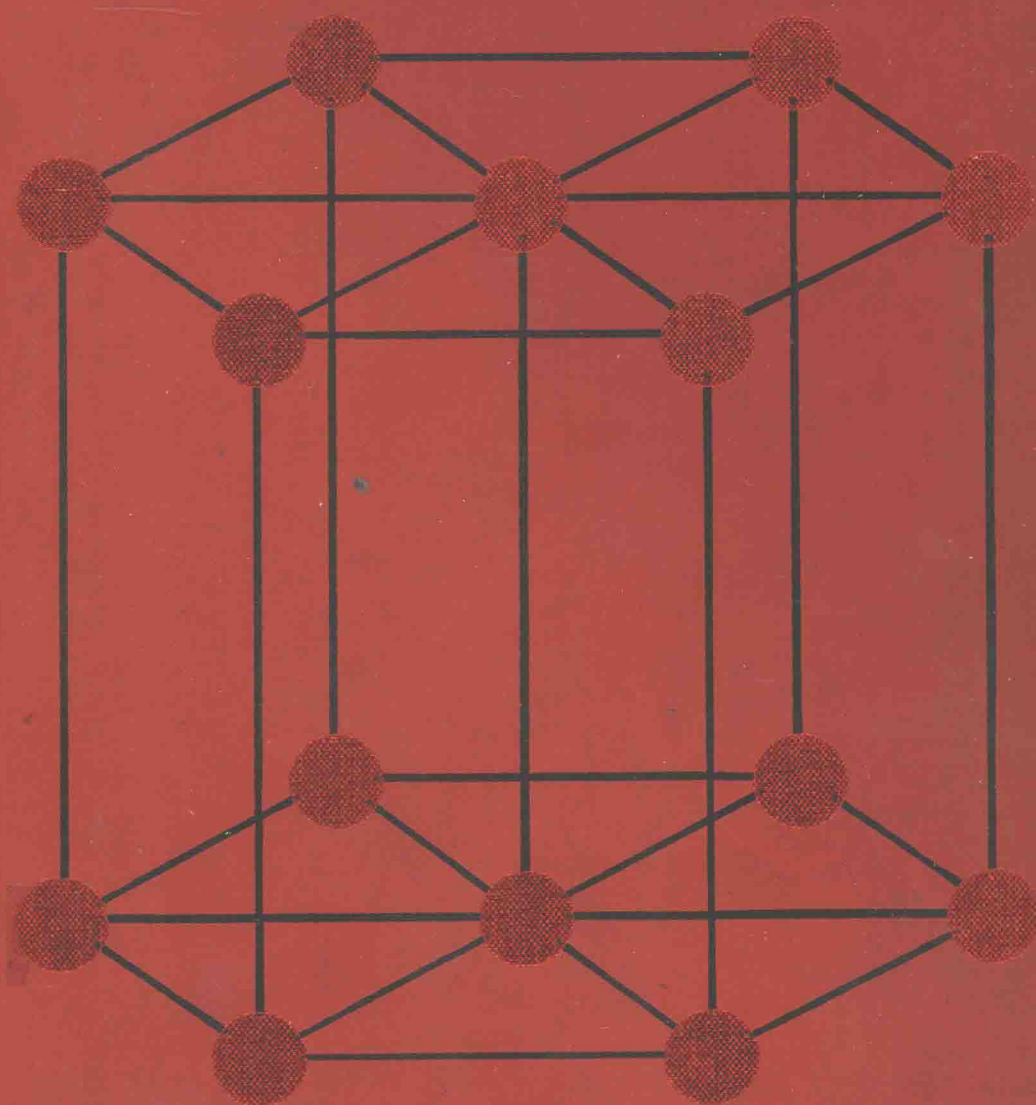


Skinner's

# *Science of Dental Materials*



PHILLIPS

Skinner's

***Science  
of  
Dental  
Materials***

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***Seventh Edition***

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# PREFACE

It is appropriate that the title of this book carry the name of E. W. Skinner, who was the author of the first four editions and the senior author of the last two.

All of those editions were marked by certain principles about which Eugene Skinner was unyielding. One was that a textbook should be organized in an orderly fashion. The reader was not to be introduced to terminology or subject matter that was out of sequence to his level of knowledge in basic science or dentistry. Therefore, each chapter was carefully structured upon the knowledge acquired by the reader in those that preceded it. Likewise, he adhered to the philosophy that it is as important to know what information should be included in a text as it is that which should be omitted. Thus, the past editions did not involve elaborate surveys of the literature. Rather, the subject matter was confined to that which was appropriately documented by research and clinical experience. Those matters which, in the view of the author, remained controversial were generally excluded. Lastly, and most important, he demanded exactness in the written word and precise accuracy in the concepts and data presented.

The body of knowledge which has accumulated since 1967 necessitated a more comprehensive revision than was needed for any of the previous editions. During the revision of each chapter and in the preparation of new manuscript those principles learned from Eugene Skinner were paramount in the mind of the author. It is hoped that the reader will find that these same standards have been maintained.

The philosophy, organization, and objectives of the seventh edition are those of the previous one. Emphasis continues to be placed on the *why* rather than the *how* in the selection and use of dental materials and their interaction with the oral environment. Although the manipulative parameters for attaining maximum performance are continually stressed, the reader is challenged to understand the rationale from which the technical procedures have evolved. Only with such conceptual thinking can the student appreciate the viability of the field and make the intelligent decisions that are required daily in the usage of dental materials.

The chronological order of presentation remains essentially unchanged. Also, the more advanced scientific concepts covered reflect the intellectual

level and broader science background of today's dental student. The relationship of the structure of materials to the oral environment is stressed to an even greater extent, without a reduction in the descriptions of the pertinent manipulative factors involved in dental technics. Because of a keener appreciation of, and need for, an understanding of the biological properties of dental materials, those characteristics are treated in greater depth. As an introduction to the discussions related to this subject, a new section in Chapter 3 has been added.

The reader will, of course, find that in order to bring the text abreast of current dental practice many chapters have been expanded, especially in such areas as composite resins, spherical and dispersion type amalgam alloy systems, metal-ceramics, and fluoride-containing materials. In addition, it was essential to introduce a discussion of materials such as the polycarboxylate cements, pour denture resins, polyether elastomeric impression materials, pit and fissure sealants, and intermediate restorative materials as well as technics such as the etching of enamel for retention of resin restoratives.

These changes in the text required reworking and expansion of the discussions of certain phenomena and properties. Specifically this includes the sections on adhesion and metallurgy and on the relationship of specific properties to the clinical behavior of the material—for example, creep and the marginal fracture of amalgam.

Conversely, the advent of many new materials and new technologies has brought about a gradual phasing out of many of the traditional technics. Thus, space allocated to subjects such as acrylic resin restoratives, high mercury-alloy ratio technics for amalgam, and certain types of dental cement systems has been reduced. The references have been updated and weighted accordingly.

Several illustrations have been added to aid in the interpretation of the text material, and a number of the figures in the past edition have been redrawn to make them more readily interpreted or more precise.

One of the aims of this revision was to eliminate any minor inaccuracies related to the composition and reactions of various materials and the terminology associated with this discipline. Too often one is guilty of accepting empirical or ill-defined statements that have been handed down through the years, even though they may not in fact be indicative of modern concepts or of commercial product formulation. For this reason, the advice of certain manufacturers was sought. It will be found that the manufacturing procedures and material composition have frequently been decidedly altered in order to bring them parallel to those now being used by the dentist. Furthermore, the chemical reactions and mechanisms involved in dental materials—*e.g.*, the elastomeric impression materials, silicate cement, and metal-ceramics—have been rewritten to coincide with the state of the art as it now exists. Terminology in the chapters on gypsum products, metallurgy, porcelain, and resin has also been clarified.

The English system of measurement was the preferred standard in the sixth edition. Since the metric system is now used in most countries and will

soon be universally accepted, it has been adopted in this revision. Because the United States is still in a transitional stage, all figures are generally given in both systems.

The trend in the sciences is now toward the use of the International System of units (SI units). For those who wish to convert certain of these measurements to that system, an Appendix has been provided.

Lastly, a textbook should be a teaching aid as well as a learning aid; that is, it should leave something for the teacher to teach. Therefore, this edition has been deliberately designed to serve the teacher as well as the student. The contents permit the teacher to make certain interpretations, to amplify, to present examples and modifications, and thus to make the text perennially timely.

RALPH W. PHILLIPS

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First, and foremost, I am indebted to all of the members of my staff. As has always been the case, they gave unselfishly of their time, energies, and knowledge when it was requested, which was frequently. In particular may I thank M. L. Swartz, R. D. Norman, R. J. Schnell, and R. V. Mehra.

The counsel of a number of researchers and educators in dental materials science and related disciplines was sought. Although not all suggestions were incorporated into this edition, a substantial share of the credit for the upgrading of the scientific accuracy of this edition should go to those individuals. They responded freely, and enthusiastically, to my inquiries and detailed requests for certain types of information. The reader who is familiar with the dental literature will readily recognize the majority of the names listed and can as readily associate the name with a particular area of competence.

These individuals were: C. W. Fairhurst, E. J. Molnar, G. M. Brauer, D. C. Smith, A. R. Docking, J. F. Glenn, D. B. Mahler, J. P. Nielsen, C. E. Ingersoll, A. D. Wilson, J. J. Tuccillo, R. Neiman, R. L. Bowen, M. Braden, J. W. McLean, M. J. Ridge, F. H. Freeman, K. H. Strader, G. Wing, J. M. Gardell, J. W. Stanford, J. Autian, J. Cresson, D. Waller, W. B. Eames, J. M. Powell, W. Lefkowitz, R. Y. Barolet, M. R. Lund, P. Binon, G. Ryge, D. L. Smith, and H. Wm. Gilmore.

Mr. R. C. Scott and staff were once again meticulous in the preparation of new illustrations.

A revision of this magnitude is an exciting yet arduous task. It would have been decidedly more formidable had it not been for the competence and patience of my secretary, Mrs. Edith Gladson. She worked tirelessly and with the exactness required during the typing of the manuscript, proofing of the galley, and preparation of the Index. Likewise, the text is unquestionably more readable due to the suggested editorial changes of Mrs. M. Lee Walters of the W. B. Saunders Company. Mr. George W. Laurie, also of Saunders, once again provided the necessary direction for an accurate and pleasing production of the manuscript.

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# CHAPTER 1

## INTRODUCTION

***Historical Background.*** Strange as it may seem, there is comparatively little historical background for the science of dental materials and their manipulation, in spite of the fact that the practice of dentistry itself antedates the Christian era. For example, gold bands and wires were used by the Phoenicians and Etruscans for the construction of partial dentures. Gold foil has been employed for dental restorative purposes for so long a period that its origin is not known.

Modern dentistry is said to have had its beginning during the year 1728, when Fauchard published a treatise describing many types of dental restorations, including a method for the construction of artificial dentures from ivory. Somewhat later, in 1756, Pfaff first described the method for obtaining impressions of the mouth in wax, from which he constructed a model with plaster of paris. The year 1792 is important as the date when de Chamant patented a process for the construction of porcelain teeth; this was followed early in the next century by the introduction of the porcelain inlay.

It is evident, then, that many of the restorative and accessory materials of today have been in use for some time, yet little scientific information about them has been available until recently. Their use was entirely an art, and the only testing laboratory was the mouth of the long-suffering patient.

The first important awakening of interest was during the middle of the nineteenth century, when research studies on amalgam began. At about the same time there are also some reports in the literature of studies on porcelain and gold foil. These rather sporadic advances in knowledge finally culminated in the brilliant investigations of G. V. Black, which began in 1895. There is hardly a phase of dentistry which was not touched upon and advanced by this tireless worker.

The next great advance in the knowledge of dental materials and their manipulation began in 1919. During this year, the United States Army requested the National Bureau of Standards to set up specifications for the selection and grading of dental amalgams for use in federal service. This research was done under the leadership of Wilmer Souder, and a very excellent report was published in 1920.<sup>1</sup> The information contained in the

report was received enthusiastically by the dental profession, and information along the same line was demanded for other dental materials.

At the time, the United States Government could not allocate sufficient funds to continue the work, so a fellowship was created and supported by the Weinstein Research Laboratories. Under such an arrangement, the sponsor provides the salary for research associates and a certain amount of equipment and supplies. The associates then work in the National Bureau of Standards under the direction of the staff members. They are to all intents and purposes members of the staff, supported by private interests. All findings are published and become common property under such an arrangement.

R. L. Coleman, W. L. Swanger, and W. A. Poppe were the Research Associates first appointed under this arrangement. Working under Dr. Souder, they investigated the properties of dental wrought and casting golds and accessory casting materials. This phase of the work resulted in the publication of an extensive and valuable research report.<sup>2</sup>

In 1928, the Dental Research Fellowship at the National Bureau of Standards was assumed by the American Dental Association. The research carried on by the American Dental Association Research Associates in conjunction with the staff members of the National Bureau of Standards has been of inestimable value to the dental profession, and it has earned for this group an international reputation. The names of individuals such as Wilmer Souder, George C. Paffenbarger, and William T. Sweeney will undoubtedly live in history as the pioneer research workers whose work began a new era of intense research production in the field of dental materials. It was the enthusiasm of these men which prompted the organization of the first courses in dental materials to be taught in the dental schools of America and abroad.

***American Dental Association Specifications.*** The work at the American Dental Association Research Division is divided into a number of categories, including the determination of those physical and chemical properties of dental materials which have clinical significance and the development of new materials, instruments, and test methods. However, the primary objective of this facility is to formulate standards or specifications for dental materials and to certify the products which meet those requirements. Such specifications are essentially standards by which the value of the particular dental materials can be gauged. They present the requirements as to the physical and chemical properties of a material which will insure that the material will be satisfactory if properly employed by the dentist. Once a specification has been formulated for a particular material, any of the various manufacturers may certify to the American Dental Association that its product meets the requirements of the particular specification. The product is then tested, and if it meets the requirements of the particular specification, its trade name and the manufacturer's name are published in the *Journal of the American Dental Association*. The manufacturer is permitted to signify on the label of the product that it has been certified by the American Dental Association.

Originally the Council on Dental Research of the American Dental Association was the guiding body in establishing specifications and standards for

dental materials. When the Council on Dental Materials and Devices was recently established, it assumed that responsibility. In this role the Council is the Administrative Sponsor of two committees of the American National Standards Institute (ANSI). The American National Standards Committee Z156 is concerned with nomenclature, standards, and specifications for all dental materials and devices with the exception of drugs and x-ray films, machines, and devices. The second committee, AN Standards Committee PH6, establishes the standards and specifications for x-ray films, machines, and devices.

Upon advice from the Council, these committees, with the aid of subcommittees, revise and formulate specifications. When a specification has been approved by the Standards Committee, it is submitted through the Council to the American National Standards Institute. Upon acceptance by that body it becomes an American National Standard. The Council on Dental Materials and Devices then has the option of accepting it as an American Dental Association Specification.

Currently there are 23 American Dental Association specifications. The number of specifications is increasing rapidly, encompassing materials and devices not presently covered by a specification. Likewise, the existing specifications are periodically revised in order to reflect changes in product formulations and new knowledge in regard to behavior of materials in the oral cavity. For example, American Dental Association specification no. 1 for dental amalgam has been revised four times.

**International Standards** For many years there has been great interest in the establishment of specifications for dental materials on an international level. Two organizations, the *Fédération Dentaire Internationale* (FDI) and the *International Standards Organization* (ISO), are working toward that goal. Originally the FDI initiated and actively supported a program for the formulation of international specifications for dental materials. As a result of that activity, nine specifications for dental materials and devices have been adopted.

The ISO is an international, nongovernmental organization whose objective is the development of international standards. This body is composed of national standards organizations from 51 countries. The *American National Standards Institute* is the United States member. The request by the FDI to the ISO that they consider FDI specifications for dental materials as ISO standards led to the formation of an ISO committee, TC106—Dentistry. The responsibility of this committee is to standardize terminology, test methods, and specifications for dental materials, instruments, appliances, and equipment.

The formation of this committee has led to an increased use of international units in defining the properties of materials. These international units are now common in specifications as well as in the scientific literature. For the convenience of the reader, a conversion table may be found in the Appendix.

There are 11 participating members and 20 observer members in the ISO committee. The nine FDI specifications have now been adopted as ISO recommendations. Thus, considerable progress has already been realized in achieving the ultimate goal of a broad spectrum of international specifications for dental materials and devices.

The benefit of such specifications to the dental profession has been inestimable. The dentist is provided with a criterion of selection which is impartial and reliable. In other words, if the dentist uses only those materials which meet the appropriate specifications, he can be assured that the material will be satisfactory. Probably no other single factor has contributed as much to the high level of dental practice in the United States as has this specification program. An awareness by the dentist of the requirements of these specifications is important in order that he may be able to recognize the limitations of the dental material with which he is working. As will be discussed frequently in the chapters to follow, no dental material is perfect in its restorative role any more than an artificial arm or leg can serve as well as the original body member which it replaces.

For this and other reasons, the research in dental materials, supervised by the Council on Dental Materials and Devices of the American Dental Association, is of vital concern in the present course in dental materials. The American Dental Association specifications for dental materials are constantly referred to in the following pages, although the specific details regarding the actual test methods employed are usually omitted. Thus, the discussion in this book assumes that the student possesses or has access to a current copy of the *Guide to Dental Materials*.

The *Guide to Dental Materials* is a small book which can be purchased from the publisher, the American Dental Association, 211 East Chicago Avenue, Chicago, Illinois, at a nominal cost. It is revised and published every two or three years as required to keep the contents up to date. It not only contains the American Dental Association specifications in detail, but it also reviews the recent researches in the field with an excellent reference bibliography, and presents the trade names of commercial products which are currently certified to meet the requirements of the particular specification involved.

**Other Research Centers.** The work at the National Bureau of Standards has stimulated similar studies in other countries. The Commonwealth Bureau of Dental Standards has been established in Australia. Its first executive officer was H. K. Worner, and it is now under the capable direction of A. R. Docking. The Australian researchers have formulated a number of specifications for the dental materials used in Australia.

A number of universities in America and abroad have established laboratories for research in dental materials. In the past few years, this source of basic information on the subject has exceeded that of all other sources combined. Until very recently, dental research activities in universities were centered solely in those which had a dental school, with most of the investigation being done in the dental school itself and by the dental faculty. Now, however, research in dental materials is also being conducted in some universities without dental schools. This dentally oriented research is being conducted in basic science departments, such as metallurgy, crystallography, materials science, engineering, and ceramics. These expanding perimeters of research in dental materials illustrate the interdisciplinary aspects of the science.

There have been countless contributions to this field by dental clinicians.

The final criterion for the success of any material or technic is its service in the mouth of the patient. The observant clinician contributes invaluable information by his keen observations and analyses of his failures and successes. Accurate records and a well controlled practice form an excellent basis for good clinical research.

Another source of information is the research laboratories of the dental manufacturers. The far-seeing manufacturer recognizes the value of a research laboratory in connection with the development and production control of his products. Unbiased information from such groups is particularly valuable. The counsel of scientists from dental and nondental industry was called upon during the course of this revision. In this way the product formulations to be found in the succeeding chapters reflect more exactly the commercial materials actually used by the dentist.

This diversity of research activity is resulting in an accelerating growth in the body of knowledge related to dental materials. Approximately one-third of all dental research is currently concerned with dental materials and instrumentation.<sup>3</sup> The growing investigative effort is resulting in a marked increase in the number of new materials, instruments, and technics being introduced to the profession. For these and other reasons, an intimate knowledge of the properties and behavior of dental materials is imperative if the modern dental practice is to remain abreast of the changing developments.

**Scope of the Course.** Not all of the materials used in dentistry are included in the course. For example, anesthetics and medicaments are not within the scope of this book. The science of dental materials is generally considered to comprise those materials which are employed in the mechanical procedures included in restorative dentistry, such as prosthetics, crown and bridge and operative dentistry. It is one of the aims of this book to introduce the materials to the beginner, and to study their physical and chemical properties as such properties are related to their proper selection and use by the dentist. However, certain biological considerations will not be ignored. It is assumed that the reader possesses a basic knowledge of physics as well as inorganic and organic chemistry.

A relatively new science has been introduced into the engineering curriculum of most universities. It is called *materials science* and is concerned with the internal structure of materials and with the dependence of properties upon these internal structures. The sequence of instruction generally proceeds from atomic structure to coarser structures, from the simple to the more complex. The source of knowledge in this field draws upon various disciplines, such as physical chemistry, solid state physics, and metallurgy. Since it is these fundamentals that govern the properties of all materials, it is logical to study the finer structural characteristics before proceeding to the more gross ones.

One should remember this changing concept of relating properties of a material to its atomic or crystalline structure when reading Chapter 2, which deals with the structure of matter and certain principles of materials science that are not always included in the course in college physics. These principles



are in turn related to the properties of dental materials, as discussed in Chapter 3.

The student may find that some supplementary reading in this subject, within his background knowledge, will be helpful. The authors have drawn to a certain extent upon the illustrative material in *Elements of Materials Science* by Van Vlack.<sup>4</sup> This introductory text to the field of materials science is highly recommended as collateral reading.

The requirements which are placed upon dental structures and materials are excessive and unique. Unfortunately, too often the dentist and patient are unaware of the limitations involved and the rigid conditions imposed in the oral cavity. Those matters are discussed in Chapter 3. The reader thereby should be increasingly aware of the difficulties involved in producing a satisfactory dental material or in designing a technic that is usable and practical, as will be continually emphasized in the discussions that follow on specific materials.

Following these chapters on the structure of matter and the physical and biological properties of dental materials are two chapters dealing with the chemistry and manipulation of gypsum products. Impression materials are then discussed. The chemistry of synthetic resins is presented as an introduction to a study of the acrylic resins as they are used for the construction of various dental structures.

Before the metallic dental materials are described, a short discussion of the principles of metallography, physical metallurgy, and tarnish and corrosion is presented as they can be applied to dental materials and procedures. The basic science of physical metallurgy is concerned with the properties of metals and alloys, whereas the study of metallography involves the constitution and structure of metallic substances. The student will find that the subject matter in Chapter 2 is used as source information in many of these discussions.

Dental amalgam, gold foil, and their manipulation are then described. This discussion is followed by a consideration of the gold alloys used in dentistry, and the materials and technics employed in dental casting procedures. The next chapter is concerned with the properties of the cements which are used in the placement of certain restorations and for other purposes. Two other nonmetallic restorative materials, silicate cement and porcelain, are then discussed. The final chapters deal with the technics employed in soldering, the base metal alloys used in dentistry, and certain other technical procedures, such as abrading, polishing, and cutting with dental burs.

It will be observed that many branches of science will be drawn upon in the presentation of the information. The disciplines of materials science, physical metallurgy, and metallography have already been mentioned. Ceramics is the study dealing with the firing and properties of dental porcelain. Various specialized branches of chemistry will be utilized. Practically all the engineering applied sciences have contributed to the subject. There is also an increasing awareness of the dentist that the biological properties of dental materials can not be divorced from their mechanical or chemical properties.