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Microstructure, Properties and Degradation

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Preface

This book contains a brief overview of dental ceramics, its microstructure, properties, and susceptibility to degradation. After the *Introduction* (Chap. 1), it presents the general context of dental ceramics, addressing special phenomena and properties as a *Biomaterial* (Chap. 2), without going too much into scientific detail of the physics and chemistry involved.

The next chapters present *Ceramic Materials for Prosthetic*, *and Restoration Use* (Chap. 3), and *For Orthodontic Use* (Chap. 4).

Chapter 5 presents dental ceramic focusing on microstructural characteristics in order to fulfill certain requirements such as specific flexural strength, elastic module, chemical resistance, and hardness essential for dental products. These bioceramics properties depend on their microstructure, which is determined by the phase present in the material, grain morphology and size, and grain interface.

Mechanical Behavior of Ceramic Materials is the subject of Chap. 6. Dental materials should withstand the forces of mastication and aggressive oral environment in which they are required to perform. Materials such as ceramic orthodontic brackets frequently fail due to the masticatory and orthodontic forces applied on them. Otherwise, the performance problems by ceramic materials are their brittleness, poor fracture resistance, and inability to absorb energy before they fracture. Therefore, as a ceramic material, dental ceramics fail due to the propagation of superficial cracks formed during their processing or due to surface impacts that occur in service. Failures of dental ceramics usually occur due to small structural defects like pores, flaws, and cracks. These defects are responsible for the loss of mechanical resistance which is especially important because of the cyclic stress and residual tension that dental ceramics are subjected to in the environment in which they are used.

Chapter 7 presents *Dental Alumina*: *Its Microstructure and Properties*. Alumina is the most common dental ceramic used in Dentistry. It combines inertness, good aesthetic properties, high mechanical resistance, chemical stability, corrosion, and wear resistance. The use of alumina is extending into different areas of Dentistry such as Orthodontics and Implantodontology. In Orthodontics, aesthetic brackets are made of high purity monocrystalline or polycrystalline alumina.

The *Degradation of Dental Ceramics* is discussed in Chap. 8. The aggressive intra-oral environment is a complex system. The saliva can have several pH

fluctuations in the course of a single day due to the type of food intake, the number of meals and soft drinks consumed in a day, hygiene habits, the use of fluoride solutions, the presence of orthodontic appliances, and oral microflora. The temperature in the oral environment, which varies from 0 to 55 °C according to the food intake, also exerts an influence. This temperature variation can occur with rapidity in seconds and it alters the structure of dental materials such as orthodontic wires.

We hope that the clear language and the application-oriented perspective are suitable for both materials engineers and dentists, professionals, and students who want to access major knowledge of dental ceramics materials.

Finally, we thank the staff of Springer-Verlag for their professional guidance in regard to this book.

Porto Alegre, Brazil, March 2013

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A. G. Stumpf

Contents

Chapter 1
Introduction

The dental prosthesis (or prosthetic Dentistry) is the specialty in Dentistry where missing teeth are artificially replaced by making mobile or fixed prosthetic elements and generically from different materials. It has been almost universal that unexpected loss of tooth structure and, particularly, missing anterior teeth create physical and functional problems and often psychological and social disturbances as well.

Ancient Greek scholars Hippocrates and Aristotle wrote about Dentistry including the use of wires to stabilize tooth and fractured jaws. The replacement of missing teeth has been practiced since 700 BC in Etruria and in the Roman Empire in the first century BC (Fig. 1.1).

In the 18th century, the prosthetic materials used were human teeth themselves, animal teeth carved as human teeth, ivory and porcelain. The total prosthesis used by the first American president George Washington was carved out of hippopotamus ivory. Pierre Fauchard was the first dentist to write a dental book and to develop several dental instruments for prosthetics and orthodontics (Figs. 1.2, 1.3 and 1.4).

Europeans only managed to master the technique of making porcelain in the 1720s and the first porcelain denture was made in 1774 by the Parisian pharmacist Alexis Duchateau. Since then, the dental prosthesis was continually perfected. The first crowns and fused feldspathic porcelain inlays were made in 1886, evolving in the 1950s with the introduction of leucite (a potassium and aluminum silicate—$KAlSi_2O_6$), improving the properties of crowns and ceramic restorations. All-ceramic prostheses, however, have only become available on market in the 1980s.

Dentists and materials scientists have sought over time to reconcile mechanical performance with esthetics. An analysis of scientific articles published between 1981 and 1999 in *The Journal of Prosthetic Dentistry* shows that the major concern has been with the mechanical aspects of the prostheses. Since then the evolution of ceramic biomaterials as prosthetic materials is concerned with getting the most esthetic result possible, without causing damage to the opposing tooth enamel and presenting adequate mechanical performance.

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Fig. 1.1 Image of a mandible with dental prosthetics done by Etruscans

Fig. 1.2 Portrait of Pierre Fauchard