SKINNER'S

SCIENCE OF DENTAL MATERIALS

Eighth Edition

Ralph W. Phillips, M.S., D.Sc.

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PREFACE

This revision is by far the most comprehensive of the seven that have preceded. Each chapter has been reworked to coincide with the current state of the art. Many required a complete restructuring. These sweeping alterations were dictated not only by the time interval since the last edition but also by the explosion that has occurred in dental materials science during the last few years. The investigative effort in this and related fields has resulted in the introduction of a host of newer systems and concepts, as well as marked changes in the formulations and techniques of usage for the traditional materials.

Thus the task of bringing this text abreast of these developments was decidedly more arduous than previously. Yet it was a challenge to develop a manuscript that hopefully would capture the excitement of this era and the new dimensions in dental practice that have been generated through research.

It will be noted that the title of this book still carries the name of E. W. Skinner, who was the author of the first four editions and the senior author of the fifth and sixth editions. His influence upon this discipline, and upon scholarly writing, was exemplary. Within my capabilities I have tried to maintain his basic philosophy in the organization of the text and the presentation of the subject material. That can best be summarized by quoting a paragraph from the Preface to the seventh edition.

"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 built 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."

Thus the philosophy, organization, and objectives of this 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.

It will be found that the contents of this revision reflect the major trends that have surfaced in the science of dental materials. One is the increasing attention focused on the structures of materials and their interaction with the oral environment. New illustrations, particularly SEM photomicrographs, and diagrams have been used to complement the text material in this regard.

A second area of expanded activity is concerned with the biological characteristics of restorative materials. This emphasis is appropriate, since the physical or mechanical properties of a particular material are secondary to that of the safety of the patient, the dentist, and the auxiliary staff. Furthermore, regulatory procedures are being expanded to insure biocompatibility of dental materials. Throughout the book these matters are woven into the text.

Lastly has been the growth of clinical research, much of which is designed to establish the precise relationship of a property, or group of properties, to clinical performance. The text is laced with references to such clinical investigations, especially to those that document recommendations for a particular system, and manipulative or clinical technique of use.

As noted, each chapter has been carefully edited and updated in terms of compositions, chemistry, and manipulative techniques. Selected references are included whenever it is felt that a literature annotation is pertinent to the statement or discussion. The reader who is familiar with the previous text will be readily conscious of these additions and revisions. However, it is appropriate in a Preface to cite areas of major change, and the following discussion describes those that are of special interest.

The general organization of the text remains the same. In the first three chapters a description of the structure of matter, the physical properties of materials, the phenomenon of adhesion, and biological considerations are presented. In regard to the latter, the regulatory procedures of the Food and Drug Administration have been covered. Similarly, the policies of the Council on Dental Materials, Instruments, and Equipment of the American Dental Association in respect to the Acceptance and Certification programs have been brought abreast of their current status.

The differences between mechanical bonding and true adhesive bonding are separated out and related to their specific dental applications, which are discussed later in the book. New sections on rheology and color have been added. Rheology is important to the discussions on dental cements and impression materials, for example. An explanation of the color phenomenon and its terminology is essential for an understanding of the technology used in fabricating certain restorations, such as those involving porcelain.

The classification of gypsum products has been redone so as to correlate with specification terminology. A section has been added on "special" products, e.g., mounting stones.

Chapters 8 and 9, on hydrocolloid impression materials, have been reorganized for ease in following the text. In the previous edition, the techniques for handling both the reversible and irreversible hydrocolloids were covered in Chapter 9. Now, Chapter 8 deals completely with the reversible hydrocolloids while the alginates are discussed in Chapter 9. Some subtle changes in technique have occurred, such as the "wet field" procedure for hydrocolloid, and these are included.

The chemistry of the elastomeric impression materials is now consistent with present knowledge and, of course, the addition silicones are included. The various types are compared in terms of properties and characteristics.

A discussion of polymers and their uses in denture prostheses follows. The chemistry has been adjusted to conform to current concepts, as have the

technical procedures. Although the fabrication of such appliances is now generally carried out by a laboratory technician, an understanding of the scientific rationale for the basic steps involved is important in order that the dental student may properly appreciate the role of the technician and understand the problems that may occur in the clinical use of artificial dentures. Furthermore, there is no other ready reference source available for those who wish to have a further understanding of the *why* in the construction of these appliances.

A section on maxillofacial prostheses has been added. Also the discussion of other polymeric materials, such as tissue conditioners and liners, has been revised.

One of the most intriguing areas of change has been that of restorative resin, with the development of microfilled composites, light-cured systems, acid etching techniques to improve mechanical bonding, enamel bond agents, and resins for the coating of eroded gingival areas. All of these, and other, materials are covered in Chapter 14, Restorative Resins, including illustrations to clarify structure and properties. The discussion on traditional acrylic resins has been markedly condensed and is used principally as a basis for the historical presentation and for better understanding of the BIS-GMA and other composite resin matrix systems.

The chapters on metallurgy and the nature of metals and alloys now cover whiskers, lattice imperfections, and dislocations in the light of recent findings. New illustrations and text are used to simplify the interpretation of phase diagrams, as by the use of brine as a model. The same may be said for Chapter 19, Tarnish and Corrosion, in which a diagram of an electrolytic cell and an expansion of oxidation-reduction reactions are used to develop the mechanisms of corrosion.

As for restorative resins, dental amalgam alloys have gone through a tremendous transition in composition, as has our appreciation of causative factors involved in clinical deterioration. At the writing of the seventh edition, these dramatic changes had not as yet emerged. Now the evolution of the high copper alloys can be traced. Illustrations are used to show the structure and reactions of these alloys and how they relate to in vivo performance. Types of high copper systems are classified and the mechanisms for eliminating the weak, corrosion prone gamma-2 phase explained. Techniques are also consistent with present practice. The section on mercury toxicity and office hygiene conforms to modern opinion.

Chapter 24 on noble metal casting alloys is virtually rewritten, as necessitated by the avalanche of new alloys that have been introduced, such as the so-called semi-precious alloys. These various types have been classified and compared on the basis of composition, color, and usage. The history of the metal-ceramic alloys is presented, since it is the basis of reference for the discussion of that restoration which follows, particularly in Chapter 31. The role of the various components, and new metals that have been added, is elaborated upon. Much of the discussion on porosity is better associated with the technical considerations associated with the casting procedure. Thus this section has been moved to Chapter 28.

The chapters on the materials and techniques related to the cast restoration come next, with appropriate revisions. The use of wax in the direct technique has been minimized, yet additional discussion has been devoted to other waxes, i.e., baseplate and corrective.

The description of phosphate-bonded investments has been moved up to Chapter 26, owing to the increased popularity of this type of investment for

the casting of small restorations. In the same vein, the discussion of these investments has been expanded.

In the two chapters devoted to casting procedures, changes and additions will be apparent. The discussion of gypsum hardeners and methods for altering the die dimensions, e.g., die spacers, has been expanded. The various types of casting machines are described and the influence of pressure gradient on efficacy has been explained. Technical considerations for phosphate-bonded investments, as they differ from those for gypsum-bonded materials, have been added. As noted earlier, the description of porosity in dental castings is now moved to this portion of the text and the subject has been subtly reclassified.

Now to the changed field of restorative and luting cements. The chapters are reorganized to better reflect usage. Luting cements are discussed in Chapter 29 and the protective agents and thermal insulating bases are placed together in Chapter 30, along with cements used for restorations. The discussion of silicate cement is minimal and is used primarily as introductory material for the glass ionomer system, which is described both as a luting agent and for the coating of eroded areas. The polycarboxylate cement is covered in greater detail, particularly in terms of technical considerations.

It was imperative that the chapter on porcelain be updated to mirror the changes that have occurred. Considerable restructuring of the subject matter will be noted, with many new illustrations to depict present usage. The compositions and properties of dental ceramics have been revised, as is information on structure and influence of technique, such as the specific effect of porosities. Particular attention is given to the metal-ceramic systems and other methods of bonding, e.g., tin oxide coatings.

The chapter on wrought alloys has been condensed, owing to the reduced usage in the construction of partial dentures. However, materials in this category, e.g., P-G-P wires, which are employed in certain other appliances, are now covered. Chapter 33 includes an expanded section on the soldering of metal-ceramic restorations.

Chapter 34, Base Metal Alloys for Dental Castings, originally Chapter 35, has been expanded to embrace the base metal alloys used for small castings as well as the traditional use in larger appliances. A comparison is made with the noble metal alloys for the metal-ceramic restoration. The matter of biological considerations, i.e., nickel and beryllium sensitivity, is faced. The subject of carbon steel is now incorporated into Chapter 37, where it fits more logically.

Much of the discussion on the basic mechanics of abrasion and polishing is still accurate and remains essentially intact. However, the sections on abrasive instruments and dentifrices are updated.

In the last chapter, the nickel-chromium alloys have been deleted from the text, since these are now seldom used in the construction of orthodontic appliances. The more common nickel-titanium and beta titanium systems are added, as are the braided and twisted wires.

This edition uses the International System of units (SI units) as the preferred system. However, since their use is not as yet universal, the English units are included. For example, temperatures are given in °C, with (°F) equivalents shown in parentheses, and stress in MPa is followed by (psi). For those who wish to convert these measurements, an Appendix has been provided. Incidentally, numerical values have frequently been rounded off to the nearest decimal unless absolute numbers are essential for precise interpretations.

RALPH W. PHILLIPS

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In a revision of this magnitude, an author must draw upon the expertise of many colleagues and friends. This I have done. The updating of the scientific accuracy of this text must be shared with those individuals. Without fail they constructively and enthusiastically responded to my queries.

I have long been blessed with a loyal, dedicated, and skilled faculty and technical staff. The quality of the manuscript, and the time table for completion, could never have been realized without their aid. As always, when requested, they gave unselfishly of their time, energies, and competence. In many instances, in addition to changes in the text material, it was necessary to recheck in vitro data and to provide new figures. A mere listing of their names is a most inadequate expression of my indebtedness to them.

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The science of dental materials has undergone a tremendous transition since the last edition of this book, as is elaborated upon in the Preface. Virtually every material and associated techniques have spawned a new generation of technology and body of knowledge. It is impossible for any one scientist, or even group of scientists, to remain fully informed of all these diverse developments. Thus an author has no recourse but to rely upon the skills and judgments of other scientists throughout the world. Some were consulted only on the validity of a figure, table, or statement. Others contributed advice on a broader basis. I was gratified that when the revision was initiated a number of colleagues volunteered to review areas germane to their particular area of interest.

As in the previous edition, not all of these suggestions could be heeded. Nevertheless, I hope all will feel comfortable with the end result. It is not possible to list everyone who provided useful information but the following were particularly helpful, and substantial credit is due them. Those familiar

with the dental literature will recognize most of the names and the areas on which their research has focused.

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CONTENTS

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.[1] 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.[2]

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. Until 1965 the primary objective of this facility was to formulate standards or specifications for dental materials and to certify the products which meet those requirements. However, when the Council on Dental Materials and Devices of the American Dental Association (now called the Council on Dental Materials, Instruments, and Equipment) was established in 1966, it assumed these responsibilities.

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 Council 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 by the use of a Seal of Certification.

The Council on Dental Materials, Instruments, and Equipment has the responsibility as the Administrative Sponsor of a standards formulating committee operating under the procedures of the American National Standards Institute. The American National Standards Committee MO156 is concerned with nomenclature, standards, and specifications for all dental materials and devices with the exception of drugs and x-ray films. A separate Council com-

mittee is responsible for dental x-ray, while the Council on Dental Therapeutics of the American Dental Association is accountable for the evaluation of drugs in dentistry.

Upon advice from the Council, the committee, with the aid of subcommittees, revises and formulates 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, Instruments, and Equipment then has the option of accepting it as an American Dental Association Specification.

Currently there are 37 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 five times.

Federal Regulations and Standards On May 28, 1976, legislation was signed into law which gave the Food and Drug Administration (FDA) of the United States the regulatory authority to protect the public from hazardous and/or ineffective medical devices. That legislation was the culmination of a series of attempts to provide safe and effective products, beginning with the passage of the Food and Drug Act of 1906, which did not include any provision to regulate medical device safety or the claims made for devices.

This newer legislation, named the Medical Device Amendments of 1976, requires the classification and regulation of all non-custom medical devices that are intended for human use. The term device includes "any instrument, apparatus, implement, machine, contrivance, implant, or in vitro reagent used in the diagnosis, cure, mitigation, treatment or prevention of disease in man or animals." Some dental products are considered drugs (e.g., fluoride products), but most products used in the operatory are considered to be devices and are thus subject to control by the FDA Bureau of Medical Devices. Also encompassed are over-the-counter (OTC) products sold to the public, such as floss and denture adhesives.

The classification of all medical and dental items is done by panels composed of non-government dental experts as well as representatives from industry and the consumer. The Dental Panel, one of 19, identifies any known hazards or problems and classifies the item into one of the following classes: Class I, II, or III. All devices are subject to general controls (Class I), which includes matters such as the registration of the manufacturer's products, adherence to good manufacturing practices, and certain record keeping requirements. If it is felt that such general controls are not in themselves adequate to ensure safety and effectiveness as claimed by the manufacturer, then the device is placed into Class II. That classification requires that it meet performance standards established by the FDA, or appropriate ones from other authoritative bodies, such as the specification program of the American Dental Association. These performance standards may relate to construction, components, ingredients, and properties of a device and may also provide that it be tested to assure that lots or individual products do conform to the regulatory requirement.

Classification into Class III, the most stringent of the three, requires that

the device have approval for safety and effectiveness before being marketed. All implanted or life supporting devices are, of course, placed in this category and require data to demonstrate safety and efficacy prior to marketing. In addition, any item that does not have adequate clinical or scientific information available that would permit the formulation of a performance standard is placed in this premarket approval category. Currently, 14 types of dental-related products have been recommended by the classification panel for that category.[3]

To date 242 dental items have been classified into one of these three classes. This activity, in conjunction with the American Dental Association specification program for dental materials and devices, is providing a crucial framework for standards developments and for better assurance to the dentist and his patients that the product is safe and effective as claimed. It should be added that a number of other countries have national government agencies comparable to the FDA that, to a certain extent, include dental materials and devices under the umbrella of their regulatory authority.

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 84 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.

There are 17 participating members and 21 observer members in the ISO committee. The nine FDI specifications have now been adopted as ISO standards. In addition 24 additional standards have been developed under ISO/TC106 since 1963, through cooperative programs with FDI. 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 that 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.

The Council also conducts another program for the evaluation of dental products, known as the Acceptance Program. This activity applies to products for which safety and effectiveness have been established by biological, laboratory and/or clinical evaluations if appropriate or where physical standards or specifications do not currently exist. Specific guidelines for acceptance for each generic area, e.g., pit and fissure sealants or powered toothbrushes, are formulated by the Council.

For this and other reasons, the research in dental materials, supervised by the Council of Dental Materials, Instruments, and Equipment 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. For those students in foreign countries, the counterpart ISO standards, if applicable, should be used as a source reference.

Thus, the discussion in this text assumes that the student has access to a current copy of the Dentist's Desk Reference — Materials, Instruments and Equipment (formerly called Guide to Dental Materials and Devices) and to the collection of Specifications and Acceptance Programs of the American Dental Association.

The Dentist's Desk Reference 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 three years in order to keep the contents up to date. It reviews the recent researches in the field with an excellent bibliography, and presents the trade names of commerical products that are currently certified to meet the requirements of the particular specifications involved. Likewise, there is a listing of other brands of products available, insofar as they are known. Products classified under the Council's Acceptance Program can also be found.

Other Standards Organizations and Research Centers The work at the Bureau of Standards has stimulated comparable programs in other countries. The Australian Dental Standards Laboratory was established in 1936. H. K. Worner and A. R. Docking, as the first two directors, are recognized for their leadership in the development of the Australian specifications for dental materials. Until 1973 this facility was known as the Commonwealth Bureau of Dental Standards. Actually the oldest among the National Standards Organizations is the British Standards Institution, which was formed in 1901 as the Engineering Standards Committee.

Other countries that have comparable organizations for developing standards and certifying to standards are Canada, Japan, France, Czechoslovakia, Germany, Hungary, Israel, India, Poland, South Africa, and Sweden. Also, by agreement among the governments of Sweden, Denmark, Finland, and Norway, the Scandinavian Institute of Dental Materials (NIOM) has been formed for testing, certification, and research regarding dental materials and equipment to be used in the four countries.

An increasing 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 universi-

ties were centered solely in those that 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 that do not have 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 technique 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.

The importance of clinical documentation for claims made relative to the in vivo performance of dental materials is now readily apparent. For example, the Acceptance Program of the Council on Dental Materials, Instruments, and Equipment requires clinical data, whenever appropriate, to support the laboratory tests for physical properties. Thus, the past decade has seen an escalation in the number of clinical investigations designed to correlate specific properties to performance and to establish the precise behavior of a given material or system. In the chapters that follow frequent reference will be made to such investigations.

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. As in the previous edition, 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. For example, in 1978 approximately 9 per cent of all U.S. support for dental research was focused upon restorative dental materials.[4] The percentage would no doubt be considerably higher if the monies spent by industry for the development of new materials, instruments, and appliances were included. This growing investigative effort is resulting in a marked increase in the number of new materials, instruments, and techniques 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. Likewise, to an extent some of the materials employed in certain specialties, e.g., orthodontics and pedodontics, are included. 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