Denture base materials: From past to future

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Abstract

There is evidence that Dentistry was practised as far back as 3000 B.C. in Egypt. Dentures are believed to have surfaced as a mode of treatment for replacing missing teeth around 700 B.C. Thereafter, a process began towards improvement in the quality of materials used for fabricating dentures, as the patients demanded better aesthetics, function and comfort. This review tracks the history of materials used as a denture base to the present stage and points towards the areas of research and development in the future.

Keywords

Denture base material, Vulcanite, Acrylic resin, Methyl methacrylate, Flexible denture, Fibre-reinforced resin

Dentistry as a speciality is believed to have begun about 3000 BC. Egypt was the medical centre of ancient world. The first dental prosthesis was believed to have been constructed in Egypt about 2500 BC. Skilfully designed dentures were made as early as 700 BC. During medieval times, dentures were seldom considered as a treatment option. They were hand carved and tied in place with silk threads and had to be removed before eating.

WOOD:

For years, dentures were designed from wood because it was readily available, relatively inexpensive and could be carved to desired shape. However, it warped and cracked in moisture, lacked aesthetics and got degraded in the oral environment.

BONE:

Dentures made from bone became very popular due to its availability, reasonable cost and carvability. It is reported that Fauchard fabricated dentures by measuring individual arches with a compass and cutting bone to fit the arches. It had better dimensional stability than wood, however, esthetic and hygienic concerns remained.

IVORY:

Ivory denture bases and prosthetic teeth were fashioned by carving this material to desired shape. These were relatively stable in the oral environment, offered esthetic and hygienic advantages compared to wood or bone. However, ivory was not readily available and was relatively expensive.

PORCELAIN:

Alexis Duchateau (1774) was the first to fabricate porcelain dentures. In 1788 AD, a French dentist, Nicholas Dubois de Chemant, made a baked-porcelain complete 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. Loomis (1854), Charles H Land (1890) and Alexander Gutowski (1962) experimented with different types of porcelain dentures.

GOLD:

In 1794 AD, John Greenwood began to swage gold bases for dentures. He also made dentures for George Washington. Usually 18 to 20 carat gold was alloyed with silver and teeth were riveted to it.

VULCANITE DENTURES:

Charles Goodyear, in 1839, discovered the process of dry-heat vulcanization of rubber by heating caoutchouc, sulphur and white lead together. In 1851, Goodyear used this technique to produce a highly cross-linked hard rubber named Vulcanite after the Roman god. The fit of these vulcanite bases allowed self retaining dentures, making earlier spring type dentures obsolete. These were the first functional, durable and affordable dentures, marking a great advancement in dental treatment. The main disadvantage of these denture bases was their dark red colour, which was difficult to pigment, and absorption of saliva making it unhygienic. Vulcanite dentures were very popular until the 1940s, until acrylic (pink plastic) denture bases replaced them.

TORTOISE SHELL:
CF Harrington (1850) introduced the first thermoplastic denture material, the tortoise shell base.

GUTTA PERCHA:
Edwin Truman (1851) used Gutta percha as a denture base but it was unstable.

CHEOPLASTIC:
Alfred A Blandy (1856) made dentures from a low fusing alloy of silver, bismuth and antimony but it was never accepted.

ALUMINIUM:
Dr. Bean (1867) invented the casting machine and did the first casting of a denture base in aluminium.

CELLULOID:
J. Smith Hyatt (1869) introduced celluloid that was later used as a denture base material because of its translucency and pink colour. However, this material did not gain much popularity because of distortion and discolouration.

BAKELITE:
Dr. Leo Bakeland (1909) introduced this phenol formaldehyde resin which was easily available but lacked colour quality.

STAINLESS STEEL and BASE METAL ALLOYS:
Ni-Cr and Co-Cr were obtained by E. Haynes (1907) but they gained popularity after 1937 because of their low density, low material cost, higher resistance to tarnish and corrosion and high modulus of elasticity. Allergy to Nickel and difficulty in adjustment posed a practical problem.

VINYL RESIN:
Mixtures of polymerized vinyl chloride and vinyl acetate were under experimentation during 1930 due to their pleasing colour but had difficult processing methods.

POLYMETHYL METHACRYLATE:
Rohm and Hass (1936) introduced PMMA in sheet form and Nemours (1937) in powder form. Dr. Walter Wright (1937) introduced Polymethyl methacrylate as a denture base material which became the major polymer to be used in the next ten years.
This material has been divided into two types based on the method of activation.

1) Heat-activated PMMA:
These are supplied in powder-liquid form. The powder contains Polymethyl methacrylate beads along with Benzoyl peroxide (Initiator), Dibutyl phthalate (plasticizer), pigments and opacifiers. The liquid contains Methyl methacrylate monomer with Hydroquinone (inhibitor), Glycol dimethacrylate (cross-linking agent) and plasticizers.
Currently, almost all denture materials are radiolucent and concerns exist about the difficulty of removing fragments of fractured dentures aspirated during accidents. Addition of Bismuth (10-15%) or uranyl salts provides adequate radiodensity, but at the cost of increased transverse deflection and water sorption.

Modifications
a) High-impact strength resin
These polymers are similar to heat-accelerated methyl methacrylate materials but are reinforced with butadiene-styrene rubber. The rubber particles are grafted to methyl methacrylate to bond to the acrylic matrix. These materials are supplied in powder-liquid form and are conventionally processed.

b) Rapid heat-polymerized resin
These are hybrid acrylics, with both chemical and heat-activated initiators, to allow rapid polymerization without the porosity that might be expected. These are polymerized in boiling water for 20 minutes immediately after being packed into a denture flask.

After bench cooling to room temperature, the denture is deflasked, trimmed and polished in the conventional manner.

Heat-activated PMMA can be processed by
nCompression technique
nInjection moulding technique

c) Microwave-activated PMMA:
Nishii (1968) first used microwave energy to polymerize denture base resin in a 400 watt microwave oven for 2.5minutes. This research was later carried on by Kimura et al (1983) and De Clerk.

Types:
a) Compression moulding technique
b) Injection moulding technique

Composition

Supplied in Powder liquid system. Special polycarbonate or fibre-reinforced plastic flasks (1985) are used instead of metallic flasks as microwaves will reflect from the surface.

Technique

Microwaves are a form of electromagnetic radiation produced by a generator called a magnetron, which can be used to generate heat inside the resin. Methylmethacrylate molecules are able to orient themselves in the electromagnetic field and at a frequency of 2450MHz, their direction changes nearly 5 billion times a second. Consequently, numerous intermolecular collisions occur causing rapid heating. As the heat required to break the benzoyl peroxide molecule into free radicals is created inside the resin, the temperature outside the flask remains cool. The polymerization heat is dispersed more efficiently and the polymerization is rapid with less risk of porosity. In addition, this technique eliminates the time needed to transfer the heat of the oven or the hot water, through the various structures, such as the flask, investment and stone cast to the resin itself. Microwaves act only on the monomer, which decreases in the same proportion as the polymerization degree increases. Therefore, the same amount of energy is absorbed by less and less monomer, making the molecules increasingly active. This self regulatory curing programme leads to complete polymerization of the resin.

The latest microwave-polymerized polymer with the injecton moulding system for denture construction claims to have the advantages of both the injection –processing and microwave-curing methods. The one-component paste form resin is packaged in a disposable plastic cartridge that elimintates mixing and direct handling. It is a polyurethane-based polymer and is biologically compatible.

Advantages: greatly reduced curing time (3 min.), shortened dough-forming time, minimal colour changes, less fracture of artificial teeth and resin bases and superior denture base adaptability, lower residual monomer ratio, most stable.

Disadvantages: Microwave polymerized acrylic resins exhibit less bond strength to the denture teeth. The occurrence of increased porosity is due to heat entrapment in the nonmetallic flasks used for the purpose. The plastic flasks and polycarbon bolts are relatively expensive and have a tendency to break down on exceeding packing pressure (1200psi) and after processing several dentures.

2) Chemically activated PMMA:

In1947, chemical activators were used to induce denture base polymerization at room temperature. These were also referred to as cold-curing, self-curing or autopolymerizing resins. Chemical activation is accomplished through the addition of a tertiary amine, such as dimethyl-para-toluidine, to the monomer, which upon mixing causes decomposition of benzoyl peroxide. This releases free radicals to initiate polymerization.

Advantage: Greater dimensional accuracy due to reduced polymerization shrinkage.

Disadvantages: Incomplete polymerization leads to greater amount of unreacted monomer in the denture base causing decreased transverse strength and is a potential tissue irritant. Water storage reduces the level of residual monomer. The colour stability is generally inferior.

Modifications:

a) Pour type (fluid resins)

The Austenal company (1955) introduced this technique. The principal difference is in the size of the polymer powder or beads. Small particle size results in a fluid mix. The mix is quickly poured into the mould and allowed to polymerize under pressure at 0.14MPa. Centrifugal casting may also be used to inject the slurry into the mould. These offered improved adaptation, dimensional stability, reduced cost and simple procedure but had low strength, higher solubility and high residual monomer levels.

VINYL ACRYLIC COPOLYMER (GEL TYPES):

Denture base plastics such as vinyl acrylic copolymer (1942) were supplied in gel form. These gels have the same components as the powder-liquid type, except that the liquid and powder have been mixed to form a gel and have been shaped into a thick sheet. Chemical accelerators cannot be used in a gel because the initiator, accelerator and monomer would be in intimate contact. Accuracy of proportioning and thoroughness of mixing are the advantages claimed for the gel types.

POLYSULPHONES:

Introduced in1981, processed by injection molding, they had very high impact strength.

LIGHT ACTIVATED DENTURE BASE RESINS: (1986)

Composition –

It consists of urethane dimethacrylate matrix with an acrylic copolymer, microfine silica fillers, and high molecular weight acrylic resin monomers, acrylic resin beads as organic fillers, a photoinitiator system and Camphoroquinone as initiator. Visible light is the activator.

Available as a single-component denture base resin as premixed sheets having a claylike consistency or rope forms and is packed in light-proof pouches to prevent inadvertent polymerization .

Technique - Opaque investing media prevents the passage of light, therefore light-activated resins cannot be flasked in a conventional manner. The denture base is moulded on an accurate cast while it is still pliable and is polymerized in a light chamber without teeth and is used as a base plate. The teeth are then processed to the base with additional material and the anatomy is sculptured while the material is still plastic. Photons from a light source activate the initiator to generate free radicals that, in turn, initiate the polymerization process. Initially, ultraviolet light was used, however, because of its effect on the retina and unpigmented oral tissues, limited penetration depth, and the loss in intensity of the ultraviolet light source over time, initiator systems activated by visible light were introduced. In the visible light-cured material, camphorquinone and an organic amine (e.g. dimethylaminoethyl methacrylate) generate free radicals when irradiated by light in the blue to violet region. Light with a wavelength of about 400-500nm is needed to trigger this reaction. Then the denture base is exposed to a high-intensity visible light source for an appropriate period. The denture is rotated on a table in the chamber to provide uniform exposure to the light source. Then the denture base is finished and polished in a conventional manner. An argon laser has also been used to polymerize composite resins and physical and mechanical properties were found to be improved.

Advantages – These resins display less porosity than chemically activated denture base resins, facilitate fabrication and final adjustment in mouth, are 25% lighter, free of methyl methacrylate, show decreased polymerization shrinkage and are non toxic.

Disadvantages –They cannot be flasked in a conventional manner, as opaque investing media prevents the passage of light. Depth of cure, shrinkage and appearance of long life free radicals are areas of concern. Factors such as light intensity, angle of illumination, and distance of resin from the light source can significantly affect the number of free radicals that are formed, thereby making this system technique sensitive.

COMMERCIALLY PURE TITANIUM:
It has the advantage of light-weight, strength and biocompatibility but requires an inert casting environment and casting defects can be a problem.

FLEXIBLE DENTURE BASE MATERIAL:
Polymerization shrinkage encountered in conventionally cured PMMA led to the development of a special injection moulding technique. Initially developed as a fluoropolymer (1962), acetal began to be used in 1971.The material used nowadays is nylon based plastic (Polyamide). Elastomeric resins can be added to resin polymer formulas to create greater flexibility and can be strengthened with glass fibres.

Unique features - The semi-crystalline nylon composition provides strength, flexibility, transparency, high impact resistance, colour stability, high creep resistance, high fatigue endurance, excellent wear characteristics, good solvent resistance, no porosity, no biological material build up or odours or stains, low water sorption and good dimensional stability, monomer and metal free and the microcrystalline structure is easy to finish and polish like acrylic.

Advantages - It is nearly unbreakable, pink coloured like the gums, can be built quite thin, and can form both the denture base and the clasps as well. The clasps are built to curl around the necks of the teeth and they are practically indistinguishable from the gums that normally surround the teeth. This type of partial denture is extremely stable and retentive, and the elasticity of the flexible plastic clasps keeps them that way indefinitely. It has superior esthetics, no metallic taste and is non allergic. Free movement is allowed by the overall flexibility and can, therefore, be referred to as “a built in stress breaker”. Long term health of tissues and teeth is maintained due to their gentle massaging action without adversely loading abutments.

Indications: Full dentures, Partial dentures, Bases and relines, in cases with bilateral inoperable undercuts when preprosthetic surgery is contraindicated.
Special applications: - For TMJ splints, for the patients allergic to acrylic monomers, as cosmetic veneers /gum veneers to mask gingival recession, in periodontally involved teeth, sensitive teeth, cancerous mouths, or other conditions in which the teeth are compromised, treatments involving high torus or cleft palate conditions, as Mouth guards in sports, Bruxism splints/Night guards, Bite splints, Space maintainer, Paediatric cases, Obturators, Speech therapy appliances and Orthodontic retainers.

The Flexible dentures in combination with Cast Partial framework–
A good alternative to the all flexible partial denture is one made with a combination cast metal framework with flexible dentures clasps. The clasps and the saddle are flexible and the rest of the components are in metal.

Advantages: This combination eliminates most of the difficulty of recurrent sore spots, since the framework resists movement and pressure from the clasps, while having the benefit of nearly invisible, gum coloured clasps. It also has the advantage of being tooth supported.

Disadvantages: Flexibility is not an advantage in complete dentures as the retentive peripheral seal can be broken in function. It is difficult to use where inter-ridge space is less as bulk of tooth is needed for mechanical retention.

Insertion: Denture is placed in very hot water (150 degrees F) for a minute prior to insertion and allowed to cool to tolerable temperature. This makes the partial as flexible as it would be at body temperature. Adjustment of clasps is done by heating in very hot water and bending it severely. Grinding is done as a last resort.

FIBER-REINFORCED DENTURE BASE RESINS:
To improve the physical and mechanical properties of acrylic resin, it was reinforced with
·EMBEDDED METAL FORMS
·FIBRES -- Fibres have been used in three forms, namely, continuous parallel, chopped and woven.

Carbon fibres

The use of Carbon fibres as denture base strengthners have been investigated by Larson et al and Sonit (1991) . Carbon fibres have been shown to improve flexural and impact strength, prevent fatigue fracture and increased fatigue resistance on treating with silane coupling agent(Yazdanie-1985). However, carbon fibres have an undesirable dark color.

Kevlar fibres (synthetic aramid fibres)

Aramid is a generic term for wholly aromatic fibres. These fibres are resistant to chemicals, are thermally stable, and have a high mechanical stability, melting point, and glass transitional temperature. They also have pleated structure that makes aramid weak as far as flexural, compression, and abrasion behaviour are concerned. This explains why aramid fibre-reinforced demonstrate a lower flexural strength than PMMA reinforced with glass fibre. Studies conducted by Berrong et al(1990) have shown to significantly increase the impact strength and the modulus of elasticity of the resin but they are also unesthetic and their use is limited to certain intraoral applications.

Glass fibres

Glass is an inorganic substance that has been cooled to a rigid condition without crystallization. Different types of glass fibres are produced commercially; these include E-glass, S-glass, R-glass, V-glass, and Cemfil. Of these, E-glass fibre, which has high alumina and low alkali and borosilicate, is claimed to be superior in flexural strength. Because the modulus of elasticity of glass fibres is very high, most of the stresses are received by them without deformation.

Polyethylene fibres

Have also been observed to increase the impact strength. Polyethylene fibres increase modulus of elasticity and flexural strength and they are almost invisible in denture base acrylic resins. Polyethylene fibres in woven form are more effective than carbon fibres in enhancing impact strength and flexural strength.

--- Polyester fiber

--- Organophilic montmorillonite.

--- Methacrylated polyhedralsilsesquioxanes.

--- Silica-glass fiber reinforced polymeric materials.

--- Nylon fibres --- are polyamide fibres and are based primarily on aliphatic chains. The chief advantage of nylon lies in its resistance to shock and repeated stressing. However, water absorption affects the mechanical properties of nylon. Nylon-reinforced bases display higher fracture resistance than PMMA.

Compared with conventional polymer materials, fibre-reinforced polymers are successful in their application primarily because of their high specific modulus and specific strength.

Alternative polymers, such as polyamide and polycarbonate have also been tested to overcome some of the mechanical deficiencies of PMMA. However, the tests have not resulted in the breakthrough of totally new denture base polymers.

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