Evolution of denture base materials

Review Article

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ABSTRACT

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. This article summarizes the historical background as well as the development of denture base materials.

KEY WORDS: Denture base material, history, resin

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INTRODUCTION

The loss of teeth by accident or disease has plagued mankind throughout the ages. In order to restore a degree of function and appearance, it has been necessary always to adapt contemporary materials to dental applications as they are available in one period of history.

As civilization has progressed there has been continued refinement of the materials available for dental practice. As time passed and civilization advanced with the development of biological, chemical and physical sciences, there occurred a slow but steady increase in both the quantity and quality of useful materials available for dental prostheses. The material should be biological compatible, readily available, reasonably inexpensive and simple to manipulate with a readily controlled technical procedure, to develop a prosthesis that is functionally effective and pleasing in appearance.[1]

The means of replacing missing tooth structure by artificial materials continues to account for a large part of the application of material sciences. Denture base materials have always been a matter of research in the field of dental materials. As aptly said that for a strong building we need a sound foundation, similarly for fabricating long lasting, esthetically and biologically acceptable dentures, we need a favorable denture base.

DEFINITION

According to Gpt-8 (2005) a denture base may be defined as the part of the denture that rests on the foundation and to which teeth are attached.[2]

MATERIALS USED BEFORE 18TH CENTURY

1. Wood
2. Bone
3. Ivory

By the 8th century the Japanese were masters of the art of woodcarving and it was possible that the earliest wooden denture was made at that time. Dentures were carved from a single piece of wood, usually sweet smelling species such as box and cherry. Natural teeth were fixed with the help of screws. George Washington also had a set of dentures made from wood. The drawbacks were that the denture bases warped and cracked in the presence of moisture and posed esthetic and hygienic challenges.[3]

Further progress was slow until the 17th century. Modern dentistry had been said to begin with Pierre Fauchard (1678-1761) who developed many prosthetic techniques. He used human teeth or teeth made from hippopotamus or elephant ivory in the denture. He

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carved dentures from a single piece of ivory or bone.

Although bone displayed better dimensional stability than wood, esthetic and hygienic concerns remain. Whereas ivory was stable in the oral environment, and offered significant esthetics but its drawbacks were that it was not readily available, and was relatively expensive.

Fauchard fabricated a denture by measuring individual arches with a compass and cutting bone to fit these arches.

In other methods a lump of wax was partly carved and partly molded to the desired shape, so it reproduced missing teeth and fit snugly against ridge and palate. This model was then used by craftsman for reproducing a denture in bone or ivory. It was very time-consuming, taking six weeks to carve a denture from bone or ivory.

According to Guerini, Pfaff (1756), Frederick the Great's dentist, developed a more effective impression technique. His method was to take, in two pieces, wax impressions of entire jaw. The pieces were separately removed, thus minimizing distortion and reassembled outside the mouth and plaster casts were made from them. This technique appears to have been unknown even to Fauchard, whose methods Pfaff otherwise closely followed. With a reasonably accurate and dimensionally stable cast available, the carver could then adapt the denture to it without frequent recourse to the patient. A block of ivory was shaped with a drill and engraving blade, using a pigment to detect high spots as a base was made to fit the casts. Tomes described a patented machine of his own invention which, he claimed, obviated the use of pigment.[4]

MATERIALS USED IN THE 18TH CENTURY

1. Gold
2. Porcelain

Gold denture base

One of most important Fauchard followers was French dentist Etienne Bourdet (1775) who made the first reference to the use of a gold base punctuated with small holes much like the sockets of teeth.[5] Projecting upward in these sockets were pins onto which ivory or natural teeth are attached. The gold base did not sit on the crest of the ridge as the denture base does today but was formed as a shallow cup.

After invention of the impression technique using softened wax and plaster of Paris, models were fabricated and gold plates could be hammered and swaged to achieve more accurate adaptation. Usually 18 to 20 carat gold was alloyed with silver and teeth were attached by riveting.

Porcelain

Although the art of firing porcelain was practised in China in the 9th and 10th centuries, it was not until 1774 that Alexis Duchateau, a Parisian apothecary, dissatisfied with his own stained hippopotamus ivory denture, was inspired to attempt to use porcelain for denture fabrication. Seeking a solution, he attempted to make a denture from porcelain at the Guerhard porcelain factory. Since he was not a dentist and was unfamiliar with taking impressions, his efforts failed.[3]

He teamed up with Parisian dentist Nicholas Dubois De Chemant. After a number of early failures the two eventually made a baked porcelain complete denture in a single block in 1788. In due course he improved its dimensional stability-a very difficult achievement because the one-piece denture had to resist distortion during firing, for which he was granted the British patent in 1791.

With the advent of porcelain, ivory, bone and animal substances were replaced. Porcelain dentures offered several advantages over animal substances. A one-piece denture was susceptible to shrinkage and distortion. The advantages of porcelain were that porcelain could be shaped easily and ensured intimate contact with the underlying tissues, could be tinted to simulate the color of teeth and oral soft tissues, was extremely stable, had minimal water sorption, smooth surfaces after glazing, less porosity and low solubility, smooth surface provided enhanced hygienic properties; but its drawbacks were brittleness and difficulty in grinding and polishing.

Chemant's denture was popular until the introduction of individually baked porcelain teeth in 1808 by an Italian dentist Giuseppangeio Fonzi. In this, teeth were attached to the denture base by a small platinum hook. This pin was soldered to a gold denture base. It was one of the most important events in the history of dentistry.

Loomis (1854) fabricated the first porcelain denture with artificial teeth.

Charles H Land (1890) made porcelain dentures with platinum bases known as continuous gum dentures.

Alexander Gutowski (1962) from West Germany made dentures from one piece of porcelain

Materials used in the 19th century

1. Tortoise Shell (1850)

2. Gutta Percha (1851)
3. Vulcanite (1851)
4. Cheoplastic (1856)
5. Rose Pearl (1860)
6. Aluminum (1867)
7. Celluloid (1870)

During the later part of the 19th century, polymers entered the field of denture base materials.

Charles Goodyear (1839) developed the art of producing rubber and in 1851 his brother Nelson Goodyear invented a process for making hard rubber called vulcanite, which was produced by heating natural rubber in the presence of sulfur to produce a hard, reddish-brown rubber with many desirable properties.[6,7]

The introduction of vulcanite into dentistry is like the discovery of fire in the history of mankind. Vulcanite was almost the answer to the dentist's problems in the fabrication of dentures. Despite its displeasing appearance vulcanite dentures fitted the ridges of the patient more exactly, so that dentures could be worn with comfort. Other advantages were economy, durability, light weight, and ease of work.

A little later in 1854 Thomas Evan introduced vulcanite as a denture base material. He made vulcanite-based dentures for Charles Goodyear senior and one year later for Charles Goodyear junior.

In 1864 John Cummings succeeded in obtaining a US patent that covered the entire process of denture fabrication, from impression to delivery with the vulcanite technique. He sold the patent rights to Goodyear Dental Vulcanite company, for which they charged license fees. Because of the vulcanite patent, dentists tried out many new materials. But most of them had properties inferior to vulcanite and therefore were soon discarded. Due to this patent many dentists started using ceramic and gold bases. The vulcanite patent expired in 1881 and the company made no further effort to renew it.

After its introduction, vulcanite remained the principal denture base material for the next 75 years. Until the introduction of PMMA in 1930, vulcanite and porcelain teeth were the standard materials for fabrication of prostheses.

In 1850 CF Harrington introduce a tortoiseshell base that was first the thermoplastic denture base material.

In 1851 Edwin Truman made a base of Gutta percha. However, the material was unstable and its use required complicated equipment.

In 1856 Alfred A Blandy used a low fusing alloy of silver, bismuth and antimony. Dentures made of this low fusing alloy were called cheoplastic dentures and the method of manipulation was called cheoplasty. He embedded a wax model of the denture in plaster of Paris and after melting the wax, he poured the metal compound. Although this metal denture was never accepted, molding and pouring technique was adopted for manufacturing of vulcanite dentures.

The first known casting of a complete aluminum base was done in 1867 by Dr. Bean. He invented the casting machine. In 1888 Carroll presented a method for casting aluminum bases under pressure.[8,9]

Although accuracy of fit and other advantages made aluminum the material of choice, the difficulty of relining, increased cost of fabrication and a potential relationship between aluminum and Alzheimer's disease had discouraged the use of aluminum and its alloys.

John Wesley Hyatt (1868) was credited with preparing the first organic plastic molding compound, which was cellulose nitrate, popularly known as celluloid. In 1870 it was first used as denture base material. The advantages of celluloid were its translucence and pink color. Celluloid provided a less expensive alternative to the high cost of purchasing a vulcanite license. It was extensively used for a time during and after the world war I because of shortage of rubber. But celluloid gradually turns black and green with age and distorts in service. Thirty percent camphor was added as a plasticizer, producing an unpleasant taste and odor. This drawback significantly reduced its application.

Thereafter various modifications of cellulose nitrate such as acetate and ethyl cellulose were produced but they all showed distortion and warping. Although cellulose plastic was soon discarded, it served a real purpose in the search for resin with more desirable esthetic qualities than vulcanite rubber.

MATERIALS USED IN THE 20TH CENTURY

1. Bakelite (1909)
2. Stainless steel (1921)
3. Cobalt Chromium (1930)
4. Vinyl Resin (1932)
5. Acrylic Resin (1937)
6. Self cure Acrylic Resin
7. Epoxy Resin (1951)
8. Polystyrene (1951)
9. Nylon (1955)

10. Polycarbonates (1967)
11. High impact acrylic (1967)
12. Polysulphones (1981)
13. Visible L.C (1947)Acrylic (1986)
14. Pure Titanium (1998)

In 1909 Dr. Leo Bakeland came out with another compound, which was a phenol formaldehyde resin and was termed as Bakelite. Its advantage was easy availability but its drawbacks were lack of uniformity, poor color quality and repair difficulties.

Use of stainless steel, silver and its alloys as denture base materials has been reported. Currently base metal alloys are gaining popularity in place of gold alloys and aluminum alloys. Ni-Cr and Co-Cr alloys were obtained by Elwood Haynes in 1907 but it was not until 1937 that RW Erdle and CH Prange of Austenal laboratories perfected the materials and techniques for use of these alloys. Since their introduction, these alloys made steady gains in popularity, but their increased use can be attributed to their low density, low material cost, light weight, higher resistance to tarnish and corrosion and high modulus of elasticity. Difficulty in adjustment and polishing and concerns over the reported Ni and Be allergies posed a challenge to the use of base metal alloys.

During 1930 mixtures of polymerized vinyl chloride and vinyl acetate were available, with pleasing color but the processing methods were difficult. In 1935 resins were developed from a reaction between glycine and phthalic anhydrite. In fact the period from 1930 to 1940 represented a period of intense experimentation both by the plastic industry and the dental profession to find a suitable material. The future for synthetic resin was not bright during this period with some dentists even returning to vulcanite.

In 1901 Otto Rohm produced the commercial compound of acrylic acid as part of a PhD thesis and produced a solid transparent polymer of acrylic acid. Rohm and Hass in 1936 introduced PMMA in the form of a transparent sheet and in 1937 Du Dout De Nemours introduced it in powder form. The first acrylic type plastic was available under the name of vernonite.

In 1937 methyl methacrylate was clinically evaluated by Wright and found to fulfill virtually all the requirements of an ideal denture base material.[10,11]

The acrylic resin represented such significant improvement in its application that by 1946 it was estimated that 95% of all dentures were fabricated using methylmethacrylate polymers. Initially acrylic resins were polymerized by heat. In Germany in 1947, acrylic resins were developed using chemical accelerators for polymerization and termed as self-cure or auto polymerization resins.

The PMMA and its copolymers continue to be the most popular non-metallic materials. Its advantages were economy, simple processing technique, stable colors, optical properties, adequate strength and other physical properties which make them ideal materials of choice, free from toxicity and easily pigmented.[12]

In 1942, vinyl acrylic copolymer (Luxene 44) and in 1948 polystyrene (Jectron), a styrene polymer developed by Charles Dimmer, were introduced as denture base materials. Both materials had greater transverse and high residual stresses.

Since 1937 when acrylic resins were introduced, the plastics industry has undergone a lot of changes in search of new materials. Nylon was introduced in London in the 1950s as a denture base material, proving to be entirely unsatisfactory owing to its poor ability to resist oral conditions, thus resulting in swelling of the denture base due to absorption of moisture. Earl Pound in 1951 described the tinting of acrylic resin denture base materials.

The Austenal company in 1955 introduced the fluid resin technique advocating the use of self-cured acrylic resins as denture bases, which offered the advantages of improved adaptation, dimensional stability, reduced cost and simple procedure, but the disadvantages of low strength, higher solubility, high residual monomer levels, poor bond strength between denture base material and resin teeth never made self-cure acrylic a material of choice as permanent denture base materials.

Different denture base materials like epoxy resin, high impact methacrylate and polypropylene were used from 1951-1967, but could not be used as absolute substitutes of PMMA.

Masamishinishi (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 *et al*., (1983) carried out research on the effects of microwave energy in denture base resins.

Stress contributed to the withdrawal of polystyrene from the market in 1971. A research development of an entirely new thermoset epoxy resin denture base at the University of Washington (1958) was thought of as an alternative to resin acrylics, but the high rate of water sorption, fracture and loss of posterior teeth, heavy deposition of stains and calculus prevented further use in the field of denture base materials.

Polycarbonate, polyethers and others have been investigated but found suitable only for limited applications.

A few undesirable properties of acrylic resin such as warping during processing, accuracy of fit, polymerization shrinkage, allergy to monomer etc. again led to increased interest in metallic denture base materials.

Faber (1957) described the technique for fabrication of lower cast metal bases. According to Faber there would be fewer tissue changes if a metal base were used. According to Faber, Peyton (1943) and Skinner (1951) also suggested the use of metal base.

In 1979 Frank E. Pulskam compared the casting accuracy of gold with base metal alloys. Type IV gold appeared to be the most accurate alloy available for denture base but the cost factor limited its application.

Polysulphones were introduced in 1981. Processed by injection molding, their impact strength was twice that of most impact resistant modified methacrylate.

In 1986, Dentsply International came out with a form of acrylic resin employing the use of visible light for polymerization. This system (Triad) comprises visible light-cured denture base material supplied in the form of sheet and arch form. It contains urethane dimethacrylate. The system eliminates the need for wax, flask boil outs and other conventional processes.

Recently the most promising metal for potential denture base application appears to be commercially pure titanium. This metal offers the advantage of light weight, strength and above all biocompatibility. Some difficulties have been encountered in the titanium casting procedure such as necessity for an inert casting environment and the presence of voids and gas inclusion in the finished casting.

Currently research is ongoing to incorporate various materials to increase the strength of PMMA resins.

The approach to strengthening the acrylic resin prosthesis had included modification or reinforcement of acrylic resin denture base material with fibers. Different fiber types have been added to acrylic resin to improve physical and mechanical properties.

Larson *et al*., (1991), Sonit (1991) and Van Ramos (1996) evaluate the effect of carbon fiber, silane treated glass fiber and polyethylene fibers in increasing the strength of PMMA.

Fibers can be used in three different forms, namely continuous parallel, chopped and woven.

FIBER REINFORCEMENTS

A. Carbon Fibers

The advantages are increase in transverse and impact strength of PMMA, increased fatigue resistance when treated with silane coupling agent.[13]

Yazdanie (1985) investigated the effect of silane treated carbon fibers on the transverse strength of acrylic resin. The study concluded that carbon fibers increase the strength and strands are more efficient than woven mats.

B. Kevlar (Synthetic Aramid Fiber)

The advantages are increase in modulus of elasticity, increase in fracture resistance.

Berrong *et al*., (1990) conducted a study to evaluate the effect of fiber reinforcement on fracture resistance of PMMA. They concluded that the use of 2% by weight Kevlar reinforcement fibers increases the fracture resistance of acrylic resin. Its disadvantages were poor esthetics because of yellow color, difficulty in polishing.[14]

C. Glass fiber reinforcement.[15-16]
D. Highly drawn linear polyethylene fibers.
E. E-fibers surface which had been treated with precured silane was powder-coated with spherical PMMA particles.
F. Polyester fiber (PE).
G. Organophilic montmorillonite (Claytone).
H. Methacrylated polyhedralsilsesquioxanes (POSS).
I. Silica-glass fiber reinforced polymeric materials.
J. Ultra high modulus polyethylene fibers.

CONCLUSION

The review of different denture 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 more than 70 years ago seem to be undergoing constant change and are the materials of choice.

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