Dental Ceramics for Restoration and Metal Veneering

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KEYWORDS

• Dental ceramics • All-ceramic restorations • Metal-ceramic restorations • Porcelain • Glass-ceramics • Zirconia • Ceramic-polymer interpenetrating network

KEY POINTS

- A facile understanding of the development, composition, microstructure, properties, and indications of various classes of ceramic dental materials.
- Knowledge of the rationale behind the choice and usage of dental ceramics to maximize esthetics and durability.
- Successful ceramic restorations depend on the balancing of multiple factors.

INTRODUCTION

According to the American College of Prosthodontists, 178 million people in the United States, which represents 55% of the US population, are missing at least 1 tooth and this number is expected to grow over the next 2 decades because of an aging population. Teeth play a critically important role in human life because loss of function reduces people's ability to eat a balanced diet, with negative consequences for systemic health. Loss of esthetics can also negatively affect social function. Both function and esthetics can be restored with dental crowns and fixed dental prostheses (FDPs). Ceramics have become increasingly popular as restorative materials because of their esthetics, inertness, and biocompatibility. Of the crowns and fixed prostheses currently produced in the United States, 80.2% are all-ceramic restorations, 16.9% are porcelain fused to metal (PFM), 2.2% are full-cast, and 0.7% are resin-based composite (RBC).[1] Demands for more esthetic and metal-free restorations, as well as soaring metal prices, are likely to increase further the number of all-ceramic prostheses.[2]

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However, a major clinical concern is that ceramics are brittle and subject to fracture.[3,4] The financial drivers for developing fracture-resistant and esthetic ceramics are high: the European crown and FDP market approached $2 billion in 2007[5]; the global crown and FDP market was estimated to be $25 billion in 2010 and more than $30 billion in 2015.[6] This article provides an overview of the background and the current knowledge base associated with dental ceramics for restoration and metal veneering, including a historical review of the development of ceramic restorations and their limitations. It also includes a summary of the current state of the art of porcelain, glass-ceramics, and polycrystalline ceramics. In addition, materials design considerations for dental prostheses are discussed.

THE HISTORY OF DENTAL CERAMICS

Shortly after the introduction of porcelain into Europe in the early eighteenth century, Alexis Duchateau, a Parisian apothecary, introduced ceramics to dentistry when he successfully replaced his ivory dentures with porcelain. With the help of a Parisian dentist, Nicholas Dubois de Chemant, Duchateau, working in concert with a new, high-technology porcelain manufacturer in 1774, created a complete set of porcelain dentures. They must have been very well made because they lasted Duchateau the rest of his life. The development of porcelain dentures was revolutionary in terms of esthetics and oral hygiene, and was recognized as such by Edward Jenner (developer of the smallpox vaccine) and the Faculty of Medicine Paris: they "…united the qualities of beauty, solidity and comfort with the exigencies of hygiene.[7]" Because the then-popular ivory-based or wood-based dentures, often using cadaver teeth, were all porous, they absorbed oral fluids and eventually became badly stained and highly unhygienic. Also, these early porcelain dentures were dysfunctional because patients had to remove them in order to eat. In addition, those complete porcelain dentures were only intended for edentulous patients, requiring the removal of the remaining teeth from patients' mouths, which was a painful procedure before the discovery of anesthesia by Horace Wells in the middle of the nineteenth century.

Porcelain inlays, onlays, and crowns were introduced by Charles Land[8] in 1886, which ultimately led to the creation of esthetic and functional ceramic restorations. However, the original dental porcelain contained a high feldspathic glass content and was extremely brittle and weak ($\sigma \sim 60$ MPa; σ stands for strength).[9,10] Therefore, despite the esthetic advantage, the early porcelain restorations were not widely applied in dentistry.[11] Dental ceramics have become increasingly popular as restorative materials because of improvements in strength and the increased goodness of fit with development of pressing and computer-assisted design (CAD)/computer-assisted manufacturing (CAM) processes. The timeline of the development of dental ceramics from the inception of initial porcelain materials to modern ceramic compositions, along with processing technologies, is shown in **Fig. 1**. The main compositions and pertinent mechanical properties of various dental ceramic materials, representative of major material classes and developments, are shown in **Table 1**.

Since Weinstein and colleagues[12,13] solved the problem of the coefficient of thermal expansion (CTE) mismatch between the porcelain veneer and metal framework in 1962, great improvements have been made in PFM systems. Until very recently, it was estimated that 70% to 80% of fixed prostheses produced in the United States were PFM (Ivoclar Vivadent, 3M ESPE, Jensen Dental, Marotta Dental Studio, and Glidewell Laboratories, personal communication, 2011). In contrast, the dental community has long recognized that to realize the full potential of dental prostheses, all-ceramic restorations are necessary. Several strategies have been developed to