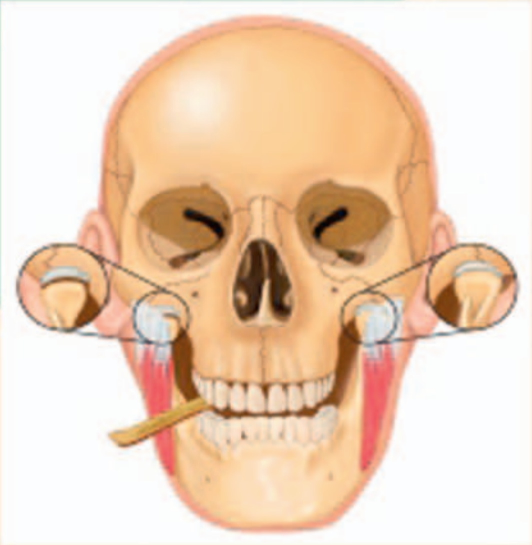
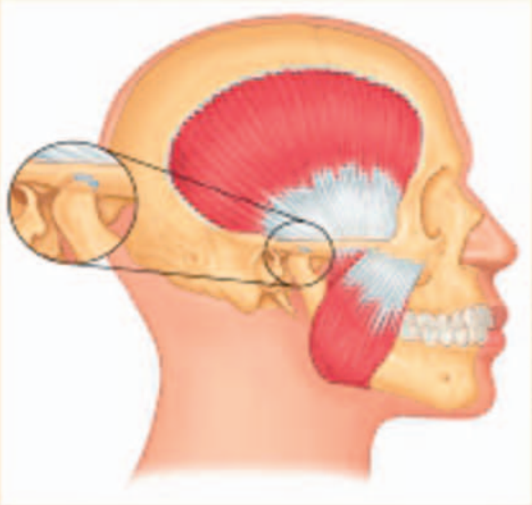
8 EDITION

Management of TEMPOROMANDIBULAR DISORDERS and OCCLUSION

Jeffrey P. Okeson





ELSEVIER

Management of Temporomandibular Disorders and Occlusion

Management of Temporomandibular Disorders and Occlusion

8TH EDITION

Jeffrey P. Okeson, DMD

Professor and Chief of the Division of Orofacial Pain
Provost's Distinguished Service Professor
Director of the Orofacial Pain Center, College of Dentistry, University of Kentucky
Lexington, Kentucky

ELSEVIER

MANAGEMENT OF TEMPOROMANDIBULAR DISORDERS
AND OCCLUSION, EIGHTH EDITION ISBN: 978-0-323-58210-0
Copyright © 2020 by Elsevier, Inc. All rights reserved.
Previous editions copyrighted 2013, 2008, 2003, 1998, 1993, 1989, 1985

No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or any information storage and retrieval system, without permission in writing from the publisher. Details on how to seek permission, further information about the Publisher's permissions policies and our arrangements with organizations such as the Copyright Clearance Center and the Copyright Licensing Agency, can be found at our website: www.elsevier.com/permissions.

This book and the individual contributions contained in it are protected under copyright by the Publisher (other than as may be noted herein)

Notice

Practitioners and researchers must always rely on their own experience and knowledge in evaluating and using any information, methods, compounds or experiments described herein. Because of rapid advances in the medical sciences, in particular, independent verification of diagnoses and drug dosages should be made. To the fullest extent of the law, no responsibility is assumed by Elsevier, authors, editors or contributors for any injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products, instructions, or ideas contained in the material herein.

ISBN: 978-0-323-58210-0

Content Strategist: Jennifer Flynn-Briggs
Content Development Manager: Ellen Wurm-Cutter
Content Development Specialist: Melissa Rawe
Publishing Services Manager: Deepthi Unni
Project Manager: Radjan Lourde Selvanadin
Design Direction: Margaret Reid

Printed in China

Last digit is the print number: 9 8 7 6 5 4 3 2 1

ELSEVIER

3251 Riverport Lane
St. Louis, Missouri 63043

ELSEVIER Book Aid International Working together to grow libraries in developing countries
www.elsevier.com • www.bookaid.org

This text is personally dedicated to my wife,
Barbara, for her continued unconditional love, support,
and understanding throughout my entire professional life.

This text is professionally dedicated to all of our patients.
It is my hope that this text may in some way help reduce their suffering.

Acknowledgments

A text such as this is never accomplished by the work of one person, but rather represents the accumulation of many who have gone before. The efforts of these individuals have led to the present state of knowledge in the field. To acknowledge each of these would be an impossible task. The multiple listing of references at the end of each chapter begins to recognize the true work behind this text. There are, however, a few individuals whom I feel both obligated and pleased to acknowledge. First is Dr. Weldon E. Bell. Although we lost this giant in 1990, he remains my mentor to this day. He was the epitome of an outstanding thinker, information simulator, and teacher. Within the seven texts he wrote on TMD and orofacial pain is found enough information to keep a normal man thinking forever. He was a very special man, and I sorely miss him still.

I would like to thank Dr. Terry Tanaka of San Diego, California, for generously sharing his knowledge with me. Over the years, I have come to value Terry's professional and personal friendship more and more. His anatomic dissections have contributed greatly to the profession's understanding of the functional anatomy of our complex masticatory system.

I would like to thank my colleague, Charles Carlson, PhD, for all that he has taught me regarding the psychology of pain. Charley and I have worked together for more than 30 years in our Orofacial Pain Center, and I have seen him develop and successfully document his concepts of physical self-regulation. These techniques have helped many of our chronic pain patients. He has generously shared his ideas and concepts in Chapter 11.

I would also like to thank the following individuals for allowing me to use some of their professional materials and insights in this text: Dr. Per-Lennart Westesson, University of Rochester, Rochester, NY; Dr. Jay Mackman, Milwaukee, Wisconsin, WI; Dr. Joseph Van Sickels, University of Kentucky, Lexington, KY; Dr. Larry Cunningham, University of Kentucky, Lexington, KY; Dr. Gerhard Undt, Vienna, Austria; Dr. Steve Burke, Centerville, Ohio, OH; Dr. Carol Bibb, UCLA, Los Angeles, CA; Dr. William Solberg, UCLA, Los Angeles, CA; Dr. Douglas Damm, University of Kentucky, Lexington, KY; Dr. Galal Omami, University of Kentucky. I also wish to thank Dr. David Hoffman for helping me acquire some of the patient images used in the text.

I would also like to acknowledge and thank Ms. Jodie Bernard at Lightbox Visual Communications and her team of wonderful artists for making this edition and the last possible.. Of course, this project could not have been completed without the support and assistance of Content Strategist Alexandra Mortimer, Content Development Specialist, Melissa Rawe, and the entire staff at Elsevier Publishers.

I also wish to acknowledge and thank my more than 60 full-time residents from 25 different countries over the years who have kept me alert, focused, and searching for the truth.

Last, but by no means least, I wish to express my gratitude to my family for their constant love, support, encouragement, and sacrifice during my writings. My mother and father inspired and encouraged me from the very beginning. My sons have understood the time commitment, and my wife has given up many evenings to my computer. I have been blessed with a wonderful, loving wife for 48 years, and her sacrifice has resulted in this textbook.

Jeffrey P. Okeson, DMD

About the Author

Jeffrey P. Okeson, DMD
Dr. Okeson is a 1972 graduate of the University of Kentucky College of Dentistry. After graduation he completed 2 years with the Public Health Service in a rotating dental internship and directorship of an outpatient clinic. He joined the faculty at the University of Kentucky in 1974. At present he is Professor and Chief of the Division of Orofacial Pain. He is also Director of the college's Orofacial Pain Center, which he established in 1977. The Orofacial Pain Center represents a multiprofessional effort in the management of chronic orofacial pain problems. Dr. Okeson has developed several postgraduate training programs in the center, including a Master of Science Degree in Orofacial Pain. He led the program in becoming one of the first fully accredited orofacial pain graduate training programs by the Commission on Dental Accreditation in the United States. Dr. Okeson has more than 240 professional publications in the areas of occlusion, temporomandibular disorders (TMDs), and orofacial pain in various national and international journals. Dr. Okeson's textbook, *Management of Temporomandibular Disorders and Occlusion,* is used in the majority of US dental schools and has been translated into 11 languages. In addition to this text, Dr. Okeson is also the author of *Bell's Orofacial Pains*. This text is also widely used in orofacial pain programs throughout the world.

Dr. Okeson is an active member of many TMD and orofacial pain organizations. He holds many offices and serves on numerous committees and boards. He is a past president and founding fellow of the American Academy of Orofacial Pain (AAOP). He is a founding diplomate and twice president of the American Board of Orofacial Pain. He has been active in the AAOP, developing treatment and curriculum guidelines for TMDs and orofacial pain. He edited the third edition of the AAOP guidelines, titled *Orofacial Pain: Guidelines for Classification, Assessment, and Management*, which has been used as treatment standards throughout the world. Dr. Okeson has presented more than 1300 invited lectures on the subject of TMDs and orofacial pain in all 50 United States and 58 foreign countries. At national and international meetings, he is frequently referred to as "the world ambassador for orofacial pain." Dr. Okeson has received several teaching awards from his dental students, as well as the campus-wide University of Kentucky Great Teacher Award. He has received the Provost's Distinguished Service Professorship, the American Academy of Orofacial Pain's Service Award and the first ever "Distinguished Alumni Award" from the College of Dentistry. He is the first and only dentist to be inducted into the University of Kentucky Hall of Distinguished Alumni. Dr. Okeson has also received "The International Dentist of the Year Award" from the Academy of Dentistry International. This is the highest award recognized by this academy and was given to him in recognition of his worldwide efforts in providing education in the area of TMDs and orofacial pain.

Preface

The study of occlusion and its relationship to function of the masticatory system has been a topic of interest in dentistry for many years. This relationship has proved to be quite complex. Tremendous interest in this area accompanied by lack of complete knowledge has stimulated numerous concepts, theories, and treatment methods. This, of course, has led to much confusion in an already complicated field of study. Although the level of knowledge today is greater than ever before, there is still much to learn. Some of today's techniques will prove to be our most effective treatments in the future. Other methods will be demonstrated as ineffective and will have to be discarded. Competent and caring practitioners must establish their treatment methods based on both their present knowledge and their constant evaluation of information received from the massive amount of ongoing research. This is an enormous task. It is my hope that this text will assist students, teachers, and practitioners in making these important treatment decisions for their patients.

I began my teaching career at the University of Kentucky in 1974 in the area of occlusion. At that time, I believed there was a need for a teaching manual that presented the topics of occlusion and temporomandibular disorders (TMDs) in an organized, logical, and scientific manner. In 1975, I developed such a manual to assist in teaching my dental students. Soon, several other dental schools requested use of this manual for their teaching programs. In 1983, the CV Mosby Publishing Company approached me with the concept of developing this manual into a complete textbook. After 2 years of writing and editing, the first edition was published in 1985. I am very pleased and humbled to learn that this text is currently being used in most of the dental schools in the United States and has been translated into 11 foreign languages for use abroad. This is professionally very satisfying, and it is my hope that the true benefit of this text is found in the improved quality of care we offer our patients.

It is a privilege to have the opportunity to update this text for the eighth time. I have tried to include the most significant scientific findings that have been revealed in the past 4 years. I believe the strength of a textbook lies not in the author's words, but in the scientific references that are offered to support the ideas presented. Unreferenced ideas should be considered only as opinions that require further scientific investigation to either verify or negate them. It is extremely difficult to keep a textbook updated, especially in a field in which so much is happening so quickly. Thirty-three years ago, in the first edition of this text, I referenced approximately 450 articles to support the statements and ideas. The concepts in this edition are supported by nearly 2400 scientific references. This reflects the significant scientific growth of this field. It should be acknowledged that as future truths are uncovered, the professional has the obligation to appropriately respond with changes that best reflect the new information. These changes are sometimes difficult for the clinician because they may reflect the need to change clinical protocol. However, the best care for our patients rests in the most scientifically supported information.

The purpose of this text is to present a logical and practical approach to the study of occlusion and masticatory function. The text is divided into four main sections: The first part consists of six chapters that present the normal anatomic and physiologic features of the masticatory system. Understanding normal occlusal relationships and masticatory function is essential to understanding dysfunction. The second part consists of four chapters that present the etiology and identification of common functional disturbances of the masticatory system. Significant supportive documentation has been included in this edition. The third part consists of six chapters that present rational treatments for these disorders according to the significant etiologic factors. Recent studies have been added to support existing treatments, as well as for new considerations. The last part consists of four chapters that present specific considerations for permanent occlusal therapy.

The intent of this text is to develop an understanding of and rational approach to the study of masticatory function and occlusion. To assist the reader, certain techniques have been presented. It should be recognized that the purpose of a technique is to achieve certain treatment goals. Accomplishing these goals is the significant factor, not the technique itself. Any technique that achieves the treatment goals is acceptable as long as it does so in a reasonably conservative, cost-effective manner, with the best interests of the patient kept in mind.

Contents

Part I: Functional Anatomy

Part II: Etiology and Identification of Functional Disturbances in the Masticatory System

Part III: Treatment of Functional Disturbances of the Masticatory System

Part IV: Occlusal Therapy

This page intentionally left blank

PART I

Functional Anatomy

The masticatory system is extremely complex. It is made up primarily of bones, muscles, ligaments, and teeth. Movement is regulated by an intricate neurologic control system made up of the brain, brainstem, and the peripheral nervous system. Each movement is coordinated to maximize function while minimizing damage to any structure. Precise movement of the mandible by the musculature is required to move the teeth efficiently across each other during function. The mechanics and physiology of this movement are basic to the study of masticatory function. Part I consists of six chapters that discuss the normal anatomy, function, and mechanics of the masticatory system. Function must be understood before dysfunction can have meaning.

1

Functional Anatomy and Biomechanics of the Masticatory System

> *"Nothing is more fundamental to treating patients than knowing the anatomy."*
>
> ***JPO***

The masticatory system is the functional unit of the body primarily responsible for chewing, speaking, and swallowing. Components also play a major role in tasting and breathing. The system is made up of bones, joints, ligaments, teeth, and muscles. In addition, an intricate neurologic controlling system regulates and coordinates all these structural components.

The masticatory system is a complex and highly refined unit. A sound understanding of its functional anatomy and biomechanics is essential to the study of occlusion. This chapter describes the anatomic features that are basic to an understanding of masticatory function. A more detailed description can be found in the numerous texts devoted entirely to the anatomy of the head and neck.

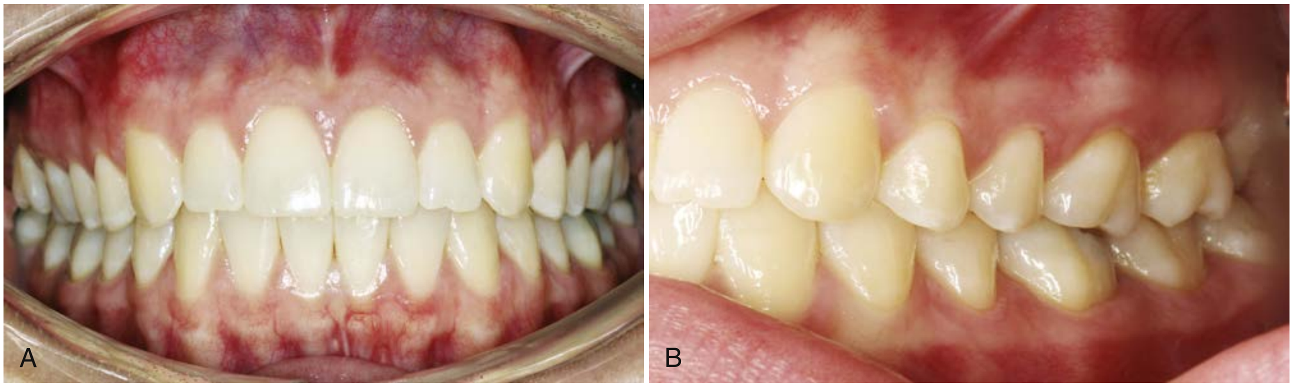
Functional Anatomy

The following anatomic components are discussed in this chapter: the dentition and their supportive structures, the skeletal components, the temporomandibular joints, the ligaments, and the muscles. After the anatomic features are described, the biomechanics of the temporomandibular joint are presented. In Chapter 2, the complex neurologic controlling system responsible for carrying out the intricate functions of the masticatory system will be presented.

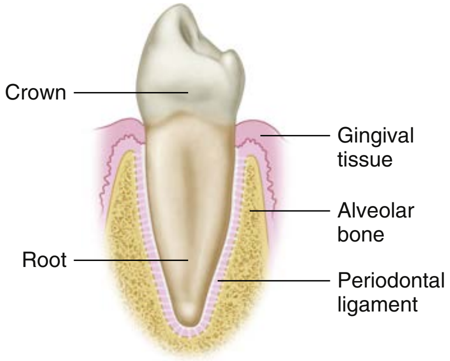
Dentition and Supportive Structures

The human dentition is made up of 32 permanent teeth (Fig. 1.1A and B). Each tooth can be divided into two basic parts: the crown, which is visible above the gingival tissue, and the root, which is submerged in and surrounded by the alveolar bone. The root is attached to the alveolar bone by numerous fibers of connective tissue that span from the cementum surface of the root to the bone. Most of these fibers run obliquely from the cementum in a cervical direction to the bone (Fig. 1.2). These fibers are known collectively as the *periodontal ligament*. The periodontal ligament not only attaches the tooth firmly to its bony socket but also helps dissipate the forces applied to the bone during functional contact of the teeth. In this sense, it can be thought of as a natural shock absorber. The periodontal ligament has specialized receptors that provide information on pressure and position. This sensory information is essential for function as will be described in the next chapter.

The 32 permanent teeth are distributed equally in the alveolar bone of the maxillary and mandibular arches: 16 maxillary teeth are aligned in the alveolar process of the maxilla, which is fixed to the lower anterior portion of the skull; the remaining 16 teeth are aligned in the alveolar process of the mandible, which is the movable jaw. The maxillary arch is slightly larger than the mandibular arch, which usually causes the maxillary teeth to overlap the mandibular teeth both vertically and horizontally when in occlusion (Fig. 1.3). This size discrepancy results primarily from the fact that (1) the maxillary anterior teeth are much wider than the mandibular teeth, which creates a greater arch width, and (2) the maxillary



• **Fig. 1.1. A.** Anterior and, **B,** lateral view of the dentition.



• Fig. 1.2. The tooth and its periodontal supportive structure. Note that the width of the periodontal ligament is greatly exaggerated for illustrative purposes.

• Fig. 1.3. Note that the maxillary teeth are positioned slightly facial to the mandibular throughout the arch.

anterior teeth have a greater facial angulation than the mandibular anterior teeth, which creates a horizontal and vertical overlapping.

The permanent teeth can be grouped into four classifications as follows according to the morphology of the crowns.

The teeth located in the most anterior region of the arches are called *incisors*. They have a characteristic shovel shape, with an incisal edge. There are four maxillary incisors and four mandibular incisors. The maxillary incisors are generally much larger than the mandibular incisors and, as previously mentioned, commonly overlap them. The function of the incisors is to incise or cut off food during mastication.

Posterior (distal) to the incisors are the *canines*. The canines are located at the corners of the arches and are generally the longest of the permanent teeth, with a single cusp and root (Fig. 1.4). These teeth are very prominent in other animals such as dogs, and hence the name “canine.” There are two maxillary and two mandibular canines. In animals, the primary function of the canines is to rip and tear food. In the human dentition, however, the canines usually function as incisors and are used only occasionally for ripping and tearing.

Still more posterior in the arch are the *premolars* (Fig. 1.4). There are four maxillary and four mandibular premolars. The premolars are also called bicuspids since they generally have two cusps. The presence of two cusps greatly increases the biting surfaces of these teeth. The maxillary and mandibular premolars occlude in such a manner that food can be caught and crushed between them. The main function of the premolars is to begin the effective breakdown of food substances into smaller particle sizes.

• Fig. 1.4. Lateral view of the posterior teeth.

The last class of teeth, found posterior to the premolars, is the *molars* (Fig. 1.4). There are six maxillary molars and six mandibular molars. The crown of each molar has either four or five cusps. This provides a large, broad surface upon which breaking and grinding of food can occur. Molars function primarily in the later stages of chewing, when food is broken down into small enough particles that can be easily swallowed.

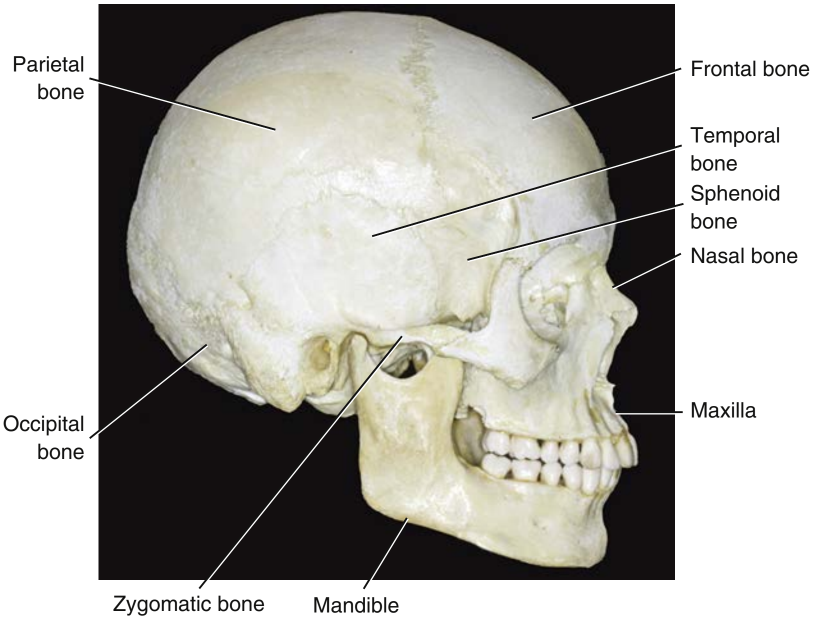
As discussed, each tooth is highly specialized according to its function. The exact interarch and intraarch relationships of the teeth are extremely important and greatly influence the health and function of the masticatory system. A detailed discussion of these relationships will be presented in Chapter 3.

Skeletal Components

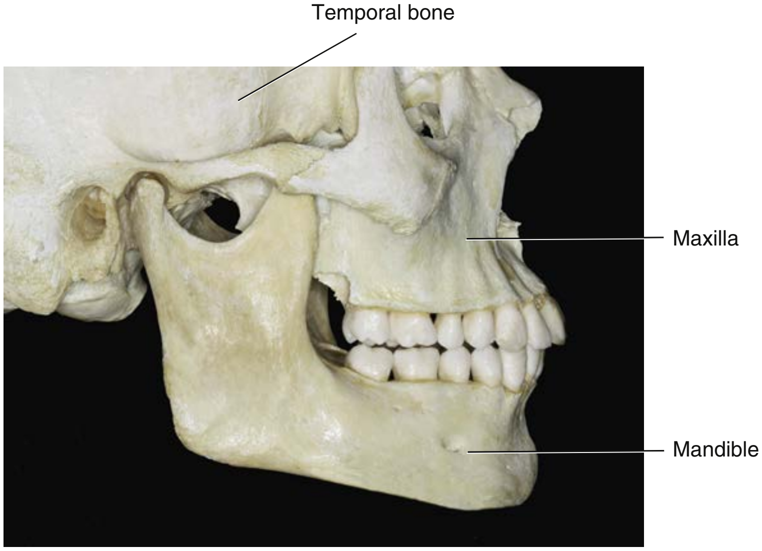
The skeletal components of the human head are the skull and mandible (Fig. 1.5). The skull is composed of several bones connected together by fissures. The major components are the temporal bone, the frontal bone, the parietal bone, the sphenoid bone, the occipital bone, the zygomatic bone, the nasal bone, and the maxilla. The mandible is a separate bone suspended below the cranium in a muscle sling. The three major skeletal components that make up the masticatory system are the maxilla and mandible, which support the teeth (Fig. 1.6), and the temporal bone, which supports the mandible at its articulation with the cranium.

The Maxilla

Developmentally, there are two maxillary bones, which are fused together at the midpalatal suture (Fig. 1.7). These bones make up the greater part of the upper facial skeleton. The border of the maxilla extends superiorly to form the floor of the nasal cavity as well as the floor of each orbit. Inferiorly, the maxillary bones form the palate and the alveolar ridges, which support the teeth. Since the maxillary bones are intricately fused to the surrounding bony components of the skull, the maxillary teeth are considered to be a fixed part of the skull and therefore make up the stationary component of the masticatory system.



• **Fig. 1.5.** The lateral view of the cranium and the mandible. The separate bones that make up the skull are labeled.



• **Fig. 1.6.** Skeletal components that make up the masticatory system: maxilla, mandible, and temporal bone.

The Mandible

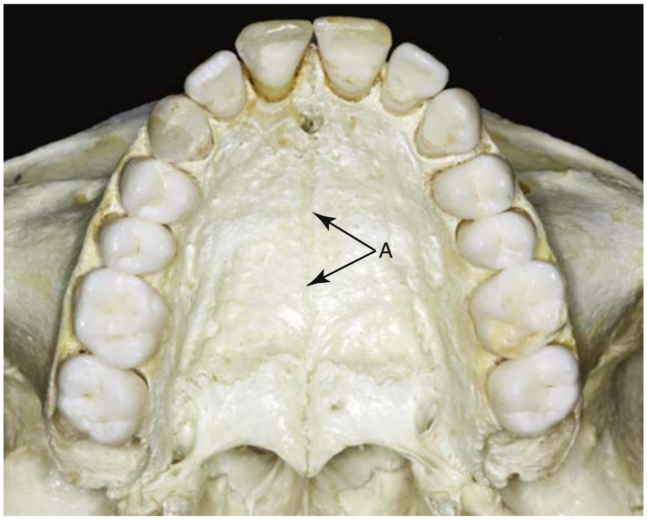
The mandible is a U-shaped bone that supports the lower teeth and makes up the lower facial skeleton. It has no bony attachments to the skull. It is suspended below the maxilla by muscles, ligaments, and other soft tissues, which therefore provide the mobility necessary to function with the maxilla.

The superior aspect of the arch-shaped mandible consists of the alveolar process and the teeth (Fig. 1.8). The body of the mandible extends posteroinferiorly to form the mandibular angle and posterosuperiorly to form the ascending ramus. The ascending ramus of the mandible is formed by a vertical plate of bone that extends upward as two processes. The anterior of these is the coronoid process. The posterior is the condyle.

The condyle is the portion of the mandible that articulates with the cranium, around which movement occurs. From the anterior view, it has a medial and a lateral projection called poles (Fig. 1.9). The medial pole is generally more prominent than the lateral. From above, a line drawn through the centers of the poles of the condyle will usually extend medially and posteriorly toward the anterior border of the foramen magnum (Fig. 1.10). The total mediolateral length of the condyle is between 18 and 23 mm, and the anteroposterior width is between 8 and 10 mm. The actual articulating surface of the condyle extends both anteriorly and posteriorly to the most superior aspect of the condyle (Fig. 1.11). The posterior articulating surface is greater than the anterior surface. The articulating surface of the condyle is quite convex anteroposteriorly and only slightly convex mediolaterally.

The Temporal Bone

The mandibular condyle articulates at the base of the cranium with the squamous portion of the temporal bone. This portion of the temporal bone is made up of a concave mandibular fossa, in which the condyle is situated (Fig. 1.12), and which has also been called the articular or glenoid fossa. Posterior to the mandibular fossa is the squamotympanic fissure, which extends mediolaterally. As this fissure extends medially, it divides into the petrosquamous fissure anteriorly and the petrotympanic fissure posteriorly. Immediately anterior to the fossa is a convex bony prominence called the articular eminence. The degree of convexity of the articular eminence is highly variable but important since the steepness of this surface dictates the pathway of the condyle when the mandible is positioned anteriorly. The posterior roof of the mandibular fossa is quite thin, indicating that this area of the temporal bone is not designed to sustain heavy forces. The articular eminence, however, consists of thick dense bone and is more likely to tolerate such forces.



• **Fig. 1.7.** The midpalatal suture *(A)* results from the fusion of the two maxillary bones during development.

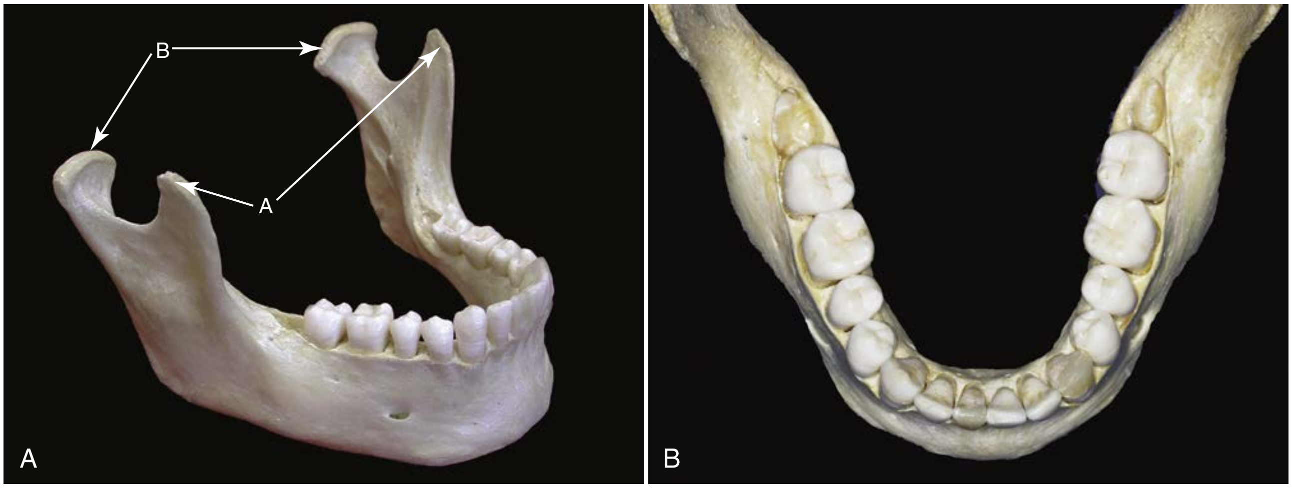
Temporomandibular Joint

The area where the mandible articulates with the temporal bone of the cranium is called the temporomandibular joint (TMJ). The TMJ is certainly one of the most complex joints in the body. It provides for hinging movement in one plane and therefore can be considered a *ginglymoid joint*. However, at the same time it also provides for gliding movements, which classifies it as an *arthrodial joint*. Thus, it has been technically considered a *ginglymoarthrodial joint*.

The TMJ is formed by the mandibular condyle fitting into the mandibular fossa of the temporal bone. Separating these two bones from direct articulation is the articular disc. The TMJ is classified as a compound joint. By definition, a compound joint requires the presence of at least three bones, yet the TMJ is made up of only two bones. Functionally, the articular disc serves as a nonossified bone that permits the complex movements of the joint. Since the articular disc functions as a third bone, the craniomandibular articulation is considered a compound joint. The function of the articular disc as a nonossified bone will be described in detail later in this chapter under the section on the biomechanics of the TMJ.

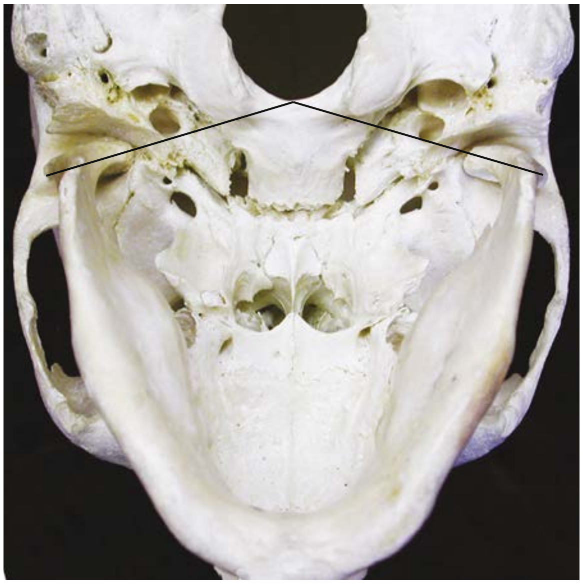
The articular disc is composed of dense fibrous connective tissue, for the most part devoid of any blood vessels or nerve fibers. The extreme periphery of the disc, however, is slightly innervated.[1,2] In the sagittal plane, it can be divided into three regions according to thickness (Fig. 1.13). The central area is the thinnest and is called the intermediate zone. The disc becomes considerably thicker both anterior and posterior to the intermediate zone. The posterior border is generally slightly thicker than the anterior border. In the normal joint, the articular surface of the condyle is located on the intermediate zone of the disc, bordered by the thicker anterior and posterior regions.

From an anterior view, the disc is generally thicker medially than laterally, which corresponds to the increased space between the condyle and the articular fossa toward the medial of the joint. The precise shape of the disc is determined by the morphology of the condyle and mandibular fossa (Fig. 1.14). During movement, the disc is somewhat flexible and can adapt to the



• **Fig. 1.8. A.** The ascending ramus extends upward to form the coronoid process *(A)* and the condyle *(B)*. **B.** Occlusal view.

• **Fig. 1.9.** The Condyle (Anterior View). Note that the medial pole *(MP)* is more prominent than the lateral pole *(LP).*

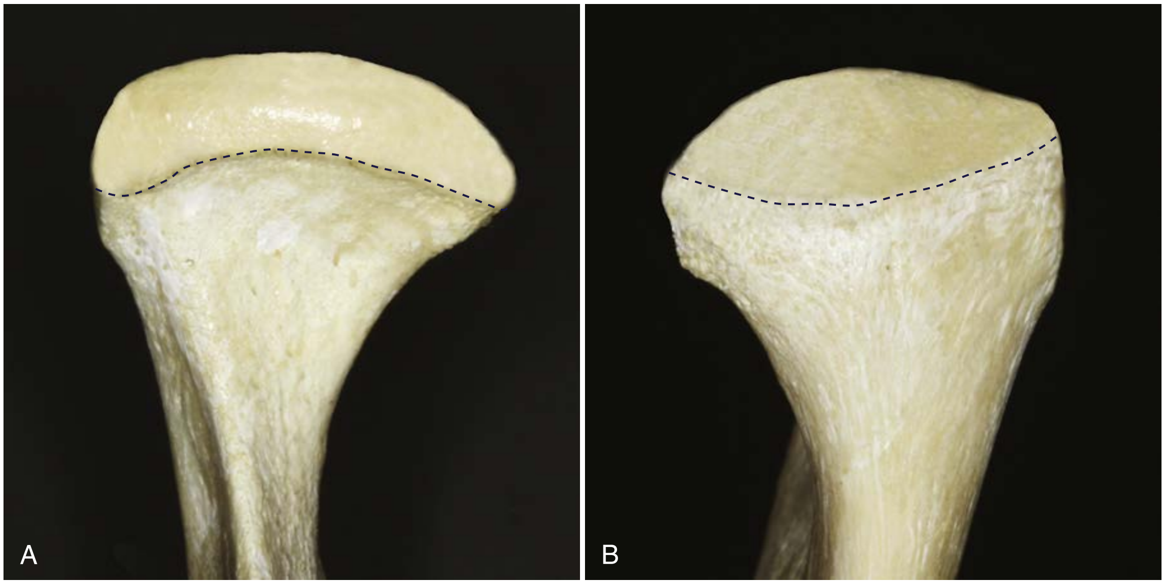


• **Fig. 1.10.** An Inferior View of Surface of the Cranium and Mandible. Note that the condyles seem to be slightly rotated so that if an imaginary line were drawn through the lateral and medial poles it would extend medially and posteriorly toward the anterior border of the foramen magnum.

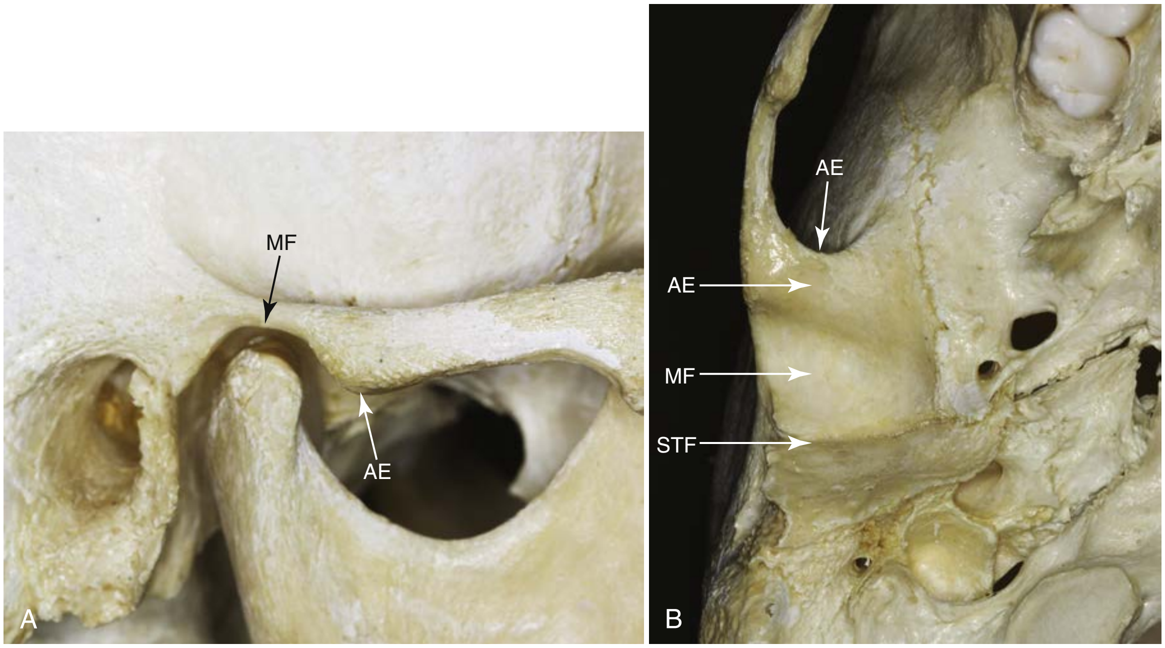
functional demands of the articular surfaces. Flexibility and adaptability do not imply that the morphology of the disc is reversibly altered during function, however. The disc maintains its morphology unless destructive forces or structural changes occur in the joint. If these changes occur, the morphology of the disc can be irreversibly altered, producing biomechanical changes during function. These changes will be discussed in later chapters.

The articular disc is attached posteriorly to a region of loose connective tissue that is highly vascularized and innervated (Fig. 1.15). This tissue is known as the *retrodiscal tissue* or posterior attachment**.** Superiorly, it is bordered by a lamina of connective tissue that contains many elastic fibers, the superior retrodiscal lamina. The superior retrodiscal lamina attaches the articular disc posteriorly to the tympanic plate. At the lower border of the retrodiscal tissues is the inferior retrodiscal lamina, which attaches the inferior border of the posterior edge of the disc to the posterior margin of the articular surface of the condyle. The inferior retrodiscal lamina is composed chiefly of collagenous fibers, not elastic fibers like the superior retrodiscal lamina. The remaining body of the retrodiscal tissue is attached posteriorly to a large venous plexus, which fills with blood as the condyle moves forward.[3,4] The superior and inferior attachments of the anterior region of the disc are to the capsular ligament, which surrounds most of the joint. The superior attachment is to the anterior margin of the articular surface of the temporal bone. The inferior attachment is to the anterior margin of the articular surface of the condyle. Both these anterior attachments are composed of collagenous fibers. Anteriorly, between the attachments of the capsular ligament the disc is also attached by tendinous fibers to the superior lateral pterygoid muscle.

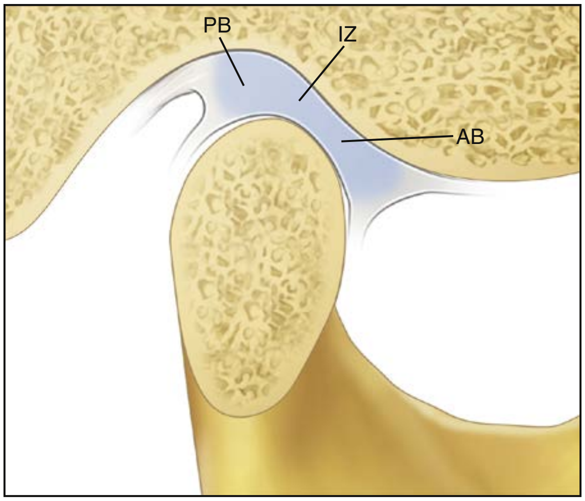
The articular disc is attached to the capsular ligament not only anteriorly and posteriorly but also medially and laterally. This divides the joint into two distinct cavities. The upper or superior cavity is bordered by the mandibular fossa and the superior surface of the disc. The lower or inferior cavity is bordered by the mandibular condyle and the inferior surface of the disc. The internal surfaces of the cavities are surrounded by specialized endothelial cells that form a synovial lining. This lining, along with a specialized synovial fringe located at the anterior border of the retrodiscal tissues, produces synovial fluid, which fills both joint cavities. Thus, the TMJ is referred to as a synovial joint. This synovial fluid serves two purposes. Since the articular surfaces of the joint are



• **Fig. 1.11.** The Condyle. **A.** Anterior and, **B,** posterior views. A dotted line marks the border of the articular surface. Note that the articular surface on the posterior aspect of the condyle is greater than on the anterior aspect.



• **Fig. 1.12.** **A.** Bony structures of the temporomandibular joint (lateral view). **B.** Articular fossa (inferior view). *AE,* Articular eminence; *MF,* mandibular fossa; *STF,* squamotympanic fissure.



• **Fig. 1.13.** Articular Disc, Fossa, and Condyle (Lateral View). The condyle is normally situated on the thinner intermediate zone *(IZ)* of the disc. The anterior border of the disc *(AB)* is considerably thicker than the intermediate zone, and the posterior border *(PB)* is even thicker.

nonvascular, the synovial fluid acts as a medium for providing metabolic requirements to these tissues. Free and rapid exchange exists between the vessels of the capsule, the synovial fluid, and the articular tissues. The synovial fluid also serves as a lubricant between articular surfaces during function. The articular surfaces of the disc, condyle, and fossa are very smooth so friction during movement is minimized. The synovial fluid helps to minimize this friction further.

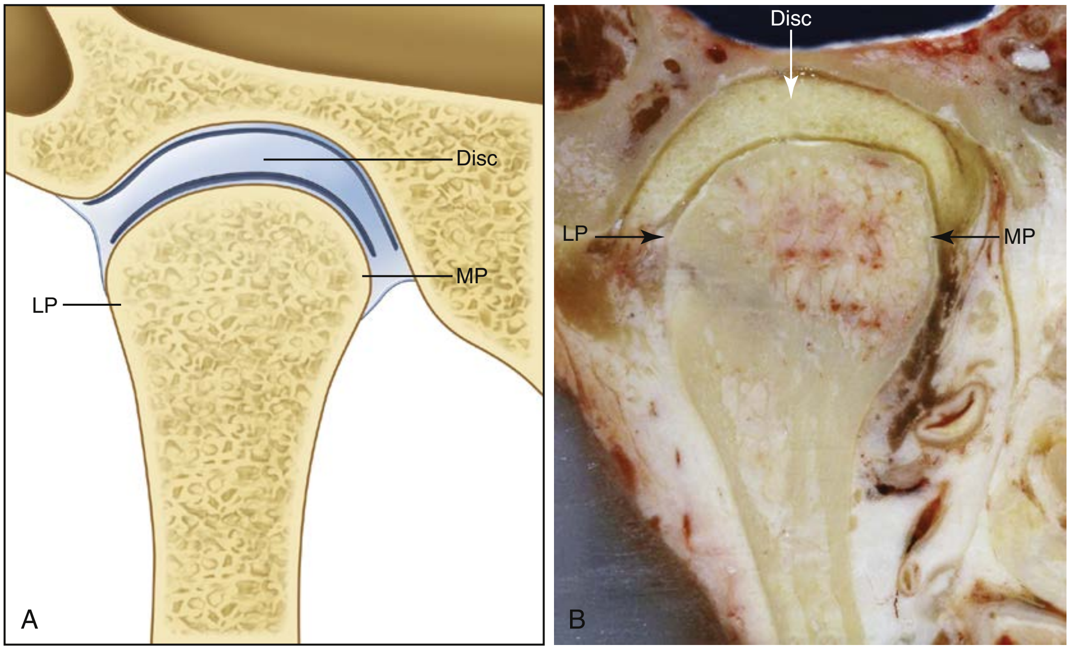
Synovial fluid lubricates the articular surfaces by way of two mechanisms. The first is called *boundary* lubrication, which occurs when the joint is moved and the synovial fluid is forced from one area of the cavity into another. The synovial fluid located in the border or recess areas is forced on the articular surface, thus providing lubrication. Boundary lubrication prevents friction in the moving joint and is the primary mechanism of joint lubrication.

A second lubricating mechanism is called *weeping* lubrication. This refers to the ability of the articular surfaces to absorb a small amount of synovial fluid.[5] During function of a joint, forces are created between the articular surfaces. These forces drive a small amount of synovial fluid in and out of the articular tissues. This is the mechanism by which metabolic exchange occurs. Under compressive forces, therefore, a small amount of synovial fluid is released. This synovial fluid acts as a lubricant between articular tissues to prevent sticking. Weeping lubrication helps eliminate friction in the compressed but not moving joint. Only a small amount of synovial fluid is expressed as a result of weeping lubrication; therefore prolonged compressive forces to the articular surfaces will exhaust this supply. The consequence of prolonged static loading of the joint structures will be discussed in later chapters.

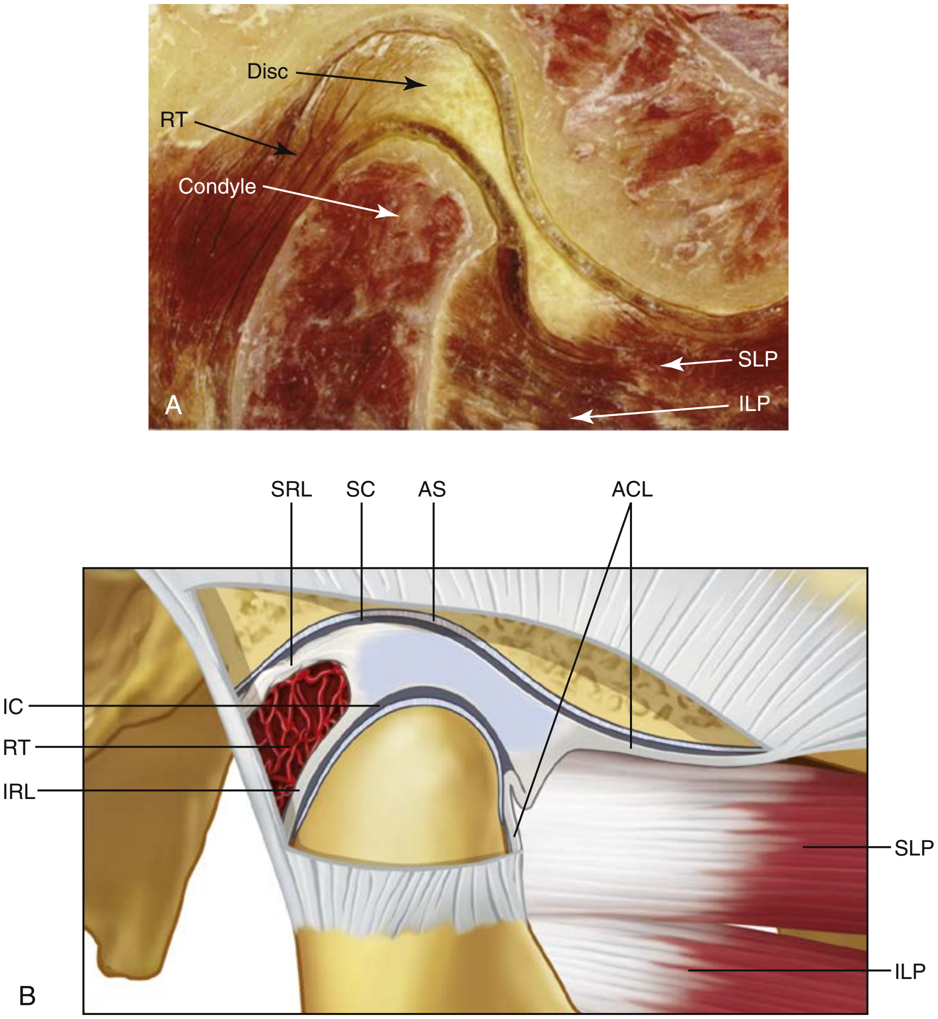
Histology of the Articular Surfaces

The articular cartilage of the TMJ is set up very differently from typical articular cartilage. The reason for this is that the mandible and TMJ form from intermembranous ossification rather than from endochondral ossification. Because of that, the articular fibrocartilage of the TMJ keeps its chondroprogenitor cells buried deep within it, unlike typical articular cartilage, which loses its chondroprogenitor cells. The zones of the articular fibrocartilage are set up differently, which allow for continued TMJ growth, repair, and remodeling.

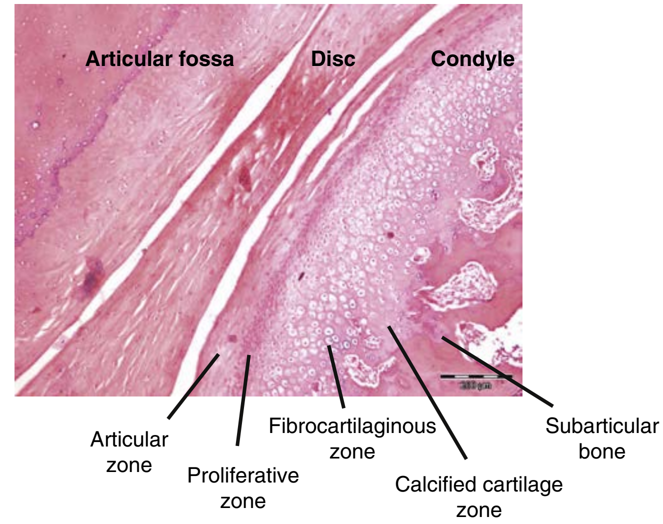
The articular cartilage of the mandibular condyle and fossa are composed of four distinct layers or zones (Fig. 1.16). The most superficial layer is called the articular zone. It is found adjacent to the joint cavity and forms the outermost functional surface. Unlike most other synovial joints, this articular layer is made of dense fibrous connective tissue rather than hyaline cartilage. Most of the collagen fibers are arranged in bundles and oriented nearly parallel to the articular surface.[6,7] The fibers are tightly packed and are able to withstand the forces of movement. It is thought



• **Fig. 1.14.** Articular Disc, Fossa, and Condyle (Anterior View). Note that the disc adapts to the morphology of the fossa and the condyle. *LP,* Lateral pole; *MP,* medial pole. (Courtesy Dr. Per-Lennart Westeson, Rochester, NY.)



• **Fig. 1.15.** Temporomandibular Joint. **A.** Lateral view and, **B,** diagram showing the anatomic components. *ACL,* Anterior capsular ligament (collagenous); *AS,* articular surface; *IRL,* inferior retrodiscal lamina (collagenous); *RT,* retrodiscal tissues; *SC* and *IC,* superior and inferior joint cavity; *SLP* and *ILP,* superior and inferior lateral pterygoid muscles; *SRL,* superior retrodiscal lamina (elastic); the discal (collateral) ligament has not been drawn. (**A.** Courtesy Dr. Per-Lennart Westeson, Rochester, NY.)



• **Fig. 1.16.** A histological section of a healthy mandibular condyle showing the four zones: articular zone, proliferative zone, fibrocartilaginous zone, and the calcified zone. ("(c)"Mathias Nordvi, The Faculty of Dentistry/University of Oslo.)

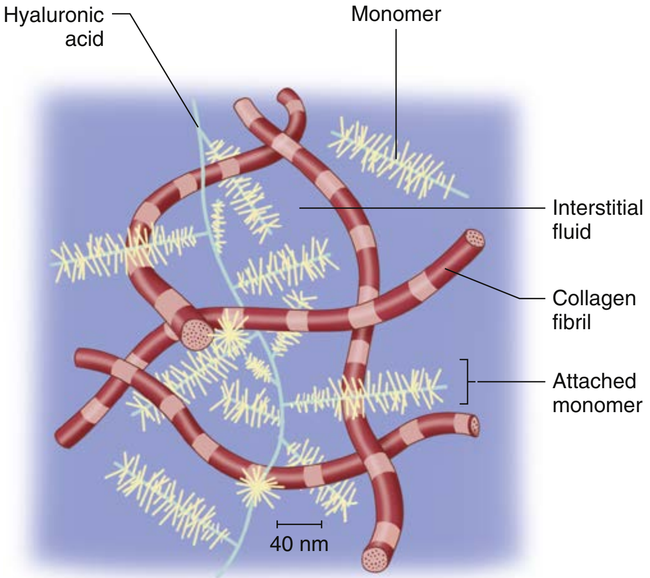
that this fibrous connective tissue affords the joint several advantages over hyaline cartilage. It is generally less susceptible than hyaline cartilage to the effects of aging and, therefore, is less likely to break down over time. It also has a much better ability to repair than does hyaline cartilage.[8] The importance of these two factors is significant in TMJ function and dysfunction and will be discussed more completely in later chapters.

The second zone is called the proliferative zone and is mainly cellular. It is in this area that undifferentiated mesenchymal tissue is found. This tissue is responsible for the proliferation of articular cartilage in response the functional demands placed on the articular surfaces during loading.

The third zone is the fibrocartilaginous zone. Here the collagen fibrils are arranged in bundles in a crossing pattern, although some of the collagen is seen in a radial orientation. The fibrocartilage appears to be in a random orientation providing a three-dimensional network that offers resistance against compressive and lateral forces.

The fourth and deepest zone is the calcified cartilage zone. This zone is made up of chondrocytes and chondroblasts distributed throughout the articular cartilage. In this zone the chondrocytes become hypertrophic, die, and have their cytoplasm evacuated, forming bone cells from within the medullary cavity. The surface of the extracellular matrix scaffolding provides an active site for remodeling activity as endosteal bone growth proceeds as it does elsewhere in the body.

The articular cartilage is composed of chondrocytes and intercellular matrix.[9] The chondrocytes produce the collagen, proteoglycans, glycoproteins, and enzymes that form the matrix. Proteoglycans are complex molecules composed of a protein core and glycosaminoglycan chains. The proteoglycans are connected to a hyaluronic acid chain forming proteoglycan aggregates that make up a great protein of the matrix (Fig. 1.17). These aggregates are very hydrophilic and are intertwined throughout the collagen network. Since these aggregates tend to bind water, the matrix expands and the tension in the collagen fibrils counteracts the swelling pressure of the proteoglycan aggregates.[10] In this way, the interstitial fluid contributes to support joint loading. The external pressure resulting from joint loading is in equilibrium with the internal pressure of the articular cartilage. As joint loading increases, tissue fluid flows outward until a new equilibrium is achieved. As loading is decreased, fluid is reabsorbed and the tissue regains its original volume. Joint cartilage is nourished predominantly by diffusion of synovial fluid, which depends on this pumping action during normal activity.[11] This pumping action is the basis for the weeping lubrication that has previously been discussed and is thought to be very important in maintaining healthy articular cartilage.[12]



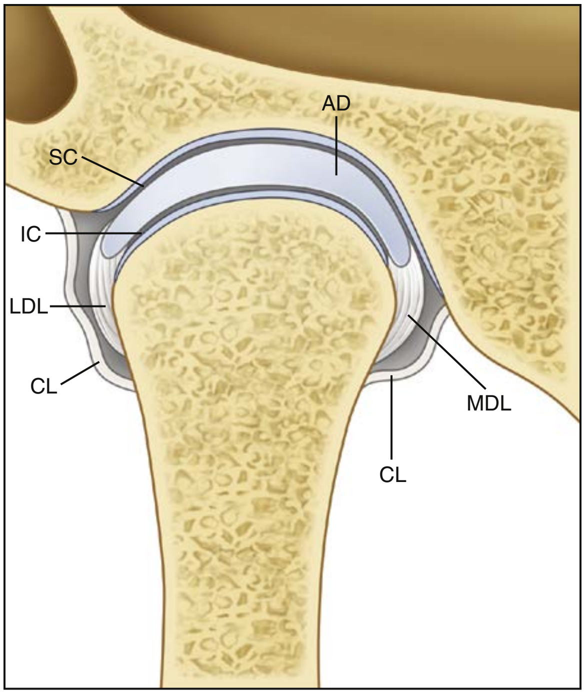
• **Fig. 1.17.** The collagen network interacting with the proteoglycan network in the extracellular matrix forming a fiber reinforced composite. (From Mow VC, Ratcliffe A: Cartilage and diarthrodial joints as paradigms for hierarchical materials and structures. *Biomaterials* 13[2]:67–81, 1992.)

Innervation of the Temporomandibular Joint

As with all joints, the TMJ is innervated by the same nerve that provides motor and sensory innervation to the muscles that control it (the trigeminal nerve). Branches of the mandibular nerve (V_3) provide the afferent innervation. Most innervation is provided by the auriculotemporal nerve as it leaves the mandibular nerve behind the joint and ascends laterally and superior to wrap around the posterior region of the joint.[13] Additional innervation is provided by the deep temporal and masseteric nerves.

Vascularization of the Temporomandibular Joint

The TMJ is richly supplied by a variety of vessels that surround it. The predominant vessels are the superficial temporal artery from the posterior, the middle meningeal artery from the anterior, and the internal maxillary artery from the inferior. Other important arteries are the deep auricular, anterior tympanic, and ascending pharyngeal arteries. The condyle receives its vascular supply through its marrow spaces by way of the inferior alveolar artery and also receives vascular supply by way of "feeder vessels" that enter directly into the condylar head both anteriorly and posteriorly from the larger vessels.[14]



• **Fig. 1.18.** Temporomandibular Joint (Anterior View). The following are identified: *AD,* Articular disc; *CL,* capsular ligament; *IC,* inferior joint cavity; *LDL,* lateral discal ligament; *MDL,* medial discal ligament; *SC,* superior joint cavity.

Ligaments

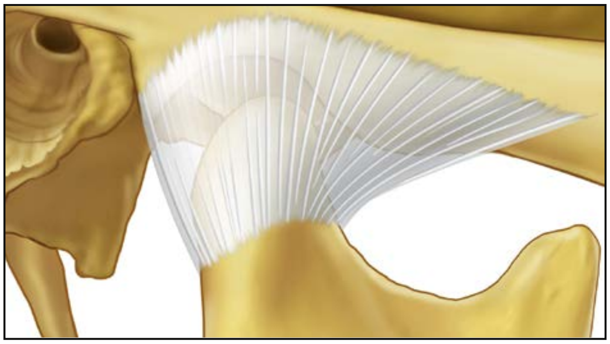
As with any joint system, ligaments play an important role in protecting the structures. Ligaments are made up of collagenous connective tissues fibers that have particular lengths. They do not stretch. However, if extensive forces are applied to a ligament, whether suddenly or over a prolonged period of time, the ligament can be elongated. When this occurs, it compromises the function of the ligament thereby altering joint function. This alteration will be discussed in future chapters that discuss pathology of the joint.

Ligaments do not enter actively into joint function but instead act as passive restraining devices to limit and restrict border movements. Three functional ligaments support the TMJ: (1) the collateral ligaments, (2) the capsular ligament, and (3) the temporomandibular ligament. There are also two accessory ligaments: (4) the sphenomandibular and (5) the stylomandibular.

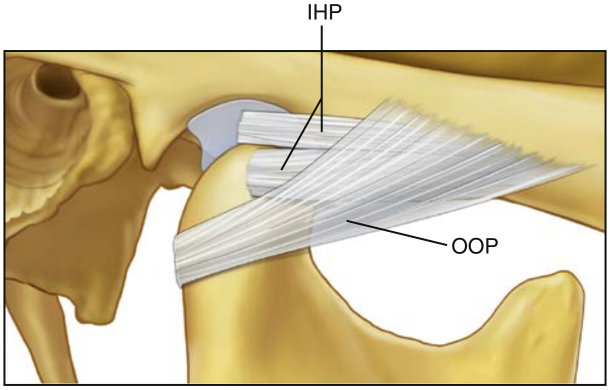
Collateral (discal) Ligaments

The collateral ligaments attach the medial and lateral borders of the articular disc to the poles of the condyle. They are commonly called the discal ligaments, and there are two. The medial discal ligament attaches the medial edge of the disc to the medial pole of the condyle. The lateral discal ligament attaches the lateral edge of the disc to the lateral pole of the condyle (Fig. 1.18). These ligaments are responsible for dividing the joint mediolaterally into the superior and inferior joint cavities. The discal ligaments are true ligaments, composed of collagenous connective tissue fibers; therefore they do not stretch. They function to restrict movement of the disc away from the condyle. In other words, they allow the disc to move passively with the condyle as it glides anteriorly and posteriorly. The attachments of the discal ligaments permit the disc to be rotated anteriorly and posteriorly on the articular surface of the condyle. Thus these ligaments are responsible for the hinging movement of the TMJ, which occurs between the condyle and the articular disc.

The discal ligaments have a vascular supply and are innervated. Their innervation provides information regarding joint position and movement. Strain on these ligaments produces pain.



• **Fig. 1.19.** Capsular Ligament (Lateral View). Note that it extends anterior to include the articular eminence and encompass the entire articular surface of the joint.



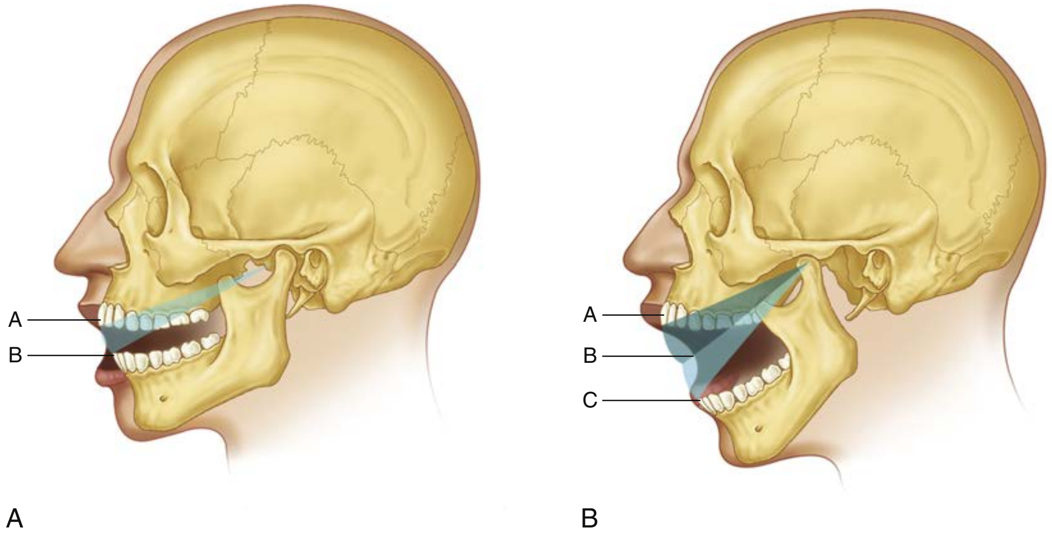
• **Fig. 1.20.** Temporomandibular Ligament (Lateral View). Note that there are two distinct parts: the outer oblique portion *(OOP)* and the inner horizontal portion *(IHP)*. The OOP limits normal rotational opening movement; the IHP limits posterior movement of the condyle and disc. (Modified from Dubrul EL: *Sicher's oral anatomy*, ed 7, St Louis, MO, 1980, The CV Mosby CO, pp 185.)

Capsular Ligament

As previously mentioned, the entire TMJ is surrounded and encompassed by the capsular ligament (Fig. 1.19). The fibers of the capsular ligament are attached superiorly to the temporal bone along the borders of the articular surfaces of the mandibular fossa and articular eminence. Inferiorly, the fibers of the capsular ligament attach to the neck of the condyle. The capsular ligament acts to resist any medial, lateral, or inferior forces that tend to separate or dislocate the articular surfaces. A significant function of the capsular ligament is to encompass the joint, thus retaining the synovial fluid. The capsular ligament is well innervated and provides proprioceptive feedback regarding position and movement of the joint.

Temporomandibular Ligament

The lateral aspect of the capsular ligament is reinforced by strong, tight fibers that make up the lateral ligament or the temporomandibular ligament. The TM ligament is composed of two parts, an outer oblique portion and an inner horizontal portion (Fig. 1.20). The outer portion extends from the outer surface of the articular



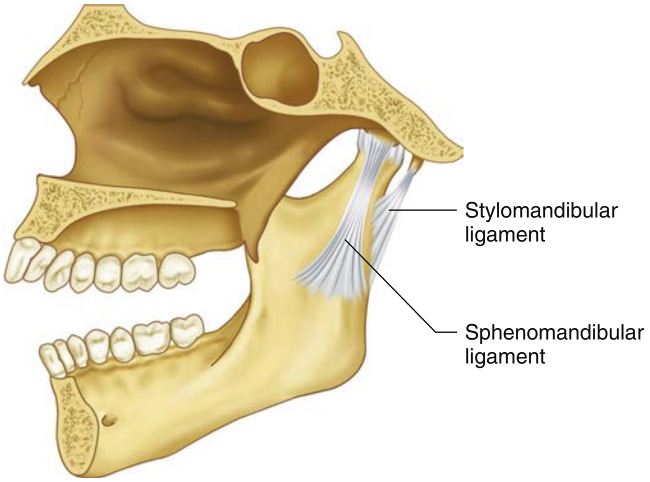
• Fig. 1.21. Effect of the Outer Oblique Portion of the Temporomandibular (TM) Ligament. As the mouth opens, the teeth can be separated about 20 to 25 mm (from *A* to *B*) without the condyles moving from the fossae. At *B* the TM ligaments are fully extended. As the mouth opens wider, they force the condyles to move downward and forward out of the fossae. This creates a second arc of opening (from *B* to *C*).

tubercle and zygomatic process posteroinferiorly to the outer surface of the condylar neck. The inner horizontal portion extends from the outer surface of the articular tubercle and zygomatic process posteriorly and horizontally to the lateral pole of the condyle and posterior part of the articular disc.

The oblique portion of the TM ligament resists excessive dropping of the condyle, therefore limiting the extent of mouth opening. This portion of the ligament also influences the normal opening movement of the mandible. During the initial phase of opening, the condyle can rotate around a fixed point until the TM ligament becomes tight as its point of insertion on the neck of the condyle is rotated posteriorly. When the ligament is taut, the neck of the condyle cannot rotate further. If the mouth were to be opened wider, the condyle would need to move downward and forward across the articular eminence (Fig. 1.21). This effect can be demonstrated clinically by closing the mouth and applying mild posterior force to the chin. With this force applied, begin to open the mouth. The jaw will easily rotate open until the anterior teeth are 20 to 25 mm apart. At this point, resistance will be felt when the jaw is opened wider. If the jaw is opened still wider, a distinct change in the opening movement will occur, which represents the change from rotation of the condyle about a fixed point to movement forward and down the articular eminence. This change in opening movement is brought about by the tightening of the TM ligament.

This unique feature of the TM ligament, which limits rotational opening, is found only in humans. In the erect postural position and with a vertically placed vertebral column, continued rotational opening movement would cause the mandible to impinge on the vital submandibular and retromandibular structures of the neck. The outer oblique portion of the TM ligament functions to resist this impingement.

The inner horizontal portion of the TM ligament limits posterior movement of the condyle and disc. When force applied to the mandible displaces the condyle posteriorly, this portion of the ligament becomes tight and prevents the condyle from moving into the posterior region of the mandibular fossa. The TM ligament therefore protects the retrodiscal tissues from trauma created by the posterior displacement of the condyle. The inner horizontal portion also protects the lateral pterygoid muscle from overlengthening or extension. The effectiveness of this ligament is demonstrated during cases of extreme trauma to the mandible. In such cases, the neck of the condyle will be seen to fracture before the retrodiscal tissues are severed or the condyle enters the middle cranial fossa.



• Fig. 1.22. The mandible, temporomandibular joint, and accessory ligaments.

Sphenomandibular Ligament

The sphenomandibular ligament is one of two TMJ accessory ligaments (Fig. 1.22). It arises from the spine of the sphenoid bone and extends downward to a small bony prominence on the medial surface of the ramus of the mandible called the lingula. It does not have any significant limiting effects on mandibular movement.

Stylomandibular Ligament

The second accessory ligament is the stylomandibular ligament (Fig. 1.22). It arises from the styloid process and extends