NINTH EDITION

SCIENCE OF DENTAL MATERIALS

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PREFACE

The Preface to the eighth edition stated, "This revision is by far the most comprehensive of the seven that have preceded." As I reflect on the work required in that revision, it seems modest by comparison with the work needed for the current edition—a reflection of the growth of the field from 1982 to 1990. New materials systems, changing concepts in the use of existing and advanced formulations, and the changes that have occurred in dental practice necessitated a major restructuring of the subject matter in many areas, the deletion of materials and techniques that no longer reflect modern treatment procedures, and the addition of topics totally foreign to the discipline as it existed in 1982. The reader will also note subtle alterations in the updating of terminology, chemistry, compositions, and values for physical and mechanical properties, as well as changes that have occurred in American Dental Association specifications, to bring the text abreast of the current state-of-the-art.

The task was arduous but decidedly challenging. Much of dental practice has been altered by advances in dental materials science and related disciplines. It is to be hoped that this edition has captured the excitement of these advances and that it will be contagious to the reader.

The title of the book still carries the name of E. W. Skinner, appropriately. He was the sole author of the first four editions and senior author of the fifth and sixth editions. I learned so much from him in terms of organization, attention to detail, and the basic philosophy of the chronology of presentation of the subjects. A paragraph from the Preface of the previous edition establishes the concept behind the design and contents of this revision:

"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."

Therefore, the objectives and general organization continue to be those of the previous editions. The emphasis remains on the *why* rather than the *how* in the selection and use of dental materials and how the oral environment impacts upon them. Naturally the manipulation parameters required for maximum performance are continually stressed. However, the reader is encouraged

to understand the *rationale for the selection* of a particular material or a technical procedure. Only in that way can the student make the intelligent decisions required in practice.

In the same vein, the clinical application of basic properties is continually stressed. The dentist must deal daily with the biological and physical properties of materials and make judgments about the practical significance of the numbers generated by such tests. One of the prime objectives of this text is to establish that base. Thus, woven through the chapters are references to documented clinical studies that bridge the gap between basic science and clinical practice. There is a liberal sprinkling of new figures illustrating success and failure as related to in vivo performance as influenced by the inherent characteristics of a material and/or manipulation parameters.

Numerous new figures have also been added, particularly SEM micrographs, that focus on the structure of materials, surface phenomena, and the effects of the oral environment as generated by clinical procedures.

Another of the major changes is an expansion of the space allocated to biological considerations. The precursor to the selection of a material or the adoption of a restorative procedure is the biocompatibility to oral tissues. The increasing vigilance of the regulatory agencies in dentistry emphasizes the growing importance of recognizing the biological characteristics of materials. Likewise, any potential hazard to dental and auxiliary personnel must be considered.

One entire chapter (Chapter 4) now deals with these matters. In another important change, discussions of how to protect against infectious diseases that might be carried by the patient—and appropriate barriers against them—will be found in each chapter where the matter is germane, as in the handling of impression materials.

Along these same lines is the subject of dental implants. In 1982, these were still surrounded by an aura of controversy. Now, however, the discipline has been recognized and accepted, and the use of implants is expanding rapidly. Therefore, it is necessary to acquaint the student with the types of devices, the materials that are used to fabricate the implant, and the inherent characteristics of each. This information is available in Chapter 29.

The reader will note that for the first time literature annotations keyed to a specific statement have been dropped. This reflects a trend in all basic science texts. When a textbook has enjoyed a certain reputation for accuracy of data and conclusions cited, documented references have limited value to the audience addressed—which in this case is primarily the undergraduate dental student. Instead, at the end of each chapter I have substituted a list of carefully selected readings for those interested in pursuing certain areas cited in the text. In addition, each citation is annotated with a few summary lines to inform the reader about the conclusions reached or the general content of the cited paper, chapter, or book. I truly believe that this departure from past editions will prove useful and will be more likely to encourage further reading.

A questionnaire was sent to all the schools that have previously adopted this text. The response was most gratifying, and I am in their debt for many helpful suggestions and constructive criticisms about weighting of subject matter, chapters in which topics should be deleted or added, and shifts in emphasis. These comments were carefully analyzed and were not taken lightly. Whenever possible the suggested changes have been incorporated into the text.

Teachers familiar with the previous edition will be aware of the additions

and alterations in each chapter. However, it is appropriate in a Preface for an author to identify areas of major change and reorganization. Let us take an abbreviated walk through the text.

In general, the chronology of presentation of the subjects remains the same. The first three chapters form the basis for all that follows. They describe the structure of matter, the physical and mechanical properties of materials, and the mechanisms of bonding. Several new illustrations have been included to aid in the interpretation of certain properties. The role of regulatory agencies is explained. Particular emphasis is on specification programs, since these requirements are referred to continually throughout the book.

Esthetic, or cosmetic, dentistry is a growing area of general practice. Essential to this field is an understanding of the principles involved in the color phenomenon. It is much easier to discuss the subject by means of color figures. Thus, for the first time two pages of color illustrations have been incorporated into Chapter 3, identified with the dimensions of color, the Munsell color system, and dental shade guides.

Chapter 4 covers biological considerations in dental biomaterials, as was noted earlier. The expanded coverage of this important subject includes the various factors involved in restorative procedures that influence pulp response. For example, the presence of the smear layer on dentin following instrumentation is introduced at this point and tied in later to dentin bond agent and the polyacrylic acid based cements.

The two chapters on gypsum products from the previous edition have been condensed into a single chapter, Chapter 5, with no loss in essential information. The new classification and requirements in the current American Dental Association specifications are cited, and a new figure has been added that helps to explain the differences in setting and working times. The inelastic impression materials, compound and zinc oxide–eugenol impression pastes, now comprise one chapter, Chapter 6, as this field has remained static.

Chapter 7 is the first of three on elastic impression materials. It covers the reversible hydrocolloids. The alginates are treated in Chapter 8. Additions include more detail on the wet field technique, the combined hydrocolloid-alginate technique, dustless alginate, modified formulations, and, of course, disinfection of the impression.

The elastomeric impression materials have seen numerous changes in these years, and these are reflected in Chapter 9. Hydrophilic silicones, mechanical mixing delivery systems, and light-cured polyethers are some of the topics added. Certain alterations in chemistry have been made based on newer information and revised formulations.

The chemistry and mechanisms of resin polymerization are discussed in Chapter 10, and newer dental polymer systems are now included. This information is essential as a lead into the following two chapters, the first of which, Chapter 11, covers resins and techniques used in the construction of dentures. Updated subjects include microwave processing and infection control. Although the denture is fabricated by the dental technician, a working knowledge of the materials used, the processing procedures, and the basic properties of denture resin systems is also important for the dentist. It provides a base for communication with the technician and an appreciation of factors that control the in vivo performance of the appliance.

One of the major changes in this field since 1982 has been identified with restorative resins. That transition is reflected in Chapter 12. Naturally the composite resin systems discussed are now consistent with the products being

marketed. The history of the evolution of dentin bond agents is presented, and the chemistry and state-of-the-art on the current materials are covered. Prosthetic resin veneering materials now include newer formulations and techniques. Sections on direct and indirect composite inlays and posterior composites have been added and changes made in numerous other topics, such as resin pit and fissure sealants.

Chapters 13 to 15 cover the broad spectrum of metallurgy and the nature of metals and alloys, and Chapter 16 deals with corrosion. It has been possible to consolidate this subject matter, essential to the metallic restorative materials that follow, into four chapters. Some of the more complicated phase diagrams have been eliminated because they are probably beyond the needs of the undergraduate dental student. Throughout these discussions, practical applications have been stressed further.

Dental amalgam still represents a substantial part of restorative dentistry. Chapter 17 is a combination of what were Chapters 20 and 21 in the eighth edition. This could be done by some reorganization of the contents and reduction in the discussion of the traditional low copper alloys, which have largely been replaced by high copper systems. New illustrations more precisely show corrosion mechanisms associated with the in vivo restoration. Technical considerations follow in Chapter 18. Additions will be noted on the subject of alloy selection criteria and the current understanding of mercury toxicity.

Direct filling golds are covered in Chapter 19. Some have felt that reduced use of this material warrants its elimination from the text. However, it is still a part of the curriculum in most schools and therefore deserves space, even though reduced modestly.

It seemed logical to combine the two chapters on casting alloys from the previous edition into one. Therefore Chapter 20 encompasses both the noble and base metal alloys. A classification system is suggested, and the entire approach to the varied systems has been rewritten. Likewise it is convenient to include the metal ceramic alloys here rather than in the chapter on dental ceramics (as in the eighth edition). The compositions of the different types of alloys are presented in detail, because these are important in decision-making on alloy selection and technical procedures in casting.

This leads into the materials involved in fabricating the cast restoration. In Chapter 21 on waxes, the section on distortion is worked into the text in a simpler yet more effective manner. Chapter 22, on investments, now also includes the silica-based materials.

Chapter 23 covers the theory and techniques of the casting process, now condensed into one chapter. Again, it has been suggested that the dental technician, not the dentist, usually fabricates the restoration. Therefore, it is argued that any in-depth discussion of the procedures involved is not pertinent to the dental student's responsibility or education. On the other hand, as with other appliances such as a denture, an understanding of the facets involved in the process is important to appreciate the role of the technician and to provide a scientific base for interaction with the technician. Furthermore, this text is a reference source for the technician, and this information is not readily available elsewhere.

Now to the dental cements. Chapter 24, which discusses restorative cements, varnishes, liners, and bases, has been moved ahead of Chapter 25, on cement luting agents. It is easier to present the polyacrylic acid-based cements in this manner, and restorative cements more naturally follow the cast

restorations. Silicate cement is still included, but only as a lead into the glass ionomer system.

Few dental materials have seen the tremendous growth, in a relatively short time frame, as has the glass ionomer cement. Therefore the discussion of this material is markedly expanded. This includes light-cured liners, metal-modified cements, and the use of the "sandwich technique." New tables and figures show the properties and fluoride release of different types, the products available, clinical performance, and essential steps in manipulation, such as removal of the smear layer.

The chapter on luting agents has additional information on the pH of cements and its relationship to pulpal irritation. Clinical data on solubility are provided, and information on resins for bonding ceramic and composite indirect restorations is expanded.

A comparable explosion has occurred in dental ceramics. Chapter 26 brings this subject abreast of new developments, such as the castable glasses, swaged foil copings, and other ceramic systems. Methods of strengthening porcelain are explored, and the factors influencing color have been identified.

Chapter 27 on soldering has been altered to conform to current terminology on soldering, brazing, and welding. The parameters that influence the brazing process, such as parent metal, flux, and filler material, are discussed. Several new figures better illustrate basic principles, such as control of gap distance and the nature of the joint.

The discussions of wrought base metal and wrought gold alloys are combined into Chapter 28. Some reorganization will also be found on the base metal alloy systems, including a new section on the nickel-titanium alloys. The characteristics of shape memory and super elasticity as related to clinical relevance are covered.

As noted earlier, implant materials are presented in Chapter 29. A figure in this chapter illustrates the three types of implants, followed by a discussion of the various materials used, their properties, and the advantages and disadvantages of each.

The last chapter deals with the basic principles of wear and abrasion, since cutting, grinding, and polishing are common steps in the fabrication and adjustment of dental restorations and appliances and in tooth preparation. Likewise, these phenomena are involved in the in vivo conditions to which materials and tooth structure are subjected. A reduced discussion of dentifrices, which stresses only the things that relate to abrasion and polishing, ends the chapter.

Matters such as therapeutic aspects do not really fall within the scope of this text. The same can be said for Chapter 35 in the eighth edition. Its discussion of cutting with burs has been dropped because it is not really a dental materials subject and can be found more appropriately in texts on operative dentistry.

Again, the current edition uses the International System of units (SI units) as the preferred one. However, since their use is not yet universal, the English equivalents are generally included. An expanded Appendix on conversion factors is provided.

RALPH W. PHILLIPS

ACKNOWLEDGMENTS

My debts are great. I feel inadequate in trying to convey my sense of appreciation to the many individuals who facilitated the march through this revision, which was of much greater magnitude than any previous one. When a book is torn apart, it is difficult to put it back together. The task was eased by the contributions of the people I would like to identify. Unquestionably the quality of the text is in no small measure due to that assistance.

I have been blessed through the years with a loyal, dedicated, and highly skilled faculty and staff in the department of dental materials. As always, they have given unselfishly of their time and competence. There is no way that the revision could have been completed within the scheduled time frame without their input. Changes in text material, rechecking of in vitro data, additional tests to fill voids in properties of certain materials, and the development of new figures were but some of the contributions made by faculty members M. L. Swartz, B. K. Moore, R. J. Schnell, J. C. Setcos, and M. W. Beatty and by the technical staff of B. F. Rhodes and H. E. Clark.

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I owe a special debt of gratitude to Edith Gladson, my secretary. Her meticulous attention to detail in typing and proofreading the entire manuscript and checking the literature was carried out patiently and efficiently. Edith's talents contributed greatly to the preciseness of the text and, for that matter, to our entire program.

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As noted in the Preface, the transition that has occurred since the previous edition is overwhelming in terms of integrating this huge body of knowledge into a workable text. Also, as is always true, it is as important to know what *not* to include in a book as what should be included. It is impossible for any scientist, or perhaps even a group of scientists, to be proficient in all of the disciplines encompassed in dental biomaterials. Therefore, I had to rely on the specialized skills, talents, and judgments of scientists throughout the world. Some were consulted on a broad basis, such as on the contents or organization of an entire chapter, whereas others were consulted only on a single table, figure, or statement. As in other editions, a number of colleagues volunteered to review areas of their special interest or study. Likewise, as is mentioned in the Preface, a host of teachers offered valuable constructive criticisms. Not all of these suggestions were heeded. Nevertheless, I sincerely hope that all will feel the end result measures up to their expectations.

The reader familiar with the dental literature will recognize the prestigious stature of these individuals and can probably identify the specific areas of their

involvement. They are: R. Neiman, C. E. Ingersoll, G. W. Marshall, Jr., S. J. Marshall, W. P. Naylor, A. J. Goldberg, J. R. Mackert, Jr., J. L. Ferracane, J. W. Stanford, H. R. Stanley, L. L. Miller, P. D. Hammesfahr, G. J. Mount, J. W. McLean, M. Durda, H. F. Morris, R. L. Erickson, D. G. Singleton, and W. Dasch.

Last, but by no means least, were the usual care and efficiency provided by the W. B. Saunders Company, and especially by Ken Neimeister. Their demand for excellence is reflected in the finished product. In particular, John Dyson, Senior Medical Editor, gave astute counsel. Long ago I learned to listen to his suggestions. Without fail they have been right on target. Furthermore his editorial skills and his feel for organization in the development of a text have been a source of constant comfort to me. You are very special to this revision, John, and to our friendship through the years.

RALPH W. PHILLIPS

CONTENTS

INTRODUCTION 1

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 that 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. 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.

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 that 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 that 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 that 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 that will ensure that the material will be satisfactory if it is 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 Accredited Standards Committee MD 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 committee is responsible for dental x-ray film, 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 49 American Dental Association specifications. The number of specifications is increasing rapidly, encompassing materials and devices not currently 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 that gave the Food and Drug Administration (FDA) of the United States the regulatory authority to protect the public from hazardous 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 noncustom 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 and which does not achieve any of its principal intended purposes through chemical action within or on the body of man or other animals and which is not dependent upon being metabolized for the achievement of any of its principal intended purposes." 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 Center for Devices and Radiological Health. 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 nongovernment 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 ensure 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 it is 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, approximately 11 types of dental-related products have been recommended by the classification panel for that category. As an example, one of these devices, the endosseous implant for prosthetic attachment, is considered a high priority relative to the necessity for adequate data to demonstrate safety and effectiveness. Manufacturers of this device now need to submit premarket approval applications for their implant(s). These are then evaluated by the Dental Panel to determine whether the pre-Amendments implants can stay on the market, or whether new implants can be marketed. A guidance written by the FDA is available to all interested parties to provide the preclinical and clinical requirements for the preparation of a premarket approval application.

To date 162 dental items have been finally classified into one of these three classes. This activity, in conjunction with the American Dental Association specification program for dental materials, is providing a crucial framework for standards developments and for better ensurance 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 23 participating members and 22 observer members in the ISO committee. The nine FDI specifications have now been adopted as ISO standards. In addition 41 new standards have been developed or are currently under development in 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 that is impartial and reliable. In other words, if the dentist uses only those materials that meet the appropriate specifications, he or she 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 dentists of the requirements of these specifications is important in order that they may be able to recognize the limitations of the