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Recent advancement of materials in prosthodontics

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Abstract

Prosthodontics is a specialty that involves the replacement and restoration of lost dental structures with artificial substitutes. Many biomaterials have been developed to satisfy the demands laid by the functional, esthetic requirements of the stomato-gnathic system. The considerable advancements in this particular field, have often left the practicing dentist perplexed with regards to the correct choice. This paper provides an overview of the key recent advancements and milestones in biomaterial science in prosthodontics. It has been shown that the performances of many biomaterials used in prosthodontics have been significantly enhanced after their scales were reduced by nanotechnology, from micron-size into nano size. On the other hand, many nanocomposites composed of nanomaterials and traditional metals, ceramics, resin, or other matrix materials have been widely used in prosthodontics because their properties, such as modulus elasticity, surface hardness, polymerization shrinkage, and filler loading, were significantly increased after the addition of the nanomaterials. In this paper, the latest research progress on the applications of nanometals, nanoceramic materials, nano resin materials, and other nanomaterials in prosthodontics was reviewed, which not only gives a detailed description of the new related investigations, but also hopefully provides important elicitation for future researches in this field.

Keywords: Artificial Substitutes, Ceramics, Matrix

Introduction

Prosthodontics is an important branch of the oral medicine. With the improvement of people's living standards and the promotion of oral health knowledge, prosthodontics increasingly received widespread attention. Prosthodontics is mainly for dental defects, treatment after tooth loss, such as lays, crowns, and dentures, also including the use of artificial prostheses for periodontal disease, temporomandibular joint disease, and maxillofacial tissue defects [1–4]. The main purposes of dentures are to restore dental function and facial appearance and maintain the wearer's health.

Dental materials of dentures can be divided into mainly three categories: resin, ceramic, and metal. They are important to fabricate dental prosthesis, which directly contacts with the oral mucosa and is under long-term use in the oral environment, so the dental materials must have comprehensive properties and good biological activity to function properly. Dental materials should have certain mechanical strength, hardness, higher fatigue strength, high elastic modulus, low thermal and electrical conductivity, good castability, and less shrinkage deformation. Chemical stability is also required, such as corrosion resistance, being not easily broken, and aging. The colors of dental materials can be formulated and maintain long-term stability. As a good oral material, it should have good biocompatibility and safety and be biofunctional [2–4]. However, due to the nature of the material itself, continued use for long period in moist environment, a variety of problems will occur during wear dentures, such as pigment adhesion, color change, and aging fracture. In recent years, nanomaterials have captured more and more attention because of their unique structures and properties. The concept of "nanomaterials" formed in the early 1980s, referring to zero-dimensional, one-dimensional, two-dimensional, and three-dimensional materials with a size of less than 100 nm [5, 6]. Nanomaterials can be divided into four categories of Nano powder, nanofiber, nanomembrane, and Nano block, in which development of nano powder is longest, and its technology is most mature [6]. Nanomaterials have small size, large surface area, high surface energy, a large proportion of surface atoms, and four unique effects: small size effect, quantum size effect,

quantum tunneling effect, and surface effect [7]. Development of nanomaterials has greatly enriched the field of research in materials science including biomaterials.

Biomaterials used in the field of prosthodontia are those used for the replacement of the lost dentition. Of the plethora of Prosthodontic biomaterials available, the clinician is often puzzled with the choice of an appropriate biomaterial because of lack of sound scientific rationale and thorough knowledge and understanding of these materials. Most commonly, the clinician is guided by hearsay knowledge of the use of materials from other clinicians and medical representatives. Evidence based practices should be encouraged to gain confidence in the use of dental biomaterials by any dental practitioner. Advances are aimed at improving the existing materials and to welcome new materials, so that the final restoration is made biocompatible and survive in the oral environment for considerable period of time. It is important to be aware of the current trend of dental practices and recent advancements of materials so that the dentist and the patient would be benefitted.

Biomaterial can be understood as any biologic or synthetic substance that can be introduced into body tissue as part of an implanted medical device or used to replace an organ, bodily function, etc. The following discussion will be based on the various commonly encountered biomaterials with theirstate of art and recent updates

Recent advances in materials

Denture Base Resins

Flexible denture base material: These materials evolved as a result of dentist satisfying the patient's need for a softer clasp and ease of insertion. This material (polyamide) is considered to be ideal for partial dentures. The resin is a biocompatible nylon thermoplastic. Its unique physical and aesthetic properties provide unlimited design versatility and eliminates the concern about acrylic allergies. [8] The denture is thin and lightweight and flexible enough to enter below the undercuts. But it is unbreakable and does not stain easily. It is comfortable to the patient as no tooth or tissue preparation is needed. The denture is esthetically very pleasing.

Microwave Cured Denture Base Resin: This resin is manipulated similar to conventional resins up to the point of curing. The microwave makes curing easier than conventional methods. Three minutes and a standard 500-watt microwave are needed to cure higher quality and more precise dentures. This process saves time, while increasing the accuracy and strength of denture bases. Source of the activator is the heat generatedby the colliding molecules which moves or vibrates around their axis. [9 10

Glass fiber reinforced denture base resin: Several types of fibers, including carbon, aramid, woven polyethylene and glass fibers, have been used to strengthen denture base resins. Carbon and aramid fibers strengthened the resin but causedclinical problems, such as difficulty in polishing and poor aesthetics. Woven polyethylene fibers are more aesthetic, but the process of etching, preparing, and positioning layers of woven fibers may beimpractical for the dental office. Silanated glass fibers are the fibers of choice for reinforcing denture base polymers. Improvement in flexural properties and fatigue resistance are seen with the use of glass fibers. [11]

Composite denture teeth: Micro filled denture teeth and Nano-filled denture teeth are available. Knoop hardness values (KHN) ranged from 28.2 to 29.8 for micro-filled composite, 18.9 to 21.6 for cross-linked acrylic, 22.7 for nano-composite, and 18.6 for conventional acrylic teeth. All micro-filled composite teeth were significantly harder than other teeth. The wear depth values were 90.5 µm for the nano-composite, 69.8 to 93.0 µm for the micro-filled composite, 80.8 to 104.0 µm for the cross-linked acrylic, and 162.5 µm for conventional acrylic teeth. The nano-composite tooth was harder and more wearresistant than the acrylic teeth but not significantly different from most of the cross-linked andmicro-filled composite teeth. [12]

Advancements in ceramics Monolithic zirconia: Zirconia, the toughest and strongest material among all dental ceramics, was in use in dentistry since the early 1990s. However, because of their insufficient translucency, zirconia cores always required porcelain veneering to achieve acceptable esthetics.[13]] This often resulted in chipping or cracking of the veneered ceramic.[14] Rates of chipping were reported to be about 3–36% after 1–5 years for fixed partial dentures.[15] To overcome this, monolithic zirconia restorations without porcelain veneering have been introduced more recently.[14]

Multi-layered zirconia: Multilayered zirconia system was introduced in 2015, aiming for superior esthetic properties. They showed gradation chroma and translucency, imitating the shade gradient of natural teeth: Gradual increase in translucency from incisal area of the crown to the gingival region.[16]

Waxes

Light curing waxes: The wax patterns of the metallic frameworks of the removable partial dentures could be made directly on the cast, using profiled waxes like: TiLight or LiWa (light curing waxes). These waxes eliminate duplicating techniques for the working models and saves time. They are used for all types of metal works, crowns, bridges, implants. After modeling, these waxes can be cured by any standard lab UV or halogen light. These waxes are easy to use, economic, cures quickly, has appreciable strength an elasticity and they are odorless and stable. [17 18]

Advancements in luting cements:

Self-adhesive resin cements: These cements were developed in 2002 with the aim to combine the favorable properties of different luting cements into single product. This material was introduced to deliver the property of simple application similar to zinc phosphate and polycarboxylate cements; pH range, moisture tolerance, and fluoride release comparable to glass ionomer cement (GIC) along with optimal mechanical properties and good esthetics of resin cements.[19]

Advancements in impression materials: Dustless alginate: To overcome these disadvantages various modifications have been done like dustless Alginate which Contain high algin content. Glycerin is incorporated on alginate particles. The high align content provides for a quality impression without the excessive flow.

Fluoride containing alginate: Addition of NaF or SnF2 in an alginate impression material may result in effective release of fluoride without deteriorating the properties of material itself. Fluoride-containing dental alginate impression materials can exert a considerable reduction in enamel solubility

Silgimix: This is an alginate replacement impression material. Silgimix is developed from vinyl polysiloxane chemistry. It addresses the shortcomings of alginate materials by giving users the ability to disinfect, the option of pouring multiple times and the ability to scan the impression electronically.

Advancements in provisional restoration:

Luxatemp materials: It is a composite provisional material available as self-cure and light cure system. Recently, several modifications were made in this line: Luxatemp fluorescence which has superior esthetics and unique handling properties, Luxatemp Ultra with high flexural strength by incorporation of nanotechnology, and Luxatemp Solar which is a light-cured material. Light curing enables for flexibility in working time.[20]

Hydrophilic Polyvinyl Siloxane: To improve hydrophilic properties, surfactant and hydrophilic monomer are added which result in a truly low contact angle. A lower contact angle measure means greater "wettability", displacing oral fluids for a more detailed impression. These additives also increase surface energy within the material, and therefore increase detailed reproductions, even in the presence of blood and saliva.

However, addition of surfactants makes the preparation of electroformed dies more difficult as the metallizing powder does not adhere well to the surface of hydrophilic addition silicone.[21]

Nano ceramic materials: The development of ceramic crown experienced long essence of ceramic materials: hydroxyapatite (HA) ceramic, glass ceramic, alumina ceramic, and zirconia ceramic. Alumina ceramics have good aesthetics, high gloss, chemical stability, wear resistance, high hardness, good biocompatibility, no allergies, and no effect on the MRI, but the biggest drawback is crisp, and it is likely to porcelain crack [22]. ZrO2 has a good abrasion resistance, physiological corrosion resistance, and biocompatibility, whose modulus of elasticity, flexural strength, and hardness are higher, compared to those of HA and titanium alloys. The strength and bending resistance of zirconia ceramics through computer aided design/computer aided manufacture are significantly higher than alumina ceramic, but they still lack toughness and high sintering temperature [23].

Maxilla facial prosthesis [24 25]:

SE-4524U: This silicone is representative of family of polymers that require moderate to high temperatures for the initiation of the cross-linking reaction. The Silas tics 44514 and 44515 available from Dow Corning are of the same general type. General Electronic provides the SE-4524U material in the form of unprocessed gum stock, with or without incorporated catalyst. The vulcanization reaction involves the combination of methyl groups on the polymer chains. An organic peroxide is used to initiate the cross-linking reaction. With this material, the prostheses must be fabricated at a temperature high enough to cause decomposition of the peroxide catalyst.

PDM Siloxane: It is a type of HTV silicone that has physical and mechanical properties that exceeded values considered clinically acceptable

Conclusion

Although, marked breakthrough in technology and recent advancements in biomaterials present with a massive assortment of materials and techniques, it is ultimately the job of the practicing dentist to choose the materials to suit the biological, functional and esthetic requirements of the restorations and replacements in the complex oral environment. It is mandatary that clinicians should be updated about various biomaterials and their manipulative characteristics and technical considerations which would enable them to render quality care for patients. Future development of prosthodontics technology has been recognized to be dependent on the progress of materials science. Nanomaterials have been playing a significant role in basic scientific innovation and clinical technological change of prosthodontics. In this paper, the latest research progress on the applications of nanometals, nanoceramic, nano resin, and other nanomaterials in prosthodontics wasreviewed.

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