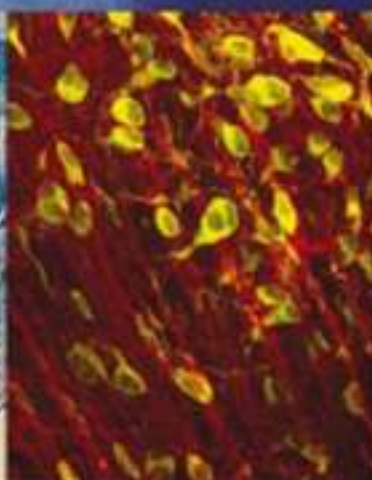
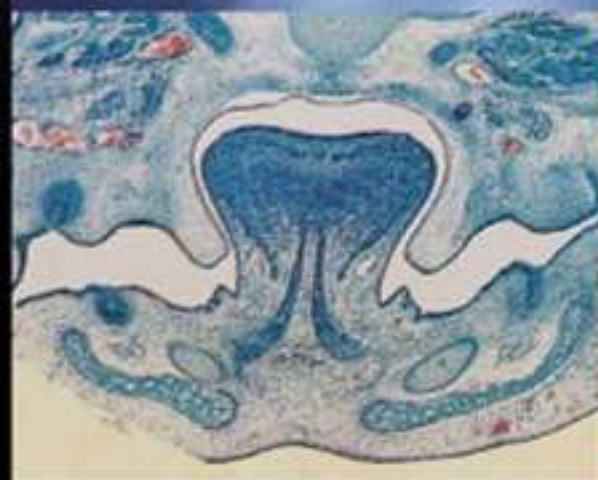
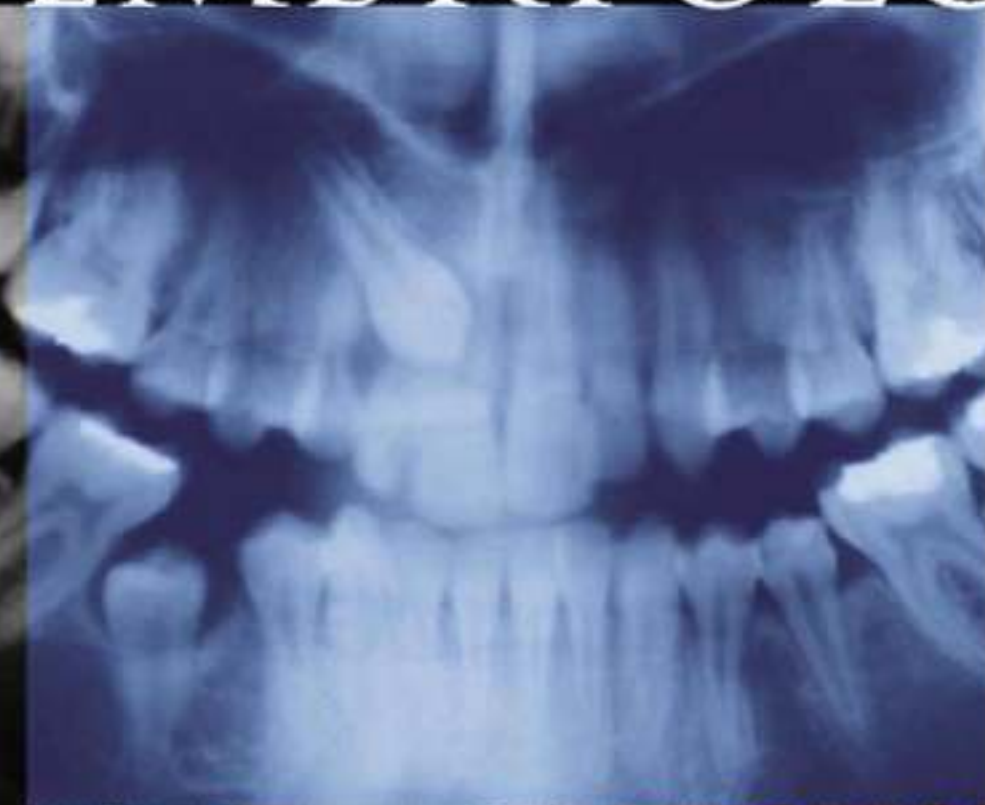


Fourth Edition

ORAL ANATOMY HISTOLOGY and EMBRYOLOGY



B. K. B. Berkovitz • G. R. Holland • B. J. Mox

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Commissioning Editor: Alison Taylor
Development Editor: Lulu Stader
Project Manager: Jane Dingwall
Designers: Sarah Russell/Kirsteen Wright
Illustrator: Marion Tasker (new figures)
Illustration Manager: Merlyn Harvey

Fourth Edition



ORAL ANATOMY, HISTOLOGY *and* EMBRYOLOGY

B. K. B. Berkovitz BDS, MSc, PhD, FDS (Eng)

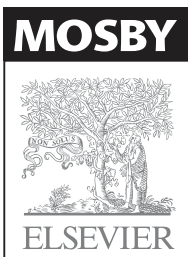
Emeritus Reader, Anatomy and Human Sciences, Biomedical and Health Sciences, King's College, London, UK

G. R. Holland BSc, BDS, PhD, CERT ENDO

Professor, Department of Cariology, Restorative Sciences and Endodontics, School of Dentistry and Department of Cell and Developmental Biology, University of Michigan, Ann Arbor, USA

B. J. Moxham BSc, BDS, PhD

Professor of Anatomy, Cardiff School of Biosciences, Cardiff University, Cardiff, UK



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Preface

This, the fourth edition of our book, follows the form and principles we established in the earlier third edition. Thus, although in that third edition we changed the format of the book from a textbook and atlas to a textbook, we retained the considerable number of illustrations, believing strongly that anatomical and histological textbooks must present information in a visual format. This fourth edition maintains this principle and we have expanded the book considerably to incorporate nearly 1100 illustrations (over twenty percent of the illustrations being new). This time, the expansion of the book has been accomplished without removing any of the topics covered in the previous edition. On the contrary, we have added a chapter on ageing of orodental tissues, because of the increased longevity of humans and the consequences of this to the types of patient seeking dental treatment. This chapter also includes some information concerning forensic dentistry and dental archaeological material. As for the earlier editions of our book, we have preferred, wherever possible, to use photographs and photomicrographs for our illustrations rather than diagrams or drawings, however expertly and artistically presented, as we wish to encourage students to look at 'real' material, warts and all!

As for the previous edition, we are adamant that dental students should not just learn basic ('core') material for oral anatomy, histology and embryology. These are important subjects that provide essential scientific material that should be appreciated by all dental surgeons who wish to consider themselves professionals (in all senses of the term). Indeed, it seems to us that a book such as this that attempts to be encyclopaedic in scope is increasingly necessary where there is a shortage of experienced teachers for the subjects covered! Furthermore, because of the increasing shortage of teachers with clinical backgrounds in dentistry, we have expanded the 'clinical considerations' section in most chapters of our book.

It is, unfortunately, increasingly difficult to obtain funding for basic dental research that involves significant amounts of morphological investigation. And yet, such research does continue and considerable advances in our knowledge of the microscopic anatomy and development of orodental tissues have occurred in recent times. All chapters have been reviewed. In some (e.g. enamel integuments), only minor changes were deemed necessary whereas in others (e.g. alveolar bone and the salivary glands) we have made significant additions. We have also taken the opportunity to improve some of the illustrations where no changes in the text were required. For example, all of the photographs relating to tooth morphology are new. Finally, we are, as ever, grateful to those readers who have provided comments and criticisms. We do not pretend to be infallible and would ask for indulgence if we have strayed from scientific rectitude!

2008

B. K. B. Berkovitz

G. R. Holland

B. J. Moxham

Acknowledgements

We are most grateful to the numerous colleagues who generously provided photographic material for our book and these have been acknowledged in the text. In addition, we owe a debt of thanks to the following researchers for their constructive criticisms of draft chapters: Dr T. Arnett, Dr A. E. Barrett, Dr J. H. Bennett, Dr S. R. Berkovitz, Dr R. Brooks, Dr M. Cobourne, Dr R. J. Cook, Professor M. C. Dean, Dr A. Grigoriadis, Dr J. D. Harrison, Dr M. Ide, Professor R. W. A. Linden, Dr H. Liversidge, Professor F. McDonald, Dr T. A. Mitsiadis, Professor P. R. Morgan, Dr I. Needleman, Professor R. G. Oliver, Dr C. Orr, Professor R. M. Palmer, Professor T. Pitt-Ford, Dr G. D. Procter, Professor P. T. Sharpe, Dr A. Thexton, Professor T. J. Watson.

We are grateful to Ms K. Kirwan for much photographic help and for producing a number of the new line diagrams. We also acknowledge photographic help from Mr G. Fox.

In vivo appearance of the oral cavity



Fig. 1.1 The oral cavity.

The oral cavity (Fig. 1.1) extends from the lips and cheeks externally to the pillars of the fauces internally, where it continues into the oropharynx. It is subdivided into the vestibule external to the teeth and the oral cavity proper internal to the teeth. The palate forms the roof of the mouth and separates the oral and nasal cavities. The floor of the oral cavity consists of mucous membrane covering the mylohyoid muscle and is occupied mainly by the tongue. The lateral walls of the oral cavity are defined by the cheeks and retromolar regions. The primary functions of the mouth are concerned with the ingestion (and selection) of food, and with mastication and swallowing. Secondary functions include speech and ventilation (breathing).

LIPS

The lips (Fig. 1.2) are composed of a muscular skeleton (the orbicularis oris muscle) and connective tissue, and are covered externally by skin and internally by mucous membrane. The red portion of the lip (the vermilion) is a feature characteristic of humans. The sharp junction of the vermilion and the skin is termed the vermilion border. In the upper lip the vermilion protrudes in the midline to form the tubercle. The lower lip shows a slight depression in the midline corresponding to the tubercle. From the midline to the corners of the mouth the lips widen and then narrow. Laterally, the upper lip is separated from the cheeks by nasolabial grooves. Similar grooves appear with age at the corners of the mouth to delineate the lower lip from the cheeks (the labiomarginal sulci). The labiomental groove separates the lower lip from the chin. In the midline of the upper lip runs the philtrum. The corners of the lips (the labial commissures) are usually located adjacent to the maxillary canine and mandibular first premolar teeth. The lips exhibit sexual dimorphism; as a general rule, the skin of the male is thicker, firmer, less mobile and hirsute. The lips illustrated are lightly closed at rest and are described as being 'competent'.

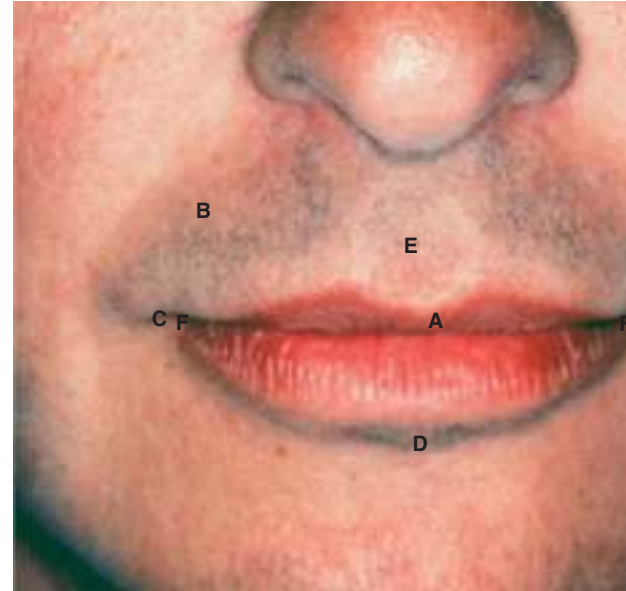


Fig. 1.2 The lips. A = tubercle; B = nasolabial groove; C = labiomarginal sulcus; D = labiomental groove; E = philtrum; F = labial commissure.

Incompetent lips (Fig. 1.3) describe a situation where, with the facial muscles relaxed, a lip seal is not produced. It is important to note that this is distinguished from conditions where the lips are held apart habitually (as often occurs with 'mouth breathing'). The posture illustrated in Figure 1.3 can be described as being 'incompetent', as the lips would be capable of producing a seal if there were no interference caused by the protruding incisors. When the lips are incompetent, the pattern of swallowing is often modified.



Fig. 1.3 Incompetent lips.

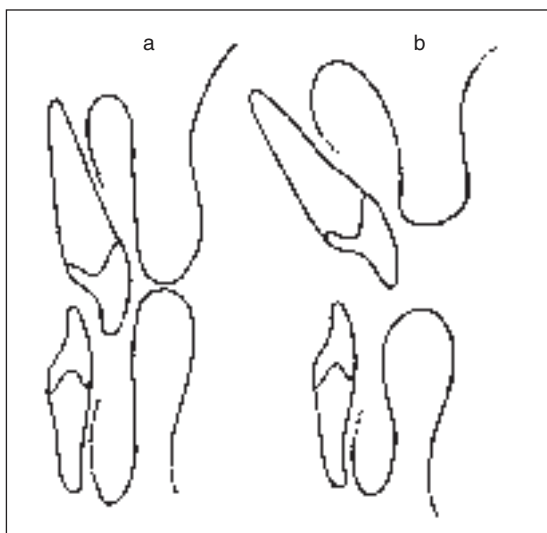


Fig. 1.4 (a) Competent lips maintaining normal inclination of the incisors. (b) Incompetent lips resulting in proclination of the upper incisors.

anterior oral seal. Accordingly, an oral seal may be formed by contact between the lower lip (or the tongue) and the palatal mucosa, and there may even be a forcible tongue thrust. It has been estimated that in the UK and the USA about 50% of children at the age of 11 years have some degree of lip incompetence.

The position and activity of the lips are important in controlling the degree of protrusion of the incisors. With competent lips (Fig. 1.4a) the tips of the maxillary incisors lie below the upper border of the lower lip, this arrangement helping to maintain the 'normal' inclination of the incisors. With incompetent lips (Fig. 1.4b) the maxillary incisors may not be so controlled and the lower lip may even lie behind them, thus producing an exaggerated proclination of these teeth. If there is tongue thrusting to provide an anterior oral seal, further forces that tend to protrude the incisors are generated. A tight, or overactive, lip musculature may be associated with retroclined incisors.

ORAL VESTIBULE

The oral vestibule (Fig. 1.5) is a slit-like space between the lips and cheeks, and the teeth and alveolus. At rest, or with the mouth open, the vestibule and oral cavity proper directly communicate between the

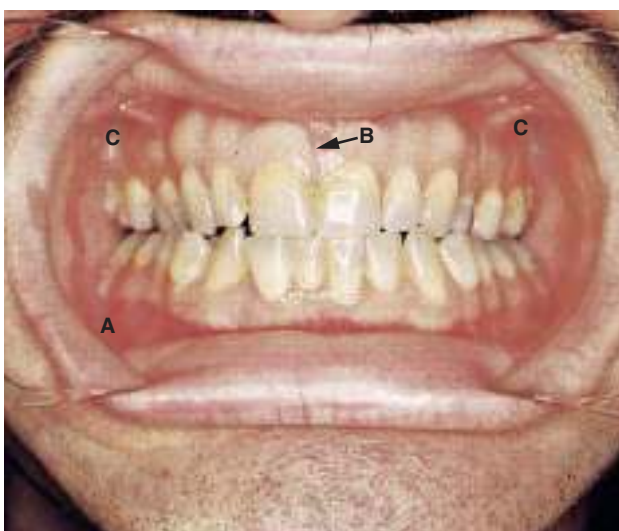


Fig. 1.5 The oral vestibule. A = vestibular fornix; B = upper labial frenum; C = frenum in the region of the upper premolar teeth.



Fig. 1.6 Midline diastema between upper central incisor teeth, produced by an enlarged labial frenum.

teeth. When the teeth occlude, the vestibule is a closed space (which communicates with the oral cavity proper only behind the last premolar and retromolar regions). This provides a pathway for the admission of nutrients in a patient whose jaws have been wired together after a fracture.

The mucosa covering the alveolus is reflected on to the lips and cheeks, forming a trough or sulcus called the vestibular fornix. In some cases, in the sulcus, the mucosa may show distinct sickle-shaped folds extending from the cheeks and lips to the alveolus. The upper and lower labial frenula are such folds in the midline. Other folds of variable length may traverse the sulcus in the region of the canines or premolars. These frenula are said to be more pronounced in the lower sulcus. All frenula consist of loose connective tissue and are neither muscle attachments nor associated with large blood vessels.

The upper labial frenum should be attached well below the gingival crest. A large frenum with an attachment near this crest may result in a midline diastema between the maxillary first incisors. Prominent frenula may also influence the stability of dentures.

GINGIVA

The gums or gingivae, the oral mucosa covering the alveolus (which supports the roots of the teeth) and the necks (cervix) of the teeth, are divided into two main components (Fig. 1.7). The gingiva lining the lower part of the alveolus is loosely attached to the underlying bone via a diffuse submucosa and is termed the alveolar mucosa. It is separated from the gingiva (which covers the upper part of the alveolus and the necks of the teeth) by a well defined junction, the gingival margin. The alveolar mucosa appears red, the gingiva pale pink. The colour differences relate to differences in the type of keratinization and the proximity to the surface of underlying blood vessels. In some cases, the blood vessels may readily be seen coursing beneath the alveolar mucosa (Fig. 1.7b). The gingiva may be further subdivided into attached gingiva and the free gingiva. The attached gingiva is firmly attached to the periosteum of the alveolus and to the teeth, and the free gingiva is attached around the cervical region of the tooth. A groove (the gingival groove) may be seen between the free and attached gingiva. This groove corresponds roughly to the floor of the gingival sulcus that is formed between the inner surface of the attached gingiva from the enamel surface of the tooth (Fig. 14.36). The interdental papilla is that part of the gingiva that fills the space between adjacent teeth. A feature of the attached gingiva is stippling. The degree of stippling varies from individual to individual and according to age, sex and the health of the gingiva. Unlike the alveolar gingiva, the free gingiva is not stippled. On the lingual surface

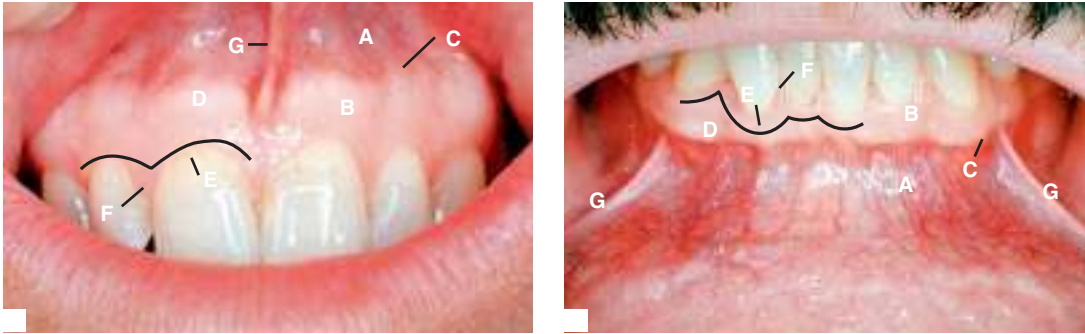


Fig. 1.7 Upper (a) and lower (b) A = alveolar mucosa; B = gingival junction, D = attached gingiva; E = interdental papilla; F = interdental papilla; G = frenum.

jaw the attached gingiva is sharply differentiated from the alveolar mucosa towards the floor of the mouth by a mucogingival line. On the palate, however, there is no obvious division between the attached gingiva and the rest of the palatal mucosa as this whole surface is keratinized masticatory mucosa.

CHEEKS

The cheeks extend intra-orally from the labial commissures anteriorly to the ridge of mucosa overlying the ascending ramus of the mandible posteriorly. They are bounded superiorly and inferiorly by the upper and lower vestibular fornices (Fig. 1.5). The mucosa is non-keratinized and, being tightly adherent to the buccinator muscle, is stretched when the mouth is opened and wrinkled when closed. Ectopic sebaceous glands without any associated hair follicles may be evident in the mucosa and are called Fordyce spots (Fig. 1.8). They are seen as small, yellowish-white spots,

occurring singly or in clusters on the margin of the lips or the cheeks (and other sites such as genital skin). They can be present in the majority of patients and are said to increase with age.

Few structural landmarks are visible in the cheeks. The parotid duct drains into the cheek opposite the maxillary second molar. The duct opening may be covered by a small fold of mucosa termed the parotid papilla (see Fig. 1.25). In the retromolar region, in front of the fauces, a fold of mucosa containing the pterygomandibular raphe extends from the upper to the lower alveolus (Fig. 1.9). The pterygomandibular space, in which the lingual and inferior alveolar nerves run, is lateral to this fold and medial to a ridge produced by the mandible. The groove lying between the ridges produced by the raphe and the mandible is an important landmark for insertion of a needle for anaesthesia of the lingual and inferior alveolar nerves (see

PALATE

The palate forms the roof of the mouth and separates the oral and nasal cavities. It is divided into the immovable hard palate anteriorly and the movable soft palate posteriorly. As their names imply, the hard palate is bony while that of the soft palate is fibrous.

The hard palate is covered by a masticatory, keratinized mucosa that is firmly bound down to underlying bone and also contains some sebaceous glands. It shows a distinct prominence immediately behind the maxillary incisors, the incisive papilla (Fig. 1.10). This papilla overlies a fossa through which the nasopalatine nerves enter on to the palate. Running posteriorly in the midline from the papilla runs a ridge called the palatine raphe. Here, the oral mucosa is attached directly to the underlying bone in the presence of a submucous layer of tissue. Palatine rugae are transverse ridges in the anterior part of the hard palate that radiate symmetrically from the incisive papilla and the anterior part of the palatine raphe. Their pattern is unique to the individual and, like fingerprints, can be used for forensic purposes to help identify individuals. At the



Fig. 1.8 Inner surface of the cheek, showing Fordyce spots as yellowish patches.

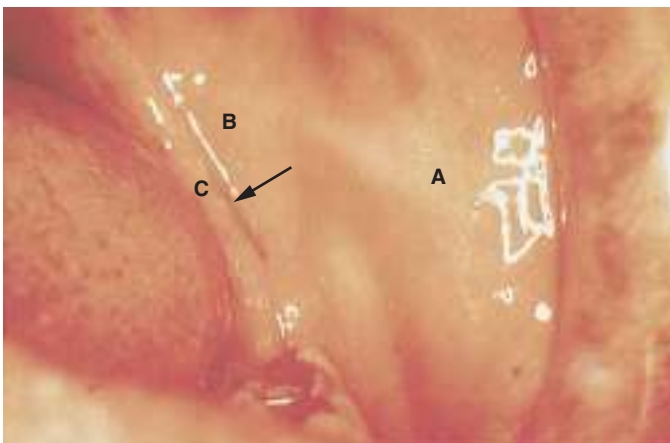


Fig. 1.9 Retromolar region. A = inner surface of cheek; B = ridge overlying ramus of mandible; C = ridge overlying the pterygomandibular raphe. The arrow indicates a landmark for the insertion of needle for local anaesthesia of the lingual and inferior alveolar nerves.

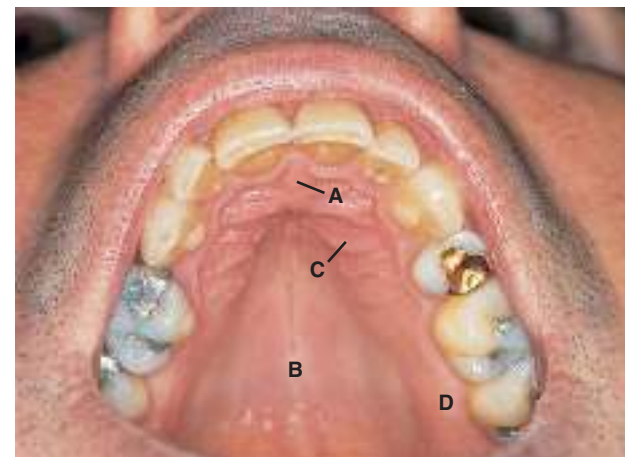


Fig. 1.10 The hard palate. A = incisive papilla; B = palatine raphe; C = palatine rugae; D = alveolus.

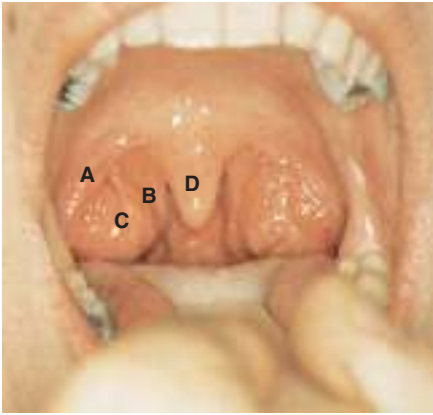


Fig. 1.11 The soft palate and oropharyngeal isthmus. A = palatoglossal fold; B = palatopharyngeal fold; C = palatine tonsil; D = uvula.

palate and the alveolus lies a mass of soft tissue (submucosa) in which run the greater palatine nerves and vessels. The shape and size of the dome of the palate varies considerably, being relatively shallow in some cases and having considerable depth in others.

The boundary between the soft palate and the hard palate is readily palpable and may be distinguished by a change in colour, the soft palate having a yellowish tint. Extending laterally from the free border of the soft palate on each side are the palatoglossal and palatopharyngeal folds (pillars of the fauces), the palatoglossal fold being more anterior (Fig. 1.11). These folds cover the palatoglossus and palatopharyngeus muscles and between them lies the tonsillar fossa that, in children, houses the palatine tonsil. The palatine tonsil is a collection of lymphoid material of variable size that is likely to atrophy in the adult. It exhibits several slit-like invaginations (the tonsillar crypts), one of which is particularly deep and named the intratonsillar cleft. The free edge of the soft palate in the midline is termed the palatal uvula. The oropharyngeal isthmus is where the oral cavity and the oropharynx meet. It is delineated by the palatoglossal folds.

Knowledge of the anatomy of the palate has clinical relevance when siting the posterior border (postdam) of an upper denture. The denture needs to bed into the tissues at the anterior border of the soft palate (at a location sometimes referred to as the 'vibrating line' because the soft palate can be seen to move here on asking a patient to say 'ah'). In most individuals two small pits, the fovea palatini, may be seen (Fig. 1.12) on either side of the midline; these represent the orifices of ducts from some of the minor mucous glands of the palate. The fovea palatini can also be seen on impressions of the palate and a postdam may usually be safely placed a couple of millimetres behind the pits.



Fig. 1.12 Oral surface of the soft palate showing the fovea palatini (arrows).

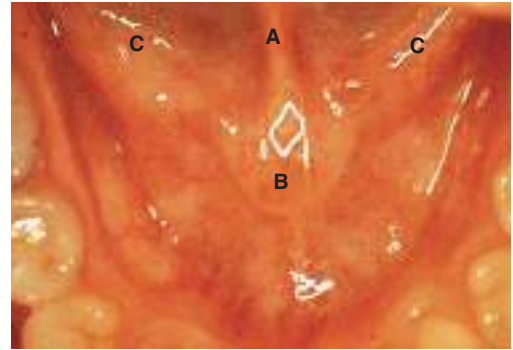


Fig. 1.13 Floor of the mouth. A = lingual frenum; B = sublingual papilla; C = sublingual folds.

FLOOR OF THE MOUTH

The moveable floor of the mouth is a small, horseshoe-shaped area above the mylohyoid muscle and beneath the movable part of the hard palate (Fig. 1.13). It is covered by a lining of non-keratinized mucosa. In the midline, near the base of the tongue, a fold of tissue called the lingual frenum extends on to the inferior surface of the tongue. The sublingual papilla, on to which the submandibular salivary ducts open into the mouth, is a large centrally positioned protuberance at the base of the tongue. On either side of this papilla are the sublingual folds, beneath which lie the submandibular ducts and sublingual salivary glands.

TONGUE

The tongue is a muscular organ with its base attached to the floor of the mouth. It is attached to the inner surface of the mandible near the midline and gains support below from the hyoid bone. It functions in swallowing and speech and carries out important sensory functions, particularly those of taste. The lymphoid material contained in the tonsils has a protective role.

The inferior (ventral) surface of the tongue, related to the floor of the mouth, is covered by a thin lining of non-keratinized mucosa that is bound down to the underlying muscles. In the midline, extending across the floor of the mouth, lies the lingual frenum (Fig. 1.14). The frenum extends across the floor of the mouth to be attached to the alveolus. Such an overdeveloped lingual frenum (ankyloglossia) can restrict movements of the tongue. Lateral to the frenum are the sublingual folds: the fimbriated folds. Also visible through the mucosa are the deep lingual veins.

The upper (dorsal) surface of the tongue may be subdivided into an anterior two-thirds (palatal part) and a posterior one-third (pharyngeal part). The junction of the palatal and pharyngeal parts is the

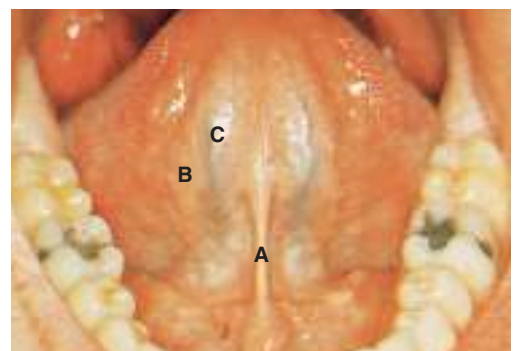


Fig. 1.14 Inferior surface of the tongue. A = lingual frenum; B = sublingual papilla; C = deep lingual vein.



Fig. 1.19 Patches of dark melanin pigment appearing in the region of the attached gingiva. Courtesy of Professor P.R. Morgan.

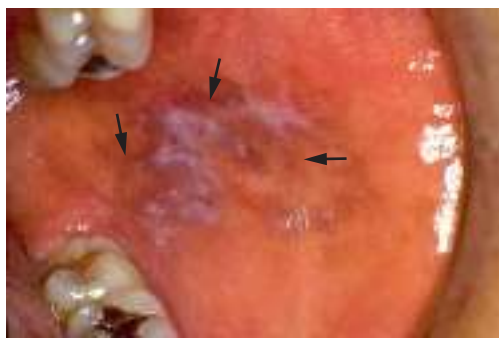


Fig. 1.20 Area of increased pigmentation (arrowed) associated with whitish patches due to lichen planus. Courtesy of Professor P.R. Morgan.

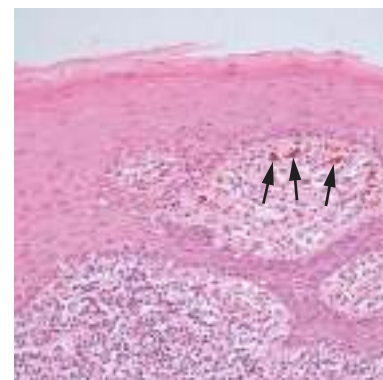


Fig. 1.21 Micrograph of biopsy taken from pigmented area seen in Fig. 1.20, showing pigment within macrophages (arrows) lying in lamina propria. The epithelium is parakeratotic giving the whitish patches (H & E; $\times 100$). Courtesy of Professor P.R. Morgan.



Fig. 1.22 Fordyce spots appearing as yellow spots on the vermilion (red zone) of the lip. The black spots below represent hair follicles on the surface of the adjacent skin of the chin. Courtesy of Professor P.R. Morgan.



Fig. 1.23 Micrograph of a Fordyce spot, showing it to be a sebaceous gland (H & E; $\times 50$). Courtesy of Professor P.R. Morgan.



Fig. 1.24 Black hairy tongue. Courtesy of Professor P.R. Morgan.



Fig. 1.25 View of buccal mucosa showing a linea alba adjacent to the parotid duct (A) at the level of the occlusal plane. In front of this line, the white patches on the cheek represent more diverse cheek chewing. Arrow shows the parotid duct. Courtesy of Professor P.R. Morgan.

well illustrated by black hairy tongue (*lingua villosa nigra*), a benign condition in which there is hypertrophy of these papillae (Fig. 1.24). Instead of being about 1 mm in length, the filiform papillae may reach up to 15 mm, giving the dorsum an appearance of being covered in fine hairs. This provides a suitable environment for bacteria (and sometimes fungi)

to accumulate and, together with retained pigments of dietary origin, may colour the surface of the tongue black. The condition is associated with the administration of antibiotics or mouthwashes which alter the normal bacterial population. It has a frequency of 10% in the population.

Examples of common benign disorders are linea alba and leukoplakia. On the inside of the cheek and level with the occlusal plane, a linear raised whitish ridge may be seen, the linea alba (Fig. 1.25). It is the result of low-grade, intermittent trauma due to folds of cheek being trapped between the teeth. More active trauma associated with chewing produces a much larger, irregular white patch (Fig.



Fig. 1.26 Section of buccal mucosa showing the linea alba to be parakeratinized compared with the normal non-keratinized state of the buccal mucosa (H & E; $\times 50$). Courtesy of Professor P.R. Morgan.



Fig. 1.27 Upper jaw showing a relatively small torus palatinus as an overgrowth of bone along the midline of the palate. Courtesy of Dr C. Dunlap.



Fig. 1.28 Upper jaw showing a large torus palatinus as an overgrowth of bone along the midline of the palate. Courtesy of Dr C. Dunlap.



Fig. 1.29 Isolated palate showing torus palatinus as an overgrowth of bone along the midline. Courtesy of the Royal College of Surgeons of England.



Fig. 1.30 Unilateral torus mandibularis on the lingual surface of the mandible. Courtesy of Professor P.R. Morgan.



Fig. 1.31 Bilateral torus mandibularis (arrows) on the lingual surface of the mandible. Courtesy of Dr C. Dunlap.



Fig. 1.32 Torus mandibularis on the buccal surface of the mandible. Courtesy of Dr C. Dunlap.



Fig. 1.33 The palate of a heavy smoker with an overall whitish appearance to the mucosa. The reddish spots highlight the orifices of the mucous glands. Courtesy of Professor P.R. Morgan.

constant irritation converts the surface epithelium from its normal non-keratinized state into a parakeratinized layer (Fig. 1.26).

Individual variation in the shape of the jaws is recognized by anatomists and pathologists. Such variations blend with benign conditions. As an example, tori are benign localized overgrowths of bone found in both the upper (torus palatinus) and lower (torus mandibularis) jaws, resulting in an increased radiopacity in the region. In the upper jaw, the enlargement is typically seen in the midline (Figs 1.27–1.29), while in the lower jaw it is usually on the lingual aspect in the canine/premolar region and may be unilateral (Fig. 1.30) or bilateral (Fig. 1.31). However, a torus mandibularis may also affect the buccal surface of the mandible (Fig. 1.32). Torus palatinus is more common in females, while torus mandibularis is slightly more common in males. Tori vary in size from small to very large and there is a tendency for them to increase in size

with age. Tori may be related to functional adaptation, but there is some evidence that their incidence is decreased in association with natural teeth being present in the jaws. They require no treatment unless they interfere with the construction of satisfactory removable dentures. The incidence varies from about 0.5% to over 65%, being low in Caucasians and more frequent in Eskimos, Mongoloids and other groups.

As an example of a disorder that highlights normal features, which may be otherwise inconspicuous, one can inspect the palate of a heavy smoker, revealing a whitish appearance that highlights the orifices of the mucous glands as reddish spots (Fig. 1.33). The white appearance is the pronounced orthokeratinized layer being present due to chronic irritation. This highlights the orifices of the ducts (as red spots) associated with the numerous mucous salivary glands present.

2

Dento-osseous structures

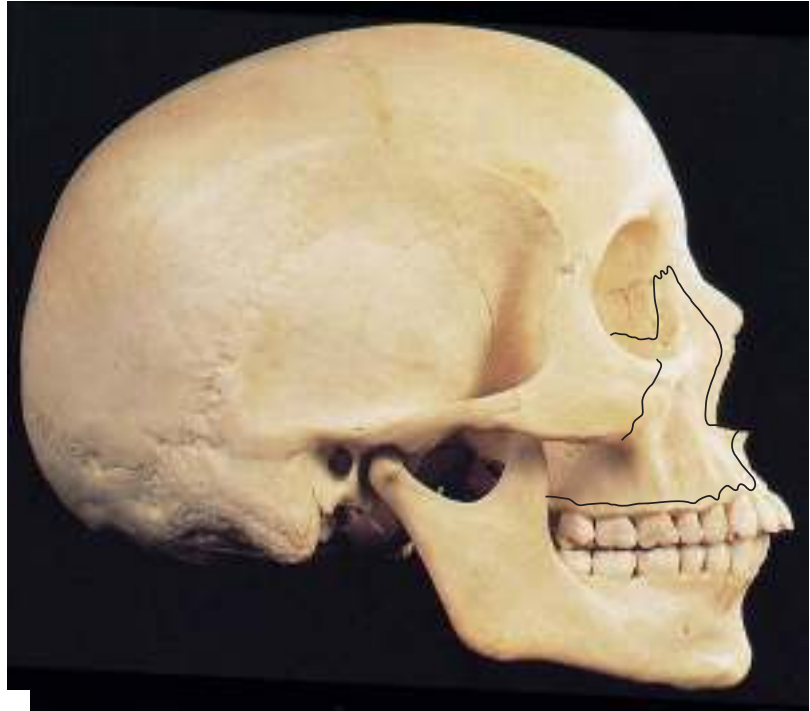
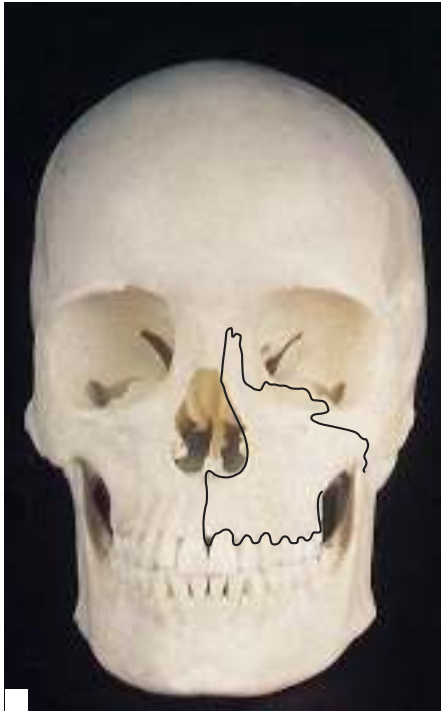


Fig. 2.1 Front (a) and side (b) views of the skull, showing the relationship between the jaws and the remainder of the skull. The black line describes the boundary of the maxillary bone.

JAWS

The jaws are the tooth-bearing bones. They comprise three bones. The two maxillary bones form the upper jaw. The lower jaw is a single bone, the mandible (Fig. 2.1).

The skull is the most complex osseous structure in the body. It protects the brain, the organs of special sense and the cranial parts of the respiratory and digestive systems. The skull is divided into the neurocranium (which houses and protects the brain and the organs of special sense) and the viscerocranium (which surrounds the upper parts of the respiratory and digestive tracts). The jaws contribute the major part of the viscerocranium, comprising about 25% of the skull. The jaws have evolved from the gill arch elements of early agnathan vertebrates. It is probable that one or two anterior gill arches gradually disappeared with the expansion of the mouth cavity, so that the gill arch that developed phylogenetically into the jaws of ancestral gnathostomes was not the first of the series. Note that the upper jaw not only contains teeth but also contributes to the skeleton of the nose, orbit, cheek and palate.

MAXILLA

The maxilla consists of a body and four processes: the frontal, zygomatic, alveolar and palatine processes. Only the palatine process cannot be seen from the lateral aspect of the maxilla (Fig. 2.2). The anterolateral surface of the maxilla (the malar surface) forms the skeleton of the anterior part of the cheek. In the midline, the alveolar processes of the two maxillae

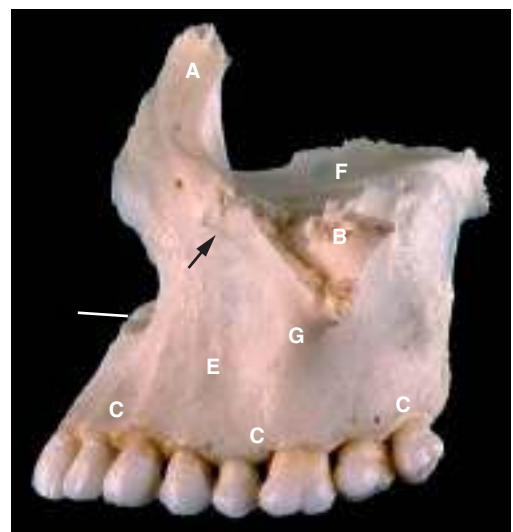


Fig. 2.2 Lateral aspect of the maxilla. A = frontal process; B = zygomatic process; C = alveolar process; D = site of anterior nasal spine; E = canine fossa; F = orbital plate; G = jugal crest. The infra-orbital foramen is arrowed.

meet at the intermaxillary suture whence they diverge laterally to form the piriform aperture. At the anterior end of the piriform aperture, in the midline, lies the bony projection of the anterior nasal spine. The malar surface of the body of the maxilla is concave, forming the canine fossa. Superiorly, the malar surface is continuous with the orbital plate of the maxilla and forms the floor

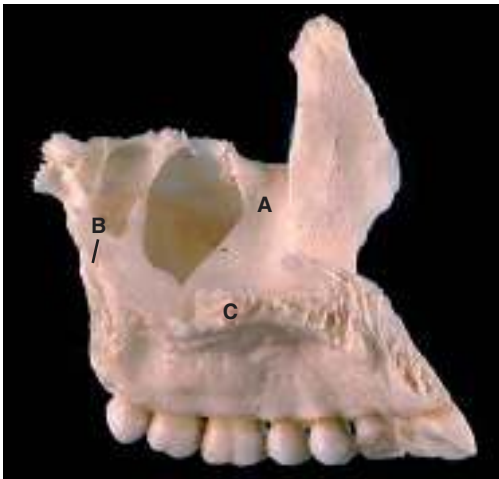


Fig. 2.3 Medial aspect of the maxilla. A = lacrimal groove; B = palatine groove; C = palatine process of maxilla. Note the large opening into the maxillary sinus.

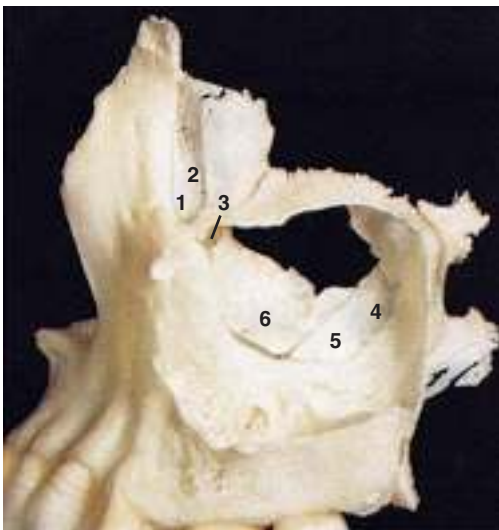


Fig. 2.4 Osteology of the maxillary air sinus showing adjacent bones reducing the size of the ostium. 1 = lacrimal groove of maxilla; 2 = lacrimal groove; 3 = lacrimal bone; 4 = ethmoid bone; 5 = palatine bone; 6 = inferior nasal concha. Courtesy of Professor R.M.H. McMinn.

Anterior to the orbital plate, the frontal process extends above the piriform aperture to meet the nasal and frontal bones. Below the infra-orbital rim lies the infra-orbital foramen through which the infra-orbital branch of the maxillary nerve and the infra-orbital artery from the maxillary artery emerge on to the face. The posterolateral surface of the maxilla (the infratemporal surface) forms the anterior wall of the infratemporal fossa. The malar and infratemporal surfaces meet at a bony ridge extending from the zygomatic process to the alveolus adjacent to the first molar tooth. This ridge is called the zygomatico-alveolar, or jugal, crest. The posterior convexity of the infratemporal surface is termed the maxillary tuberosity and presents several small foramina associated with the posterior superior alveolar nerves (which supply the posterior maxillary teeth). The zygomatic process extends from both the malar and the infratemporal surfaces of the maxilla. From the entire lower surface of the body arises the alveolar process, which supports the maxillary teeth.

The medial aspect of the maxilla is illustrated in Figure 2.3. This part of the maxilla forms the lateral wall of the nose. In the specimen illustrated, the central hollow of the body of the maxilla (the maxillary air sinus or antrum) is divided by a bony septum. In front of the antrum lies a deep

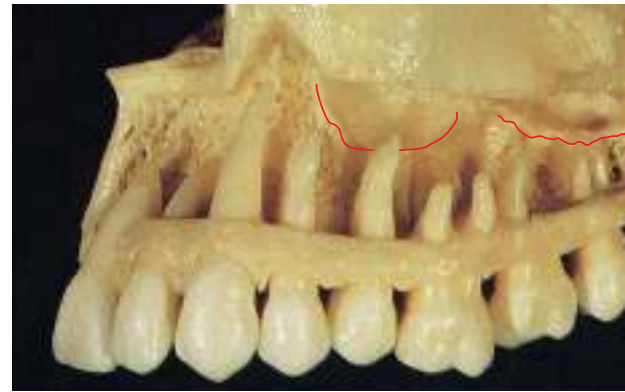


Fig. 2.5 Lateral view of the maxilla, showing close relationship of cheek teeth to the floor of the maxillary sinus (red outline).

vertical groove called the lacrimal groove. This groove merges with the edge of the lacrimal bone to form the nasolacrimal canal. Below the antrum lies the palatine groove, which is converted into a canal by the greater palatine nerve and artery by the perpendicular plate of the palatine bone. The maxillary palatine process extends horizontally from the medial surface of the maxilla where the body meets the palatine process.

The lateral wall of the nasal fossa consists mainly of the lateral process of the maxilla. This surface of the isolated bone is occupied by the large maxillary hiatus (Fig. 2.3). To reduce the size of this hiatus the hiatus is overlapped by the lacrimal bone and the ethmoid bone in front, the palatine bone behind and the inferior concha below (Fig. 2.4).

Maxillary sinus

The maxillary sinus (antrum) is the largest of the paranasal sinuses. It is situated in the body of the maxilla. It is pyramidal in shape. The medial wall (medial wall) forms part of the lateral wall of the nose. The roof of the sinus is formed by the floor of the orbit and the floor of the sinus is formed by the alveolar process and part of the palatine process of the maxilla. The posterior wall of the sinus is the facial surface of the maxilla and the posterior wall is the infratemporal surface of the maxilla. Running in the roof of the sinus is the infra-orbital nerve and vessels. The anterior superior alveolar nerve and vessels run in the anterior wall of the sinus. The posterior superior alveolar nerve and vessels pass through canals in the posterior wall of the sinus. The medial wall of the maxillary sinus contains the ostium (ostium) of the sinus that leads into the middle meatus of the nasal cavity. The opening lies well above the floor of the sinus, its position is such that it is far from drainage (see Fig. 5.4a). Infections of the maxillary sinus require surgical intervention, creating a more favourable drainage pathway closer to the floor of the sinus.

The roots of the cheek teeth are related to the floor of the maxillary sinus (Fig. 2.5). The most closely related are the roots of the permanent maxillary molar, especially the apex of its palatal root. The roots of the first and third molars and the second premolar are further away. Sometimes, only mucosa separates the roots of the teeth from the sinus. Care must be taken (particularly when extracting fractured teeth) to avoid creating an oro-antral fistula, when an epithelial channel exists between the oral cavity and maxillary sinus.

The maxillary air sinus is lined by respiratory epithelium (pseudo-columnar epithelium), with numerous goblet cells. The sinus is supplied by the infra-orbital nerve and superior alveolar branches of the maxillary nerve.

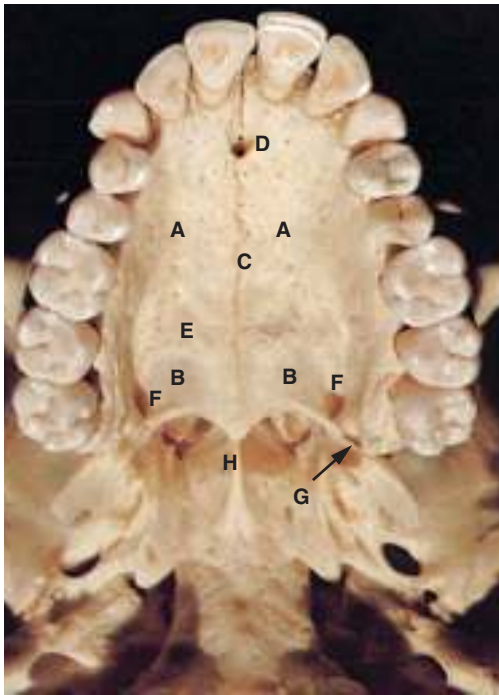


Fig. 2.6 Oral surface of the hard palate.
A = palatine processes of maxillae
B = horizontal plates of the palatine bones
C = median palatine suture
D = incisive fossa
E = transverse palatine suture
F = greater palatine foramina
G = lesser palatine foramen
H = posterior nasal spine.

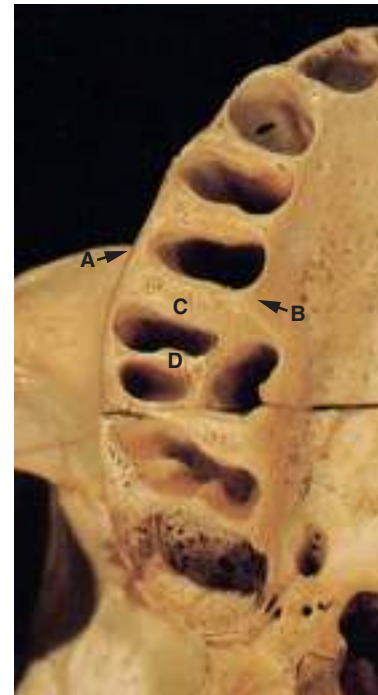


Fig. 2.7 View of the maxilla following removal of teeth to show the disposition of the roots in the alveolus.
A = buccal alveolar plate
B = palatal alveolar plate
C = interdental bony septa between the second premolar and first permanent molar
D = interradicular septum between the buccal roots of first permanent molar.

An inferior view of the maxillae shows their important contributions to the hard palate (Fig. 2.6). The four major bones contributing to the hard palate are the palatine processes of the maxillae and the horizontal plates of the palatine bones. The maxillary palatine processes arise as horizontal plates at the junction of the bodies and alveolar processes of the maxillae. The boundary between the palatine and alveolar processes is well defined in its posterior aspect only; anteriorly, the angle between the two is less well defined. The junction between the palatine processes in the midline is termed the median palatine suture. Anteriorly, behind the central incisors, this junction is incomplete, thus forming the incisive fossa, through which pass the nasopalatine nerves. Unlike the nasal surface, the oral surface of the palatine process is rough and irregular. The posterior edges of the palatine processes articulate with the horizontal plates of the two palatine bones to form the transverse palatine suture. Laterally, this junction is incomplete, forming the greater palatine foramina, through which pass the greater palatine nerves and vessels. Behind the greater palatine foramina lie the lesser palatine foramina, through which pass the lesser palatine nerves and vessels. The junction of the two palatine bones in the midline completes the median palatine suture. The posterior borders of the horizontal palatine plates are concave and, in the midline, form a sharp ridge of bone called the posterior nasal spine. To the posterior edge of the hard palate is attached the fibrous palatine aponeurosis of the soft palate, which is formed by the tendons of the tensor veli palatini muscles.

MAXILLARY ALVEOLUS

The maxillary alveolar processes extend inferiorly from the bodies of the maxillae and support the teeth within bony sockets (Fig. 2.7). Each maxilla can contain a full quadrant of eight permanent teeth or five deciduous teeth. The form of the alveolus is related to the functional demands put upon the teeth. When the teeth are lost the alveolus resorbs.

Essentially, the alveolar process consists of two parallel plates of cortical bone, the buccal and palatal alveolar plates, between which lie the sockets of individual teeth. Between each socket lie interalveolar or interdental septa. The floor of the socket has been termed the fundus, its rim the alveolar crest. The form and depth of each socket is defined by the form and length of the root it supports, and thus shows considerable variation. In multirooted teeth, the sockets are divided by interradicular septa.

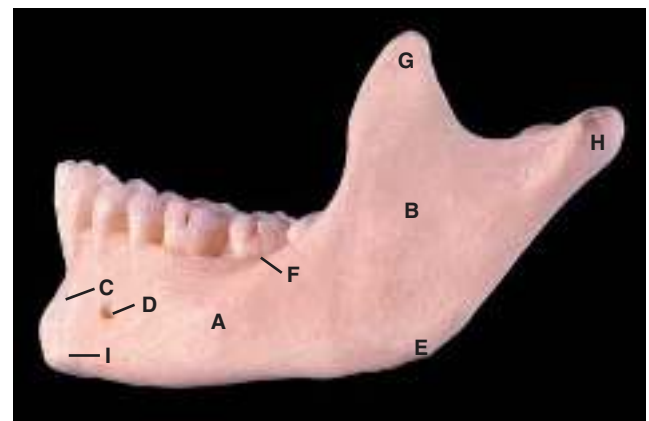


Fig. 2.8 Lateral aspect of the mandible. A = Body; B = ramus; C = incisive fossa; D = mental foramen; E = angle; F = external oblique line; G = coronoid process; H = condyle; I = mental protuberance.

The apical regions of the sockets of anterior teeth are close to the nasal fossae, while those of posterior teeth are closely related to the maxillary air sinuses. The positions of the sockets in relation to the buccal and palatal alveolar plates are shown in Figure 2.12.

MANDIBLE

The mandible consists of a horizontal, horseshoe-shaped body, the body of the mandible, and two vertical components, the rami, which join the body posteriorly at obtuse angles. The body of the mandible is formed by the mandibular teeth and their associated alveolar processes. The body consists of two lateral halves that meet in the midline at the symphysis. As viewed laterally (Fig. 2.8), on either side of the body, the external oblique line runs from the inferior margin of the body to the inferior margin of the body lies a distinct prominent mental tubercle. These tubercles constitute the mental protuberance. Above the mental protuberance lies a shallow depression called the incisive fossa. Behind this fossa, the canine eminence overlies the mandibular canine. Midway in the height of the body of the mandible, the mental foramen, related to the premolar teeth, is the mental foramen. The mental

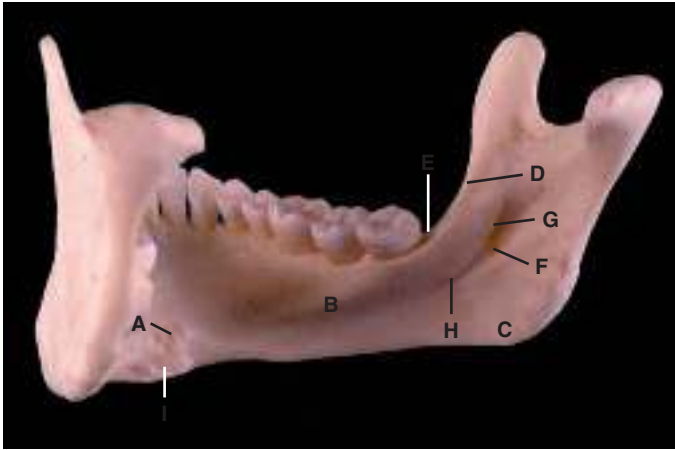


Fig. 2.9 Inner (medial) surface of the mandible. A = genial spines (tubercles); B = internal oblique ridge (mylohyoid ridge); C = attachment area for medial pterygoid muscle; D = temporal crest; E = retromolar triangle; F = mandibular foramen; G = lingula; H = mylohyoid groove; I = digastric fossa.

of the inferior alveolar nerve and artery pass on to the face through this foramen. The most common position for the mental foramen is on a vertical line passing through the mandibular second premolar. During the first and second years of life, as the prominence of the chin develops, the direction of the opening of the mental foramen alters from facing forwards to facing upwards and backwards. Rarely, there may be multiple mental foramina. The inferior margin of the mandibular body meets the posterior margin of the ramus at the angle of the mandible. This area is irregular, being the site of insertion of the masseter muscle and stylomandibular ligament. The alveolus forms the superior margin of the mandibular body. The junction of the alveolus and ramus is demarcated by a ridge of bone, the external oblique line, which continues downwards and forwards across the body of the mandible to terminate below the mental foramen. As this line progresses upwards, it becomes the anterior margin of the ramus and ends as the tip of the coronoid process. The coronoid and condylar processes form the two processes of the superior border of the ramus. The coronoid process provides attachment for the temporalis muscle. The condylar process has a neck supporting an articular surface, which fits into the mandibular fossa of the temporal bone to form a moveable synovial joint (the temporomandibular joint). The concavity between the coronoid and condylar processes is called the mandibular notch.

Several important features are seen on the internal (medial) surface of the mandible (Fig. 2.9). Close to the midline, on the inferior surface of the mandibular body, lie two shallow depressions called the digastric fossae, into which are inserted the anterior bellies of the digastric muscles. Above the fossae, in the midline, are the genial spines or tubercles. There are generally two inferior and two superior spines, which serve as attachments for the geniohyoid muscles and the genioglossus muscles, respectively. Passing upwards and backwards across the medial surface of the body of the mandible is a prominent ridge. This is termed the mylohyoid or internal oblique ridge. From this ridge, the mylohyoid muscle takes origin. The mylohyoid ridge arises between the genial spines and digastric fossa and increases in prominence as it passes backwards to end on the anterior surface of the ramus. Because the mylohyoid muscle forms the floor of the mouth, the bone above the mylohyoid ridge forms the anterior wall of the oral cavity proper, while that below the ridge forms the lateral wall of the submandibular space (see page 78). The following features may be seen on the medial surface of the ramus. Around the angle of the mandible, the bone is roughened for the attachment of the medial pterygoid muscle. Commencing at the tip of the coronoid process, a ridge



Fig. 2.10 Lateral view of the mandible, showing the roots of the teeth and the relationship to the mandibular canal (A). B = mandibular foramen.



Fig. 2.11 The mandibular alveolus and the arrangement of the teeth, showing the socket of the left second permanent mandibular molar that has previously been extracted and the socket has healed.

of bone called the temporal crest runs down the anterior surface of the ramus to end behind the mandibular molars at the retromolar triangle. In the centre of the medial surface of the ramus lies the mandibular foramen, through which the inferior alveolar nerve and artery pass. The mandibular canal. A bony process, the lingula, extends from the anterior surface of the foramen. The lingula is the site of attachment of the sphenomandibular ligament (see page 64). The mylohyoid muscle is seen running down from the posteroinferior surface of the coronoid process.

The mandibular canal, that transmits the inferior alveolar nerve and veins, begins at the mandibular foramen and extends to the premolar teeth, where it bifurcates into the mental and incisive canals (Fig. 2.10). The course of the mandibular canal and its relationship to the teeth is variable; this variation is illustrated in connection with the course of the inferior alveolar nerve (Fig. 4.6).

MANDIBULAR ALVEOLUS

As for the maxilla, the mandibular alveolus consists of buccal and lingual alveolar plates joined by interdental and interradicular septa. In the region of the second and third molars, the external oblique line is superimposed upon the buccal alveolar plate. The form and position of the tooth sockets are related to the morphology of the roots of the teeth and the functional demands placed upon them.



Fig. 2.12 Buccolingual sections through the maxilla and mandible demonstrating the distribution of alveolar bone in relation to the roots of the teeth. (a) Maxillary incisor region. (b) Maxillary canine region. (c) Maxillary premolar region. (d) Maxillary molar region. (e) Mandibular incisor region. (f) Mandibular canine region. (g) Mandibular premolar region. (h) Mandibular molar region. Note the relationship of the mandibular cheek teeth to the mandibular canal (A) and of the maxillary cheek teeth to the maxillary sinus (B). Courtesy of the Royal College of Surgeons of England.

Figure 2.12 illustrates buccolingual sections through the teeth and jaws, demonstrating the directional axes and bony relationships of the teeth and their alveoli and the relative thickness of the buccal and lingual alveolar plates. The relationships of the mandibular teeth to the mandibular canal, and the maxillary teeth to the maxillary sinus have clinical significance. Thus, the thickness of bone may determine the direction in which teeth are levered during extractions and explain why local infiltration techniques can be used for anaesthetizing anterior mandibular teeth but not mandibular molar teeth. Care must be taken when exploring for fractured roots in the maxillary region in order to avoid an oro-antral fistula, due to the presence of the maxillary sinus in close relationship to the maxillary molar teeth, while the presence of the inferior alveolar nerve and its branches requires care when placing dental implants in the mandibular region.

TOOTH MORPHOLOGY

Humans have two generations of teeth: the deciduous (or primary) dentition and the permanent (or secondary) dentition. No teeth are erupted into the mouth at birth but, by the age of 3 years, all the deciduous teeth have erupted. By 6 years, the first permanent teeth appear and thence the deciduous teeth are exfoliated one by one to be replaced by their permanent successors. A complete permanent dentition is present at or around the age of 18 years. Thus, given the average life of 75 years, the functional lifespan of the deciduous dentition is only 5% of this total while, with care and luck, that of the permanent dentition can be over 90%. In the complete deciduous dentition there are 20 teeth – 10 in each jaw; in the complete permanent dentition there are 32 teeth – 16 in each jaw.

In both dentitions, there are three basic tooth forms: incisiform, caniniform and molariform. Incisiform teeth (incisors) are cutting teeth, with thin, blade-like crowns. Caniniform teeth (canines) are piercing or tearing teeth, having a single, stout, pointed, cone-shaped crown. Molariform teeth

(molars and premolars) are grinding teeth possessing a number of cusps on an otherwise flattened biting surface. Premolars are bicuspid teeth which are peculiar to the permanent dentition and replace the deciduous premolars. Table 2.1 gives definitions of terms used for the descriptive classification of tooth form.

DENTAL NOTATION

The types and numbers of teeth in any mammalian dentition are expressed using dental formulae. The type of tooth is represented by an initial letter – I for incisors, C for canines, P for premolars, and M for molars. The deciduous dentition is indicated by the letter D. The dental formula for the deciduous human dentition is $DI_2^2 DC_1^1 DM_2^2 = 10$, and for the permanent dentition $I_2^2 C_1^1 PM_2^2 M_3^3 = 16$, where the numbers for each letter refer to the number of teeth of each type in the upper and lower jaws on one side only. Identification of teeth is made not only according to their deciduous or permanent status but also according to their anatomical location within the jaws. The tooth-bearing part of the jaws can be divided into four quadrants: the right and left maxillary and mandibular quadrants. A tooth may thus be identified by the quadrant in which it is located – e.g. a right maxillary deciduous incisor or a left mandibular permanent molar. In both the permanent and deciduous dentitions, the incisors may be distinguished according to their position to the midline. Thus, the incisor nearest the midline is the central incisor and the more laterally positioned incisor the lateral incisor. The permanent premolars and the permanent and deciduous molars can also be distinguished according to their mesiodistal position (see Fig. 2.13). The molar most mesially positioned is the first molar, the one behind it being the second molar. In the deciduous dentition, the tooth most distally positioned is the third molar. The first premolar is the first premolar, the premolar behind it being the second premolar.

Table 2.1 Some terms used for the description of tooth form

Crown	Clinical crown – that portion of a tooth visible in the oral cavity Anatomical crown – that portion of a tooth covered with enamel
Root	Clinical root – that portion of a tooth which lies within the alveolus Anatomical root – that portion of a tooth covered by cementum
Cervical margin	The junction of the anatomical crown and the anatomical root
Occlusal surface	The biting surface of a posterior tooth (molar or premolar)
Cusp	A pronounced elevation on the occlusal surface of a tooth
Incisal margin	The cutting edge of anterior teeth, analogous to the occlusal surface of the posterior teeth
Tubercle	A small elevation on the crown
Cingulum	A bulbous convexity near the cervical region of a tooth
Ridge	A linear elevation on the surface of a tooth
Marginal ridge	A ridge at the mesial or distal edge of the occlusal surface of posterior teeth. Some anterior teeth have equivalent ridges
Fissure	A long cleft between cusps or ridges
Fossa	A rounded depression in a surface of a tooth
Buccal	Towards, or adjacent to, the cheek. The term buccal surface is reserved for that surface of a premolar or molar which is positioned immediately adjacent to the cheek
Labial	Towards, or adjacent to, the lips. The term labial surface is reserved for that surface of an incisor or canine which is positioned immediately adjacent to the lips
Palatal	Towards, or adjacent to, the palate. The term palatal surface is reserved for that surface of a maxillary tooth which is positioned immediately adjacent to the palate
Lingual	Towards, or adjacent to, the tongue. The term lingual surface is reserved for that surface of a mandibular tooth which lies immediately adjacent to the tongue
Mesial	Towards the median. The mesial surface is that surface which faces towards the median line following the curve of the dental arch
Distal	Away from the median. The distal surface is that surface which faces away from the median line following the curve of the dental arch

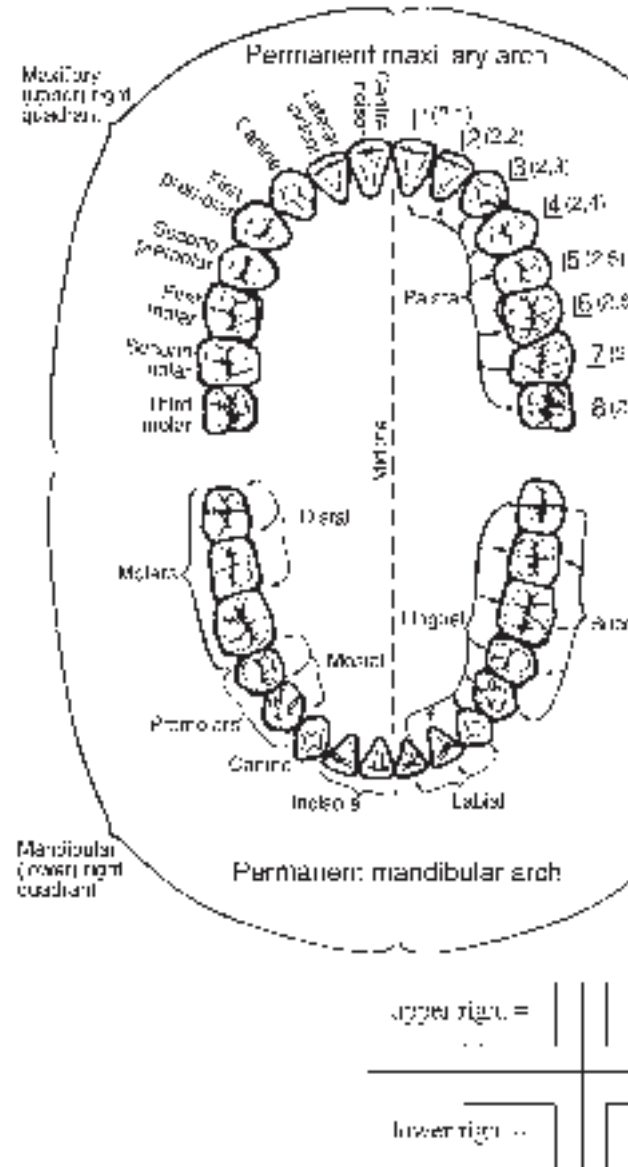


Fig. 2.13 Terminology employed for the identification of teeth according to their location in the jaws.

A dental shorthand may be used in the clinic to simplify tooth identification. The permanent teeth in each quadrant are numbered 1–8 and the deciduous teeth in each quadrant are lettered A–E. The symbols for the quadrants are derived from an imaginary cross, with the horizontal bar placed between the upper and lower jaws and the vertical bar running between the upper and lower central incisors. Thus, the maxillary right first permanent molar is allocated the symbol $\overline{6}$ and the mandibular left deciduous canine \overline{c} . This system of dental shorthand is termed the Zsigmondy system. An alternative scheme has been devised by the Federation Dentaire Internationale, in which the quadrant is represented by a number:

- | | | |
|-------------------------------|---|-----------|
| 1 = maxillary right quadrant | } | Permanent |
| 2 = maxillary left quadrant | | |
| 3 = mandibular left quadrant | | |
| 4 = mandibular right quadrant | | |
| 5 = maxillary right quadrant | } | Deciduous |
| 6 = maxillary left quadrant | | |
| 7 = mandibular left quadrant | | |
| 8 = mandibular right quadrant | | |

In this system, the quadrant number prefixes a tooth number. Thus, the maxillary right first permanent molar is symbolized as 1,6 and the mandibular left deciduous canine as 7,3.

Figure 2.13 summarizes some of the terminology employed for the identification of teeth according to their location in the jaws.

DIFFERENCES BETWEEN TEETH OF THE DECIDUOUS AND PERMANENT DENTITIONS

- The dental formula for the deciduous dentition is: $DI_2^2 DC_1^1 DM_2^2 = 10$
That of the permanent dentition is: $I_2^2 C_1^1 PM_2^2 M_3^3 = 16$.
- The deciduous teeth are smaller than their corresponding successors although the mesiodistal dimensions of the deciduous premolars are generally less than those for the permanent molars.
- Deciduous teeth have a greater constancy of shape than permanent teeth.
- The crowns of deciduous teeth appear bulbous, often having a pronounced labial or buccal cingula.
- The cervical margins of deciduous teeth are more sharply demarcated and pronounced than those of the permanent teeth, bulging at the cervical margins rather than gently tapering.



Fig. 2.14 Models of deciduous (a) and permanent (b) dental arches and some examples of deciduous and permanent teeth. (c) Deciduous canine. (d) Permanent canine. (e) Deciduous second molar. (f) Permanent first molar.

6. The cusps of newly erupted deciduous teeth are more pointed than those of the corresponding permanent teeth.
7. The crowns of deciduous teeth have a thinner covering of enamel (average width 0.5–1.0 mm) than the crowns of permanent teeth (average width 2.5 mm).
8. The enamel of deciduous teeth, being more opaque than that of permanent teeth, gives the crown a whiter appearance.
9. The enamel of deciduous teeth is softer than that of permanent teeth and is more easily worn.
10. Enamel of deciduous teeth is more permeable than that of permanent teeth.
11. The aprismatic layer of surface enamel (see pages 111–112) is wider in deciduous teeth.
12. The enamel and dentine of all deciduous teeth exhibit neonatal lines (see pages 115, 142).
13. The roots of deciduous teeth are shorter and less robust than those of permanent teeth.
14. The roots of deciduous incisors and canines are longer in proportion to the crown than those of their permanent counterparts.
15. The roots of deciduous molars are widely divergent, extending beyond the dimensions of the crown.
16. The pulp chambers of deciduous teeth are proportionally larger in relation to the crowns than those of the permanent teeth. The pulp horns in deciduous teeth are more prominent.
17. The root canals of deciduous teeth are extremely fine.
18. The dental arches for the deciduous dentition are smaller.

Some of these differences are illustrated in Figure 2.14.

The following descriptions of individual teeth will be considered according to tooth class (incisors, canines, premolars and molars) rather than by membership of the permanent or deciduous dentition. For each class, the permanent teeth will be described before the deciduous teeth. This arrangement allows emphasis of the basic features common to each class to be made.

To help visualize the tooth as a three-dimensional object, the illustrations of each tooth are arranged according to the 'third angle projection technique', which aligns each side of a tooth to its occlusal or incisal aspect. The morphology of the pulp is treated independently of the mor-

Table 2.2 Average dimensions of the permanent teeth

Tooth	Crown height (mm)	Length of root (mm)	Mediodistal crown diameter (mm)	L c d (mm)
Maxillary				
1	10.5	13.0	8.5	
2	9.0	13.0	6.5	
3	10.0	17.0	7.5	
4	8.5	14.5	7.0	
5	8.5	14.0	7.0	
6	7.5	12.5	10.5	
7	7.0	11.5	9.5	
8	6.5	11.0	8.5	
Mandibular				
1	9.0	12.5	5.0	
2	9.5	14.0	5.5	
3	11.0	15.5	7.0	
4	8.5	14.0	7.0	
5	8.0	14.5	7.0	
6	7.5	14.0	11.0	
7	7.0	12.0	10.5	
8	7.0	11.0	10.0	

Table 2.3 Average dimensions of the deciduous teeth

Tooth	Crown height (mm)	Length of root (mm)	Mediodistal crown diameter (mm)	L c d (mm)
Maxillary				
A	6.0	10.0	6.5	
B	5.6	10.2	5.2	
C	6.5	13.0	6.8	
D	5.1	10.0	7.1	
E	5.7	11.7	8.4	
Mandibular				
A	5.0	9.0	4.0	
B	5.2	9.8	4.5	
C	6.0	11.2	5.5	
D	6.0	9.8	7.7	
E	5.5	12.5	9.7	

phology of the external surfaces of the teeth on pages 28–30. The chronology of the developing dentitions see page 365, for the dimensions of the teeth see Tables 2.2 and 2.3, and for ethnic differences in tooth morphology see pages 24–28.

INCISORS

Human incisors have thin, blade-like crowns that are adapted for cutting and shearing of food preparatory to grinding. Viewed from the distal, the crowns of the incisors are roughly triangular in shape, the apex of the triangle at the incisal margin of the tooth (Fig. 2.15). This shape is thought to facilitate the penetration and cutting of food. Viewed buccally or lingually, the incisors are trapezoidal, the shortest sides being the base of the crown cervically.

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