Textbook and Color Atlas of Salivary Gland Pathology
Diagnosis and Management

Eric R. Carlson  DMD, MD, FACS
Robert A. Ord  DDS, MD, FRCS, FACS, MS
TEXTBOOK AND COLOR ATLAS OF SALIVARY GLAND PATHOLOGY

DIAGNOSIS AND MANAGEMENT
Edition first published 2008
© 2008 Wiley-Blackwell

Blackwell Munksgaard, formerly an imprint of Blackwell Publishing was acquired by John Wiley & Sons in February 2007. Blackwell’s publishing programme has been merged with Wiley’s global Scientific, Technical, and Medical business to form Wiley-Blackwell.

Editorial Office
2121 State Avenue, Ames, Iowa 50014-8300, USA

For details of our global editorial offices, for customer services and for information about how to apply for permission to reuse the copyright material in this book please see our website at www.wiley.com/wiley-blackwell.

Authorization to photocopy items for internal or personal use, or the internal or personal use of specific clients, is granted by the publisher, provided that the base fee is paid directly to the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923. For those organizations that have been granted a photocopy license by CCC, a separate system of payments has been arranged. The fee codes for users of the Transactional Reporting Service are ISBN-13: 978-0-8138-0262-6 (alk. paper)
ISBN-10: 0-8138-0262-8 (alk. paper)
WI 17 T355 2008]
RCB15.5.T49 2008
616.3′16–dc22
2008006941

A catalogue record for this book is available from the U.S. Library of Congress.

Set in 10.5/12pt ITC Slimbach by SNP Best-set Typesetter Ltd., Hong Kong
Printed in Singapore by Markono Print Media Pte Ltd

Disclaimer
The contents of this work are intended to further general scientific research, understanding, and discussion only and are not intended and should not be relied upon as recommending or promoting a specific method, diagnosis, or treatment by practitioners for any particular patient. The publisher and the author make no representations or warranties with respect to the accuracy or completeness of the contents of this work and specifically disclaim all warranties, including without limitation any implied warranties of fitness for a particular purpose. In view of ongoing research, equipment modifications, changes in governmental regulations, and the constant flow of information relating to the use of medicines, equipment, and devices, the reader is urged to review and evaluate the information provided in the package insert or instructions for each medicine, equipment, or device for, among other things, any changes in the instructions or indication of usage and for added warnings and precautions. Readers should consult with a specialist where appropriate. The fact that an organization or Website is referred to in this work as a citation and/or a potential source of further information does not mean that the author or the publisher endorses the information the organization or Website may provide or recommendations it may make. Further, readers should be aware that Internet Websites listed in this work may have changed or disappeared between when this work was written and when it is read. No warranty may be created or extended by any promotional statements for this work. Neither the publisher nor the author shall be liable for any damages arising herefrom.
Contents

Foreword vii
By R. Bruce MacIntosh, DDS
Preface ix
Acknowledgments xi
Contributors xiii

Chapter 1 Surgical Anatomy, Embryology, and Physiology of the Salivary Glands
By John D. Langdon, FKC, MB BS, BDS, MDS, FDSRCS, FRCS, FMedSci 3

Chapter 2 Diagnostic Imaging of Salivary Gland Pathology
By Pradeep K. Jacob, MD, MBA 19

Chapter 3 Infections of the Salivary Glands 67

Chapter 4 Cysts of the Salivary Glands 91

Chapter 5 Sialolithiasis 109

Chapter 6 Systemic Diseases Affecting the Salivary Glands 131

Chapter 7 Classification, Grading, and Staging of Salivary Gland Tumors
By John J. Sauk, DDS, MS, FAAAS, FAHNS 149

Chapter 8 Tumors of the Parotid Gland 171

Chapter 9 Tumors of the Submandibular and Sublingual Glands 199

Chapter 10 Tumors of the Minor Salivary Glands 217

Chapter 11 Non-salivary Tumors of the Salivary Glands 263

Chapter 12 Trauma and Injuries to the Salivary Glands 287

Chapter 13 Miscellaneous Pathologic Processes of the Salivary Glands 315

Index 327
Foreword

The mention of “head and neck cancer” immediately connotes the sobering realities and potentials of oral squamous cell carcinoma. Left to secondary recollection and awareness is the significance of salivary gland malignancy. The same can be said for the general perception of benign salivary neoplasia. In this brilliant new textbook, authors Carlson and Ord correct these notions, focusing proper emphasis on the group of diseases which, in their malignant form, represent some three percent of all North American head and neck tumors, affecting a minimum of twenty-five hundred victims per year.

One marvels at the dedication, energies, and resources—to say nothing of the expertise—mustered to produce a volume of this depth and expanse. While almost forty percent of the effort is directed toward the vitally significant elements of classification, diagnosis, and clinical care of neoplasia, there is more—much more—here, for both the training and practicing readerships. The whole array of salivary gland dysfunctions is marvelously displayed in meaningful clinical color, in easily grasped sketches and graphs, and in well-chosen descriptive imaging. From the mandatory fundamentals for such an undertaking—John Langdon’s discourse on macro- and microanatomy, Pradeep Jacob’s presentation on imaging diagnostics (forty-five pages!), John Sauk’s explanations of current classification and staging of tumors—to the surgical demonstrations of pathology, anatomy, and technique, the visual material is extraordinary.

What are the vagaries in defining the SMAS layer, can cell type be distinguished on the basis of imaging alone, what influence do genomics and biomarkers have in clinical classification, does contemporary understanding explain the etiology of mucous escape phenomena? Up-to-date propositions on such topics occupy these chapters. Clinical challenges, traditional and new, e.g., transection of ducts and nerves, intraductal micromanipulations, salivary diagnostics—they’re all here, presented in clear, expansive, prose (twenty-eight pages of information on sialolithiasis alone!). The detriments of age and metabolic disorder on gland function, the genesis of non-salivary tumors inside the glands, and the lodging of metastatic disease within their confines receive emphasis in these pages. So do the presence of aberrant glands and the esoteric transplantation of salivary tissue in the management of xerophthalmia.

The Textbook and Color Atlas of Salivary Gland Pathology is authoritative. Its authors do not write anecdotally, but from the combined experience of decades which has elevated them both to international recognition in the field of head and neck neoplasia. Their clinical material here presented represents volumes in the operating room, and the comprehensive bibliographies in each of the text’s chapters testify to the authors’ awareness of their topic and their world-views. Eric Carlson displays the fruits of his earlier endeavors in Pittsburgh, Detroit, and Miami, and speaks now from his position as Professor and Chairman in the Department of Oral and Maxillofacial Surgery at the University of Tennessee Graduate School of Medicine in Knoxville. Robert Ord established his worthy reputation in Britain before resettling himself in Baltimore on the western shores of the Atlantic some twenty years ago, where he now serves as Professor and Chairman of the Department of Oral and Maxillofacial Surgery at the University of Maryland. Theirs is the first tome in this domain engineered authoritatively by oral and maxillofacial surgeons, and does honor to their colleagues and forebears in the specialty who have toiled in the vineyards of salivary gland pathology. Neither in design nor execution, however, is their marvelous achievement directed to a parochial audience. Rather, surgeons or clinicians of whatever ilk will offer the authors a nod of appreciation in benefitting from this text.

Probably, one day, an expansion of this work will be written; and, undoubtedly, Carlson and Ord will write it.

R. Bruce MacIntosh, DDS
Detroit
Preface

The concept of this book devoted to the diagnosis and management of salivary gland pathology arose from our long-standing friendship and professional relationship, when we first collaborated in the early 1990s. This led to a trip to India with the Health Volunteers Overseas in 1996, where we operated on numerous complex cancer cases, including salivary gland malignancies. Dr. Carlson’s interest in benign and malignant tumor surgery was fostered by the expert surgical tutelage of Dr. Robert E. Marx at the University of Miami Miller School of Medicine/Jackson Memorial Hospital in Miami, Florida. It was the training by Professor John Langdon who nurtured Dr. Ord’s love of the parotidectomy. Over the years, following the publication of several papers and book chapters devoted to salivary gland surgery, we realized that a textbook and atlas related to this discipline should be produced. It was believed that a work written by two surgeons who shared similar surgical philosophies would be a unique addition to the current literature. This has been a project that we have approached with energy and enthusiasm, which hopefully is evident to the reader.

The diagnosis and management of salivary gland pathology is an exciting and thought-provoking discipline in medicine, dentistry, and surgery. It is incumbent on the clinician examining a patient with a suspected developmental, neoplastic, or non-neoplastic lesion of the major or minor salivary glands to obtain a comprehensive history and physical examination, after which time a differential diagnosis is established. A definitive diagnosis is provided with either an excisional or incisional biopsy, depending on the gland involved and the differential diagnosis established preoperatively. A complete understanding of the anatomic barriers surrounding a salivary gland lesion is paramount when performing surgery for a salivary gland neoplasm.

It is the purpose of this Textbook and Color Atlas of Salivary Gland Pathology to provide both text and clinical images, thereby making this a singular work. The reader interested in the science and evidence-based medicine associated with the management of salivary gland pathology will be attracted to our text. The reader interested in how to perform salivary gland surgery as a function of diagnosis and anatomic site will find the real-time images useful. To that end, artist sketches are limited in this book. Where appropriate, algorithms have been included as a guide for diagnosis and management. It is our hope that this text and atlas will find a home on the bookshelves of those surgeons who share our fascination with the diagnosis and management of salivary gland disease.
Acknowledgments

I would like to thank the loves of my life, Susan, Katie, and Kristen Carlson, for excusing me during the time required to write this book. I also thank my father, Reinhold Carlson, who has always reminded me that the goal of education is not to give you all the answers, but to provide resources where you can find them. I hope this book represents a resource for answers to your questions regarding the diagnosis and management of salivary gland pathology.

ERC
To my wife, Sue.
RAO

We thank Sophia Joyce, Senior Commissioning Editor; Shelby Hayes, Editorial Assistant; Erin Magnani, Production Editor; and Sarah Brown, Copy Editor for their valuable and insightful editorial support, without whom this book would not have been possible.

ERC, RAO
Contributors

Eric R. Carlson, DMD, MD, FACS
Professor and Chairman
Department of Oral and Maxillofacial Surgery
Director, Oral and Maxillofacial Surgery Residency Program
University of Tennessee Medical Center and the University of Tennessee Cancer Institute
Knoxville, Tennessee

Robert A. Ord, DDS, MD, FRCS, FACS, MS
Professor and Chairman
Department of Oral and Maxillofacial Surgery
University of Maryland Medical Center and the Greenbaum Cancer Institute
Baltimore, Maryland

Pradeep Jacob, MD, MBA
Clinical Assistant Professor
Department of Radiology
The University of Tennessee at Chattanooga
College of Medicine
Chattanooga, Tennessee

John D. Langdon, FKC, MB BS, BDS, MDS, FDSRCS, FRCS, FMedSci
Emeritus Professor of Maxillofacial Surgery
King’s College
London, England

John J. Sauk, DDS, MS, FAAAS, FAHNS
Dean and Professor
School of Dentistry
University of Louisville
Louisville, Kentucky
TEXTBOOK AND COLOR ATLAS OF SALIVARY GLAND PATHOLOGY

DIAGNOSIS AND MANAGEMENT
Chapter 1
Surgical Anatomy, Embryology, and
Physiology of the Salivary Glands

John D. Langdon, FKC, MB BS, BDS, MDS, FDSRCS, FRCS, FMedSci

Outline

Introduction
The Parotid Gland
Embryology
Anatomy
Contents of the Parotid Gland
The Facial Nerve
Auriculotemporal Nerve
Retromandibular Vein
External Carotid Artery
Parotid Lymph Nodes
Parotid Duct
Nerve Supply to the Parotid

The Submandibular Gland
Embryology
Anatomy
The Superficial Lobe
The Deep Lobe
The Submandibular Duct
Blood Supply and Lymphatic Drainage
Nerve Supply to the Submandibular Gland
Parasympathetic Innervation
Sympathetic Innervation
Sensory Innervation

The Sublingual Gland
Embryology
Anatomy
Sublingual Ducts
Blood Supply, Innervation, and Lymphatic Drainage

Minor Salivary Glands
Histology of the Salivary Glands
Control of Salivation
Summary
References

Introduction

There are three pairs of major salivary glands consisting of the parotid, submandibular, and sublingual glands. In addition there are numerous minor glands distributed throughout the oral cavity within the mucosa and submucosa.

On average about 0.5 liters of saliva are produced each day but the rate varies throughout the day. At rest, about 0.3 ml/min are produced, but this rises to 2.0 ml/min with stimulation. The contribution from each gland also varies. At rest, the parotid produces 20%, the submandibular gland 65%, and the sublingual and minor glands 15%. On stimulation, the parotid secretion rises to 50%.

The nature of the secretion also varies from gland to gland. Parotid secretions are almost exclusively serous, the submandibular secretions are mixed, and the sublingual and minor gland secretions are predominantly mucinous.

Saliva is essential for mucosal lubrication, speech, and swallowing. It also performs an essential buffering role that influences demineralization of teeth as part of the carious process. When there is a marked deficiency in saliva production, xero-stomia, rampant caries, and destructive periodontal disease ensue. Various digestive enzymes—salivary amylase—and antimicrobial agents—IgA, lysozyme, and lactoferrin—are also secreted with the saliva.

The Parotid Gland

EMBRYOLOGY

The parotid gland develops as a thickening of the epithelium in the cheek of the oral cavity in the 15 mm Crown Rump length embryo. This thickening extends backward toward the ear in a plane superficial to the developing facial nerve. The deep aspect of the developing parotid gland produces bud-like projections between the branches of the facial nerve in the third month of intra-uterine life. These projections then merge to form the deep
lobe of the parotid gland. By the sixth month of intra-uterine life the gland is completely canalized. Although not embryologically a bilobed structure, the parotid comes to form a larger (80%) superficial lobe and a smaller (20%) deep lobe joined by an isthmus between the two major divisions of the facial nerve. The branches of the nerve lie between these lobes invested in loose connective tissue. This observation is vital in the understanding of the anatomy of the facial nerve and surgery in this region (Berkovitz, Langdon, and Moxham 2003).

ANATOMY

The parotid is the largest of the major salivary glands. It is a compound, tubuloacinar, merocrine, exocrine gland. In the adult, the gland is composed entirely of serous acini.

The gland is situated in the space between the posterior border of the mandibular ramus and the mastoid process of the temporal bone. The external acoustic meatus and the glenoid fossa lie above together with the zygomatic process of the temporal bone (Figure 1.1). On its deep (medial) aspect lies the styloid process of the temporal bone. Inferiorly, the parotid frequently overlaps the angle of the mandible and its deep surface overlies the transverse process of the atlas vertebra.

The shape of the parotid gland is variable. Often it is triangular with the apex directed inferiorly. However, on occasion it is more or less of even width and occasionally it is triangular with the apex superiorly. On average, the gland is 6 cm in length with a maximum of 3.3 cm in width. In 20% of subjects a smaller accessory lobe arises from the upper border of the parotid duct approximately 6 mm in front of the main gland. This accessory lobe overlies the zygomatic arch.

The gland is surrounded by a fibrous capsule previously thought to be formed from the investing layer of deep cervical fascia. This fascia passes up from the neck and was thought to split to enclose the gland. The deep layer is attached to the mandible and the temporal bone at the tympanic plate and styloid and mastoid processes (Berkovitz and Moxham 1988; Ellis 1997; McMinn, Hutchings, and Logan 1984; Williams 1995). Recent investigations suggest that the superficial layer of the parotid capsule is not formed in this way but is part of the superficial musculo-aponeurotic system (SMAS) (Flatalu and Mills 1995; Gosain, Younis, and Madiedo et al. 1993; Jost and Levert 1983; Mitz and Peyronie 1976; Thaller, Kim, and Patterson et al. 1989; Wassef 1987; Zigiotto, Liverani, and Ghibellini 1991). Anteriorly the superficial layer of the parotid capsule is thick and fibrous but more posteriorly it becomes a thin translucent membrane. Within this fascia are scant muscle fibers running parallel with those of the platysma. This superficial layer of the parotid capsule appears to be continuous with the fascia overlying the platysma muscle. Anteriorly it forms a separate layer overlying the

![Figure 1.1. A lateral view of the skull showing some of the bony features related to the bed of the parotid gland. 1: Mandibular fossa; 2: Articular eminence; 3: Tympanic plate; 4: Mandibular condyle; 5: Styloid process; 6: Ramus of mandible; 7: Angle of mandible; 8: Mastoid process; 9: External acoustic meatus. Published with permission, Martin Dunitz, London, Langdon JD, Berkowitz BKB, Moxham BJ, editors, Surgical Anatomy of the Infratemporal Fossa.](image-url)
masseteric fascia, which is itself an extension of the deep cervical fascia. The peripheral branches of the facial nerve and the parotid duct lie within a loose cellular layer between these two sheets of fascia. This observation is important in parotid surgery. When operating on the parotid gland, the skin flap can either be raised in the subcutaneous fat layer or deep to the SMAS layer. The SMAS layer itself can be mobilized as a separate flap and can be used to mask the cosmetic defect following parotidectomy by reattaching it firmly to the anterior border of the sternocleidomastoid muscle as an advancement flap (Meningaud, Bertolus, and Bertrand 2006).

The superior border of the parotid gland (usually the base of the triangle) is closely molded around the external acoustic meatus and the temporomandibular joint. An avascular plane exists between the gland capsule and the cartilaginous and bony acoustic meatus (Figure 1.2). The inferior border (usually the apex) is at the angle of the mandible and often extends beyond this to overlap the digastric triangle, where it may lie very close to the posterior pole of the submandibular salivary

gland. The anterior border just overlaps the posterior border of the masseter muscle and the posterior border overlaps the anterior border of the sternocleidomastoid muscle.

The superficial surface of the gland is covered by skin and platysma muscle. Some terminal branches of the great auricular nerve also lie superficial to the gland. At the superior border of the parotid lie the superficial temporal vessels with the artery in front of the vein. The auriculotemporal branch of the mandibular nerve runs at a deeper level just behind the superficial temporal vessels.

The branches of the facial nerve emerge from the anterior border of the gland. The parotid duct also emerges to run horizontally across the masseter muscle before piercing the buccinator muscle anteriorly to end at the parotid papilla. The transverse facial artery (a branch of the superficial temporal artery) runs across the area parallel to and approximately 1 cm above the parotid duct. The anterior and posterior branches of the facial vein emerge from the inferior border.

The deep (medial) surface of the parotid gland lies on those structures forming the parotid bed. Anteriorly the gland lies over the masseter muscle and the posterior border of the mandibular ramus from the angle up to the condyle. As the gland wraps itself around the ramus it is related to the medial pterygoid muscle at its insertion on to the deep aspect of the angle. More posteriorly, the parotid is molded around the styloid process, the styloglossus, stylohyoid, and stylopharyngeus muscles from below upward. Behind this, the parotid lies on the posterior belly of the digastric muscle and the sternocleidomastoid muscle. The digastric and the styloid muscles separate the gland from the underlying internal jugular vein, the external and internal carotid arteries and the glossopharyngeal, vagus, accessory, and hypoglossal nerves and the sympathetic trunk.

The fascia that covers the muscles in the parotid bed thickens to form two named ligaments (Figure 1.3). The stylomandibular ligament passes from the styloid process to the angle of the mandible. The mandibulolophohyoid ligament (the angular tract) passes between the angle of the mandible and the stylohyoid ligament. Inferiorly it usually extends down to the hyoid bone. These ligaments are all that separates the parotid gland anteriorly from the posterior pole of the superficial lobe of the submandibular gland.


CONTENTS OF THE PAROTID GLAND

The Facial Nerve
From superficial to deep, the facial nerve, the auriculotemporal nerve, the retromandibular vein, and the external carotid artery pass through the substance of the parotid gland.

The facial nerve exits the skull base at the stylomastoid foramen. The surgical landmarks are important (Figure 1.4). To expose the trunk of the facial nerve at the stylomastoid foramen the dissection passes down the avascular plane between the parotid gland and the external acoustic canal until the junction of the cartilaginous and bony canals can be palpated. A small triangular extension of the cartilage points toward the facial nerve as it exits...
the foramen (Langdon 1998b). The nerve lies about 9 mm from the posterior belly of the digastric muscle and 11 mm from the bony external meatus (Holt 1996). The facial nerve then passes downward and forward over the styloid process and associated muscles for about 1.3 cm before entering the substance of the parotid gland (Hawthorn and Flatau 1990). The first part of the facial nerve gives off the posterior auricular nerve supplying the auricular muscles and also branches to the posterior belly of the digastric and stylohyoid muscles.

On entering the parotid gland the facial nerve separates into two divisions, temporofacial and cervicofacial, the former being the larger. The division of the facial nerve is sometimes called the “pes anserinus” due to its resemblance to the foot of a goose. From the temporofacial and cervicofacial divisions, the facial nerve gives rise to five named branches—temporal, zygomatic, buccal, mandibular, and cervical (Figure 1.5). The peripheral branches of the facial nerve form anastomotic arcades between adjacent branches to form the parotid plexus. These anastomoses are important during facial nerve dissection, as accidental damage to a small branch often fails to result in any facial weakness due to dual innervation from adjacent branches. Davis et al. (1956) studied these patterns following the dissection of 350 facial nerves in cadavers. The anastomotic relationships between adjacent branches fell into six patterns (Figure 1.6). They showed that in only 6% of cases (type VI) is there any anastomosis between the mandibular branch and adjacent branches. This explains why, when transient facial weakness follows facial nerve dissection, it is usually the mandibular branch that is affected.

Auriculotemporal Nerve
The auriculotemporal nerve arises from the posterior division of the mandibular division of the trigeminal nerve in the infratemporal fossa. It runs backward beneath the lateral pterygoid muscle between the medial aspect of the condylar neck and the sphenomandibular ligament. It enters the

---

Figure 1.4. Anatomical landmarks of the extratemporal facial nerve. 1: Cartilaginous external acoustic meatus; 2: Parotid gland; 3: Sternocleidomastoid muscle; 4: Tip of the mastoid process; 5: Styloid process; 6: Posterior belly of digastric muscle. Published with permission, Martin Dunitz, London, Langdon JD, Berkowitz BKB, Moxham BJ, editors, Surgical Anatomy of the Infratemporal Fossa.

Figure 1.5. Clinical photograph of dissected facial nerve following superficial parotidectomy.
anteromedial surface of the parotid gland passing upward and outward to emerge at the superior border of the gland between the temporomandibular joint and the external acoustic meatus. This nerve communicates widely with the temporofacial division of the facial nerve and limits the mobility of the facial nerve during surgery (Flatau and Mills 1995). Further communications with the temporal and zygomatic branches loop around the transverse facial and superficial temporal vessels (Bernstein and Nelson 1984).

**Retromandibular Vein**
The vein is formed within the parotid gland by the union of the superficial temporal vein and the maxillary vein. The retromandibular vein passes downward and close to the lower pole of the parotid, where it often divides into two branches passing out of the gland. The posterior branch passes backward to unite with the posterior auricular vein on the surface of the sternocleidomastoid muscle to form the external jugular vein. The anterior branch passes forward to join the facial vein.

The retromandibular vein is an important landmark during parotid gland surgery. The division of the facial nerve into its temporofacial and cervicofacial divisions occurs just behind the retromandibular vein (Figure 1.7). The two divisions lie just superficial to the vein in contact with it. It is all too easy to tear the vein while exposing the division of the facial nerve!

**External Carotid Artery**
The external carotid artery runs deeply within the parotid gland. It appears from behind the posterior belly of the digastric muscle and grooves the parotid before entering it. It gives off the posterior auricular artery before ascending and dividing into its terminal branches, the superficial temporal and maxillary arteries at the level of the condyle. The superficial temporal artery continues vertically to emerge at the superior border of the gland and crosses the zygomatic arch. Within the substance of the parotid it gives off the transverse facial artery, which emerges at the anterior border of the gland to run across the face above the parotid duct. The maxillary artery emerges from the deep aspect of the gland anteriorly to enter the infratemporal fossa. The maxillary artery gives off the deep auricular artery and the anterior tympanic artery within the substance of the parotid. All these branches from the external carotid also give off numerous
small branches within the parotid to supply the gland itself.

**Parotid Lymph Nodes**

Lymph nodes are found within the subcutaneous tissues overlying the parotid to form the preauricular nodes and also within the substance of the gland. There are typically ten nodes within the substance of the gland, the majority being within the superficial lobe and therefore superficial to the plane of the facial nerve. Only one or two nodes lie within the deep lobe (Garetea-Crelgo et al. 1993; Marks 1984; McKean, Lee, and McGregor 1985). All the parotid nodes drain into the upper deep cervical chain.

**Figure 1.7.** The facial nerve and its relationship to the retromandibular vein within the parotid gland. 1: Facial nerve at stylomastoid foramen; 2: Temporofacial branch of facial nerve; 3: Cervicofacial branch of facial nerve; 4: Temporal branch of facial nerve; 5: Zygomatic branch of facial nerve; 6: Buccal branch of facial nerve; 7: Mandibular branch of facial nerve; 8: Cervical branch of facial nerve; 9: Posterior belly of digastric muscle; 10: Retromandibular vein and external carotid artery. Published with permission, Martin Dunitz, London, Langdon JD, Berkowitz BKB, Moxham BJ, editors, Surgical Anatomy of the Infratemporal Fossa.
Parotid Duct
The parotid duct emerges from the anterior border of the parotid gland and passes horizontally across the masseter muscle. The surface markings of the duct are obtained by drawing a line from the lowest point of the alar cartilage to the angle of the mouth (Figure 1.8). This line is bisected and its midpoint is joined with a straight line to the most anterior point of the tragus. This line is divided into three equal parts and the middle section corresponds to the position of the parotid duct. The duct lies approximately 1 cm below the transverse facial vessels. The accessory lobe of the parotid gland, when present, drains into its upper border via one or two tributaries. Anastomosing branches between the buccal and zygomatic branches of the facial nerve cross the duct. At the anterior border of the masseter, the duct bends sharply to perforate the buccal pad of fat and the buccinator muscle at the level of the upper molar teeth. The duct then bends again to pass forward for a short distance before entering the oral cavity at the parotid papilla.

Nerve Supply to the Parotid
The parasympathetic secretomotor nerve supply comes from the inferior salivatory nucleus in the brain stem (Figure 1.9). From there the fibers run in the tympanic branch of the glossopharyngeal nerve contributing to the tympanic plexus in the middle ear. The lesser petrosal nerve arises from the tympanic plexus leaving the middle ear and running in a groove on the petrous temporal bone in the middle cranial fossa. From here it exits through the foramen ovale to the otic ganglion, which lies on the medial aspect of the mandibular branch of the trigeminal nerve. Postsynaptic postganglionic fibers leave the ganglion to join the auriculotemporal nerve, which distributes the parasympathetic secretomotor fibers throughout the parotid gland. Some authorities suggest that there are also some parasympathetic innervations to the parotid from the chorda tympani branch of the facial nerve.

The sympathetic nerve supply to the parotid arises from the superior cervical sympathetic ganglion. The sympathetic fibers reach the gland via the plexus around the middle meningeal artery. They then pass through the otic ganglion without synapsing and innervate the gland through the auriculotemporal nerve. There is also sympathetic innervation to the gland arising from the plexuses that accompany the blood vessels supplying the gland.

Sensory fibers arising from the connective tissue within the parotid gland merge into the auriculotemporal nerve and pass proximally through the otic ganglion without synapsing. From there the fibers join the mandibular division of the trigeminal nerve. The sensory innervation of the parotid capsule is via the great auricular nerve.
The Submandibular Gland

EMBRYOLOGY

The submandibular gland begins to form at the 13 mm stage as an epithelial outgrowth into the mesenchyme forming the floor of the mouth in the linguogingival groove. This proliferates rapidly, giving off numerous branching processes that eventually develop lumina. Initially the developing gland opens into the floor of the mouth posteriorly, lateral to the tongue. The walls of the groove into which it drains come together to form the submandibular duct. This process commences posteriorly and moves forward so that ultimately the orifice of the duct comes to lie anteriorly below the tip of the tongue close to the midline.

ANATOMY

The submandibular gland consists of a larger superficial lobe lying within the digastric triangle in the neck and a smaller deep lobe lying within the floor of the mouth posteriorly (Figure 1.10). The two lobes are continuous with each other around the posterior border of the mylohyoid muscle. As in the parotid gland, the two “lobes” are not true lobes embryologically, as the gland arises as a single epithelial outgrowth. However, surgically it consists of the two lobes as described above. It is a mixed seromucinous gland.

The Superficial Lobe

The superficial lobe lies within the digastric triangle. Its anterior pole reaches the anterior belly of
the digastric muscle and the posterior pole reaches
the stylomandibular ligament. This structure is all
that separates the superficial lobe of the sub-
mandibular gland from the parotid gland. It is
important to realize just how close the lower pole
of the parotid is to the posterior pole of the sub-
mandibular gland, as confusion can arise if a mass
in the region is incorrectly ascribed to the wrong
anatomical structure (Figure 1.2). Superiorly, the
superficial lobe lies medial to the body of the man-
dible. Inferiorly it often overlaps the intermediate
tendon of the digastric muscles and the insertion
of the stylohyoid. The lobe is partially enclosed
between the two layers of the deep cervical fascia
that arise from the greater cornu of the hyoid bone
and is in intimate proximity of the facial vein and
artery (Figure 1.11). The superficial layer of the
fascia is attached to the lower border of the man-
dible and covers the inferior surface of the super-
ficial lobe. The deep layer of fascia is attached to
the mylohyoid line on the inner aspect of the man-
dible and therefore covers the medial surface of
the lobe.

The inferior surface, which is covered by
skin, subcutaneous fat, platysma, and the deep
fascia, is crossed by the facial vein and the cervical

---

**Figure 1.10.** The relationship of the superficial and
deep lobes of the submandibular gland. Cross-sectional
anatomy (a). The superficial lobe from outside (b). The
relationship of the deep and superficial lobes to the mylo-
hyoid muscle (c).

**Figure 1.11.** Superficial dissection of the left submandibu-
lar gland. The investing layer of the deep cervical fascia is
elevated off of the submandibular gland and the facial vein
is identified.
branch of the facial nerve, which loops down from the angle of the mandible and subsequently innervates the lower lip. The submandibular lymph nodes lie between the salivary gland and the mandible. Sometimes one or more lymph nodes may be embedded within the salivary gland.

The lateral surface of the superficial lobe is related to the submandibular fossa, a concavity on the medial surface of the mandible, and the attachment of the medial pterygoid muscle. The facial artery grooves its posterior part lying at first deep to the lobe and then emerging between its lateral surface and the mandibular attachment of the medial pterygoid muscle from which it reaches the lower border of the mandible.

The medial surface is related anteriorly to the mylohyoid from which it is separated by the mylohyoid nerve and submental vessels. Posteriorly, it is related to the styloglossus, the stylohyoid ligament, and the glossopharyngeal nerve separating it from the pharynx. Between these, the medial aspect of the lobe is related to hyoglossus muscle from which it is separated by styloglossus muscle, the lingual nerve, submandibular ganglion, hypoglossal nerve, and deep lingual vein. More inferiorly, the medial surface is related to the stylohyoid muscle and the posterior belly of the digastric.

**The Deep Lobe**
The deep lobe of the gland arises from the superficial lobe at the posterior free edge of the mylohyoid muscle and extends forward to the back of the sublingual gland (Figure 1.12). It lies between the mylohyoid muscle inferolaterally, the hyoglossus and styloglossus muscles medially, the lingual nerve superiorly and the hypoglossal nerve and deep lingual vein inferiorly.

**The Submandibular Duct**
The submandibular duct is about 5 cm long in the adult. The wall of the submandibular duct is thinner than that of the parotid duct. It arises from numerous tributaries in the superficial lobe and emerges from the medial surface of this lobe just behind the posterior border of the mylohyoid. It crosses the deep lobe, passing upward and slightly backward for 5 mm before running forward between the mylohyoid and hyoglossus muscles. As it passes forward, it runs between the sublingual gland and genioglossus to open into the floor of the mouth on the summit of the sublingual papilla at the side of the lingual frenum just below the tip of the tongue. It lies between the lingual and hypoglossal nerves on the hyoglossus. At the anterior border of the hyoglossus muscle it is crossed by the lingual nerve. As the duct traverses the deep lobe of the gland it receives tributaries draining that lobe.

**Blood Supply and Lymphatic Drainage**
The arterial blood supply arises from multiple branches of the facial and lingual arteries. Venous blood drains predominantly into the deep lingual vein. The lymphatics drain into the deep cervical group of nodes, mostly into the jugulo-omohyoid node, via the submandibular nodes.

**Nerve Supply to the Submandibular Gland**

*Parasympathetic Innervation*
The secretomotor supply to the submandibular gland arises from the submandibular (sublingual) ganglion. This is a small ganglion lying on the upper part of the hyoglossus muscle. There are additional ganglion cells at the hilum of the gland. The submandibular ganglion is suspended from the lingual nerve by anterior and posterior filaments (Figure 1.13).
Surgical Anatomy, Embryology, and Physiology of the Salivary Glands

The parasympathetic secretomotor fibers originate in the superior salivatory nucleus and the preganglionic fibers, then travel via the facial nerve, chorda tympani, and lingual nerve to the ganglion via the posterior filaments connecting the ganglion to the lingual nerve. They synapse within the ganglion, and the postganglionic fibers innervate the submandibular and sublingual glands (Figure 1.9). Some fibers are thought to reach the lower pole of the parotid gland.

Sympathetic Innervation
The sympathetic root is derived from the plexus on the facial artery. The postganglionic fibers arise from the superior cervical ganglion and pass through the submandibular ganglion without synapsing. They are vasomotor to the vessels supplying the submandibular and sublingual glands. Five or six branches from the ganglion supply the submandibular gland and its duct. Others pass back into the lingual nerve via the anterior filament to innervate the sublingual and other minor salivary glands in the region.

Sensory Innervation
Sensory fibers arising from the submandibular and sublingual glands pass through the ganglion without synapsing and join the lingual nerve, itself a branch of the trigeminal nerve.

The Sublingual Gland

EMBRYOLOGY
The sublingual gland arises in 20 mm embryos as a number of small epithelial thickenings in the linguogingival groove and on the outer side of the groove. Each thickening forms its own canal and so many of the sublingual ducts open directly onto the summit of the sublingual fold. Those that arise within the linguogingival groove end up draining into the submandibular duct.

ANATOMY
The sublingual gland is the smallest of the major salivary glands. It is almond shaped and weighs approximately 4 g. It is predominantly a mucous gland. The gland lies on the mylohyoid and is covered by the mucosa of the floor of the mouth, which is raised as it overlies the gland to form the sublingual fold. Posteriorly, the sublingual gland is in contact with the deep lobe of the submandibular gland. The sublingual fossa of the mandible is located laterally and the genioglossus muscle is located medially. The lingual nerve and the submandibular duct lie medial to the sublingual gland between it and the genioglossus.

Sublingual Ducts
The gland has a variable number of excretory ducts ranging from 8 to 20. The majority drain into the floor of the mouth at the crest of the sublingual fold. A few drain into the submandibular duct. Sometimes, a collection of draining ducts coalesce anteriorly to form a major duct (Bartholin’s duct), which opens with the orifice of the submandibular duct at the sublingual papilla.

Blood Supply, Innervation, and Lymphatic Drainage
The arterial supply is from the sublingual branch of the lingual artery and also the submental branch of the facial artery. Innervation is via the sublingual ganglion as described above. The lymphatics drain to the submental nodes.
Minor Salivary Glands

Minor salivary glands are distributed widely in the oral cavity and oropharynx. They are grouped as labial, buccal, palatoglossal, palatal, and lingual glands. The labial and buccal glands contain both mucous and serous acini, whereas the palatoglossal glands are mucous secreting. The palatal glands, which are also mucous secreting, occur in both the hard and soft palates. The anterior and posterior lingual glands are mainly mucous. The anterior glands are embedded within the muscle ventrally and they drain via four or five ducts near the lingual frenum. The posterior lingual glands are located at the root of the tongue. The deep posterior lingual glands are predominantly serous. Additional serous glands (of von Ebner) occur around the circumvallate papillae on the dorsum of the tongue. Their watery secretion is thought to be important in spreading taste stimuli over the taste buds.

Histology of the Salivary Glands

The salivary glands are composed of large numbers of secretory acini, which may be tubular or globular in shape. Each acinus drains into a duct. These microscopic ducts coalesce to form lobular ducts. Each lobule has its own duct and these then merge to form the main ducts. The individual lobes and lobules are separated by dense connective tissue, which is continuous with the gland capsule. The ducts, blood vessels, lymphatics, and nerves run through and are supported by this connective tissue.

The acini are the primary secretory organs but the saliva is modified as it passes through the intercalated, striated, and excretory ducts before being discharged into the mouth and oropharynx (Figure 1.14). The lobules also contain significant amounts of adipose tissue particularly in the parotid gland. The proportion of adipose tissue relative to excretory acinar cells increases with age.

In the human parotid, the excretory acini are almost entirely serous. In the submandibular gland, again, the secretory units are mostly serous but there are additional mucous tubules and acini. In some areas the mucinous acini have crescentic “caps” of serous cells called serous demilunes. In the sublingual gland the acini are almost entirely mucinous, although there are occasional serous acini or demilunes.

The serous cells contain numerous proteinaceous secretory (zymogen) granules. These granules contain high levels of amylase. In addition, the secretory cells produce kallikrein, lactoferrin, and lysozyme. In mucous cells, the cytoplasm is packed with large pale secretory droplets.

Initially the secretory acini drain into intercalated ducts. These function mainly to conduct the saliva but they may also modify the electrolyte content and secrete immunoglobulin A. The intercalated ducts drain into striated ducts, which coalesce into intralobular and extralobular collecting ducts. The intercalated duct cells are very active metabolically and they transport potassium and bicarbonate into saliva. They reabsorb sodium and chloride ions so that the resulting saliva is hypotonic. They also secrete immunoglobulin A, lysozyme, and kallikrein. The immunoglobulin is produced by plasma cells adjacent to the striated duct cells and it is then transported through the epithelial lining into the saliva. The main collecting ducts are simple conduits for saliva and do not modify the composition of the saliva.

Myoepithelial cells are contractile cells closely related to the secretory acini and also much of the duct system. The myoepithelial cells lie between the basal lamina and the epithelial cells. Numerous cytoplasmic processes arise from them and surround the serous acini as basket cells. Those associated with the duct cells are more fusiform and are aligned along the length of the ducts. The cytoplasm of the myoepithelial cells contains actin myofilaments, which contract as a result of both parasympathetic and sympathetic activity. Thus the myoepithelial cells “squeeze” the saliva out of the secretory acini and ducts and add to the salivary secretory pressure.