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Evolution of Denture Base Materials from Past to New Era

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Abstract
Computer-aided technology is an emerging method for fabricating complete dentures. Consolidated information about historical background, current status, and scope for the future is lacking. The purpose of this literature review was to analyze the existing literature on denture base materials for fabricating complete dentures and provide the reader with a historical background, current status, and future perspectives on the emerging technology. The review of different denture base materials provides a clear picture about the various developments that have taken place in this field. The polymers, especially acrylic resins after entering this field for more than 70 years seem to be undergoing constant change and are the materials of choice
Key words: - *Acrylicresin, Methyl methacrylate, Flexible denture, Fiber-reinforced resin*

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I. Introduction

Dentistry as a speciality is believed to have begun about 3000 BC in Egypt. [1] As civilization progressed there has been continued refinement of both the quantity and quality of useful materials making it biologically simple to manipulate and technically controlled to develop a prosthesis that is functionally effective and pleasing in appearance. [2 - 4]The discovery of denture base materials has revolutionized the dental material sciences. [5]

History

Skillfully designed dentures were made as early as 700 BC and 'Talmud' a collection of books of Hebrews in 352-407 AD mentioned that teeth were made of gold, silver, andwood. The first dental prosthesis is believed to have been constructed in Egypt about 2500 BC.During medieval times dentures were seldom considered, when installed they were hand carved and tied in place with silk threads. Those wearing full denture had to remove them before eating. Upper and lower teeth fit poorly and were held together by steel springs

Materials before the 18th century

By the 8th century the Japanese carved wooden dentures from sweetsmelling species like cherry and natural teethwere fixed with the help of screws. George Washington, former American presidentalso had a set of dentures made from wood. Thedrawback was that they were hygiene challenging due to moisture. [6] Pierre Fauchard (1678-1761) fabricated dentures by measuring individual arches with a compass developed and used human teeth or teeth made from hippopotamus or elephant ivory in the denture. It had better dimensional stability than wood; however, esthetic and hygienic concerns remained. According to Guerini, Pfaff (1756), Frederick the Great's dentist, developed a more effective impression technique. [2] Tomes described a patented machine of his own invention which he claimed obviated the use of pigment. [7] Ivory denture bases and prosthetic teeth were relatively stable in the oral environment, offered esthetic and hygienic advantages compared to wood or bone. [1]

Materials used in the 18th century

It was Etienne Bourdet who made the first reference to the use of a gold base punctuated with small holes much like the sockets of teeth. [8] In 1794 AD, John Greenwood began to use gold bases for dentures. 18 to 20 carat gold was usually alloyed with silver and teeth were fitted to it. [1] Alexis Duchateau (1774) was the first to fabricate porcelain dentures. In 1788 AD, a French dentist, Nicholas Dubois de Chemant, made a baked-porcelaincomplete denture in a single block. The advantages were that it could be shaped easily, ensured intimate contact with the underlying tissues, was stable, had minimal water sorption, smooth surfaces after glazing, less porosity, low solubility and could be tinted but its drawbacks were brittleness and difficulty in grinding and polishing. [1]

Materials used in the 19th century

In 1808 Italian dentist Giuseppangeio Fonzi introduced individually baked porcelain teeth in which teeth were attached to the denture base by a small platinum hook. [2] In 1839, Charles Goodyear discovered a method of producing rubber, and Nelson Goodyear in 1851 invented a process for making hard rubber or vulcanite. In 1855, Charles Goodyear patented a process for making denture bases of vulcanite. [9, 10] Loomis fabricated the first porcelain denture with artificial teeth in 1854. Charles H Land in 1890 made porcelain dentures with platinum bases known as continuous gum dentures. [2] White was considered as the most noble and grandest figures in the history of dentistry. [11]The pleasing appearance of Vulcanite was almost the answer to the dentist's problems in the fabrication of dentures and it was considered as the principal denture base material for the next 75 years. [2]CF Harrington in 1850 introduced the tortoise shell base as first thermoplastic denture material,. Edwin Truman in 1851 used Gutta percha as a denture base but it was unstable. Alfred A Blandy in 1856 made dentures from a low fusing alloy of silver, bismuth and antimony but it was never accepted. [1]Dr. Bean invented the casting machine. It was Carroll in 1888 who presented a method for casting aluminum bases under pressure.[12,13] John Wesley Hyatt (1868) was credited with preparing the first organic plastic molding compound, which was cellulose nitrate, popularly known as celluloid which was used as denture base material in 1870. [2]

Materials used in the 20th century

In 1909 Dr. Leo Bakeland introduced phenol formaldehyde resin which was easily available but lacked color quality. Ni-Cr and Co-Cr were obtained by E. Haynes in 1907but they gained popularity only after 1937.[1] During 1930 mixtures of polymerized vinyl chloride and vinyl acetate were made. In 1935 resins were developed from a reaction between glycine and phthalic anhydrite.[14]PMMA in the form of a transparent sheet was introduced byRohm and Hass in 1936 and in 1937 Du Dout De Nemours introduced it in powder form. The first acrylic type plastic was available under the name of vernonite. [2] Methyl methacrylate was clinically evaluated by Wright during 1937 and found to fulfill virtually all the requirements of an ideal denture base material.[15,16] In 1942, vinyl acrylic copolymer (Luxene 44) and polystyrene (Jectron), a styrene polymer developedby Charles Dimmer, were introduced as denture basematerials during 1948. Nylon was introduced inLondon in the 1950s as a denture base material, provingto be entirely unsatisfactory owing to its poor abilityto resist oral conditions, thus resulting in swelling ofthe denture base due to absorption of moisture. EarlPound in 1951 described the tinting of acrylic resindenture base materials. [2]

Polymethylmethacrylate material has been divided into two types based on the method of activation. Heat activated and chemically activated. [1] Masamishinishi in 1968 first reported the use of microwave energy to polymerize acrylic denture base material in a 400 watt microwave oven for 2.5 minutes and later Kimura in 1983 carried out research on the effects of microwave energy in denture base resins. [2]In1947, chemical activators were used to induce denture base polymerization at room temperature. These were also referred to as cold-curing, self-curing.[2] The Austenal company in 1955 introduced the use of self-cured acrylic resins as denture bases, because of its disadvantage it was never made a material of choice as permanent denture base materials.[2]The heat-cured dentures showed considerable changes in contour after they had been repaired by the heat-curing method. The self-cured dentures exhibited practically no changes during repair. [17 - 19].In 1961 chemists grafted PMMA resins which show increase in resistance to impact fracture. [20] Polysulphones were introduced in 1981. Processed byinjection molding, their impact strength was twicethat of most impact resistant modified methacrylate.In 1986, Dentsply International introduced a formof acrylic resin employing the use of visible light forpolymerization which eliminates the need forwax, flask boil outs and other conventional processes.[2] Polymerization shrinkage encountered inconventionally cured PMMA led to the development ofa special injection molding technique. Initiallydeveloped as a fluoropolymer in 1962, acetal began tobe used in 1971. Nowadays nylonbased plastic (Polyamide) is used. Elastomeric resins can beadded to resin polymer formulas to create greaterflexibility and can be strengthened with glass fibers. [1] Addition of silane treated radioopaque powdered glass to clear polymethylmethacrylate resulted in composites that had greater optical translucency than commercially available pink denture bases. [21] The Flexible dentures in combination with Cast Partialframework–A good alternative to the all flexible partial. [1]

New era in denture base resins

Different fiber types have been added to acrylic resin to improve physical and mechanical properties. Larson and Sonit in 1991 and Van Ramos in 1996 evaluated the effect of carbon fiber, silane treated glass fiber and polyethylene fibers in increasing the strength of PMMA (Poly methyl methacrylate).[2] The advantages of carbon fibersare increase in transverse and impact strength increased fatigueresistance when treated with silane coupling agent.[22] Yazdanie in 1985 concluded that carbon fibers increase the strength and strands are more efficient than woven mats.[2] Berrong in 1990 conducted a study to evaluate theeffect of fiber reinforcement on fracture resistance of PMMA and concluded that the use of 2% by weightKevlar reinforcement fibers increase the fracture resistance.[23] Different types of glass fibres are produced commercially; these include E-glass, S-glass, R-glass, V-glass and Cemfil. Of these, E-glass fiberreceives stresses without deformation because of high elasticity. [24, 25] Other materials that include E-fibers surface which had been treated withprecured silane were powder-coated with sphericalPMMA particles, Polyester fiber (PE), Organophilic montmorillonite (Claytone),Methacrylated polyhedralsilsesquioxanes (POSS), Silica-glass fiber reinforced polymeric materials, Ultra high modulus polyethylene fibers. [2]

Continuous fiber provides superior reinforcement over chopped fibers. Six mm chopped glass fibers with 5% fiber in combination result in increase in transverse strength, elastic modulus& impact strength. Glass fibers may be modified by plasma polymerization technique using HEMA (2-hydroxy methylacrylate), EDA (Ethylenediamine), and TEGDMA (Tetraethyleneglycol Dimethacrylate). [26]Each strand of this E-glass is computer impregnated with a PMMA (porous polymer) and silane coupler that allows dissoloution bonding to acrylic. (e.g. Preat Perma Fiber)[27]Diurethane dimethacrylate, Polyurethane, Polyethylenterephthalate and Polybutylenterephthalate are hypoallergenic denture base materials which exhibit significantly lower residual monomer content than PMMA.[28, 29] Light activated indirect composite containing methane dimethacrylate (UDMA) is an alternative to PMMA for patients hypersensitive to PMMA. [10] But unfortunately these materials are not completely risk free. [27] Addition of hydroxy-apatite fillers and Al2O3 in the ratio 2.2:1 increases fracture toughness.[30,32] Addition of ceramic or sapphire whiskers, 2% quaternary ammonium, addition of 11-14% of several compounds of either bismuth or uranium or 35% of an organo-zirconium compound improves thermal diffusivity.[33 - 35] Addition of Triphenyl Bismuth (Ph3Bi) is a promising new additive to provide radiopacity. Thermoplastic Resins is a new material, during which a fully polymerized basic material is softened by heat (without chemical changes) and injected afterwards, has opened up a new chapter in making dentures.[36]

In 2004 Paul Franklin found that addition of glass flakes increased fracture toughnessup to 69%. [37]In 2007a mesoporous silica MCM-48 with highest mechanical and thermophysical properties was used as a reinforcement agent forpoly (methyl acrylate) (PMA). [38] In 2009 another system which combined the benefits of both heat and self curewas introducedin which the residual monomer was reduced.Monomer can be further reduced to below 1% by activating the RMR (residual monomer reduction) function. [39]Researchers also investigated the behaviour of a 7 wt% nano-zirconium oxide modified heat cured PMMA.[40] The result showed that the addition improved hardness levels, flexural strength, and fracture toughness of the heat cured PMMA denture base.[41 -42]In 2017 incorporating 0.4% TiO2 nanoparticles into a 3D printed poly-methylmethacrylate (PMMA) denture base was investigated to improve its antibacterial and mechanical properties .[42 -44]T. Vasilieva, Aung Myat Hein found that plasma modification of the dentures made of heat curing PMMA is likely to produce oxygen-containing polar hydroxyl, carbonyl and carboxyl groups at the polymer surface that increase the SFE and wet ability of the polymer and improve its adhesion to oral tissues.[45]Malvika Nagrath in 2018 stated that the PCL-PMMA surface was capable of releasing the drug over sustained time periods and was able to reduce Candida albicans colonization.[46]

Before the introduction of CAD/CAM technology, the congruence between denture base and denture-bearing tissues was always impeded by the resin's polymerisation shrinkage [47]. The shrinkage results in distortions of the denture base and has a negative impact on fit and retention of complete dentures.[48 - 50] Denture base adaptation is influenced by the amount of polymerization shrinkage that occurs during processing. [51-56]The retention offered by milled prepolymerized PMMA complete denture bases was significantly higher than that of conventional heat-polymerized denture bases.[57]In CAD/CAM fabrication, denture bases are milled from fully polymerized acrylic resin pucks[58] and are therefore not subject to shrinkage or distortion phenomenon.[59,60] In 2018Otto Steinmassl foundthat AvaDent Digital Dentures, Whole You Nexteeth prosthesis andWieland Digital Dentures have a significantly higher precision of denture base fit than the conventional dentures. So CAD/CAM dentures will show better clinical retention, as well as a reduced frequency of denturerelated traumatic ulcers. Digital design and automatic processing are able to compensate some manual errors. Nevertheless, meticulous adjustment and profound prosthodontic knowledge remain unreplaceable for a successful prosthodontic rehabilitation.[61]

II. Conclusion

The transition from naturally occurring materials to the application of synthetic resins in denture construction indicates the extent of development taking place. Research carried out by workers has promoted the foundation of future knowledge and it can be hoped that the unending search for denture base materials with desirable qualities will always continue. The ability to manufacture complete dentures using computer-aided technology has untold educational, investigational, and clinical possibilities for the future.

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