A Review on Utilities, Modifications and Physiochemical properties of PMMA as a Denture Base Material.

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Abstract-*Dental practice continues to evolve in parallel with the development of new materials and new technologies. It is noted, however, that the materials used for the manufacture of removable prostheses do not seem to have similar innovations. Today, majority of complete denture bases manufactured are still made of acrylic resin, PMMA (poly methyl methacrylate), developed 70 years ago. Acrylic resins have remained anchored in our business because of their many qualities (ease of processing, physical, mechanical, aesthetic properties, cost, low toxicity, ease of use, etc.), but they also have various limitations. Once inserted into the oral cavity, the prosthesis is subjected to repeated mechanical, biological, and chemical stresses. In this review, we covered the status of Poly-methyl methacrylate (PMMA) as the denture base material. Dental practice, PMMA (poly methyl methacrylate), removable prostheses, acrylic resin, denture base materials.*

INTRODUCTION

Removable prostheses are also subject to numerous biological and chemical constraints linked to their intra-oral use. The oral cavity is composed of a bacterial flora, which participates in the proper functioning of the mouth by fighting against the various aggressors of the environment. In the absence of hygiene, this balance can be disturbed, which can lead to infection of the oral mucosa [1]. The accumulation of microbial plaque on the bases of dental prostheses is thus involved in inflammation of the mucous membranes and prosthetic stomatitis [1]. Likewise, hand-carried bacterial contamination is also a frequent problem, which implies impeccable hygiene of the prostheses is necessary.

In addition to bacterial problems, the removable prosthesis is subjected to chemical stress in the oral cavity. The oral environment undergoes many variations in pH levels over the course of a day which leads to deleterious conditions for the materials. Likewise, the porosity of dental restorative materials as well as tartar particles can act as a reservoir and prolong the duration of exposure. These exposures are detrimental to dental materials since the flexural strength and hardness of acrylic resins are influenced by our food intake [2]. Beyond mechanical and biological constraints, prostheses are also subject to aging and hygiene. Prostheses can thus become a source of infection when manual dexterity and visual acuity are compromised, especially in the elderly.

Ideally, the material utilized for prosthetic base should therefore have optical, mechanical, and chemical properties suitable for its prolonged use in the oral cavity and its extra-oral handling. It is in fact expected of the latter that it has biological tolerance towards the tissues, sufficient biomechanical resistance, and good adhesion, obtained by precision and high wettability.

1. DIFFERENT MATERIALS USED FOR REMOVABLE PROTHETIC BASES: -

1.1 Previously Used materials: -

Historically, the oldest removable prostheses found dated from the Etruscan period (8th-9th centuries BC). These are gold lamellae, which rest on the mesial and distal faces of adjacent teeth on which animal teeth are fixed using rivets. However, the first complete removable prostheses appeared only during 15th and 16th centuries.

They were made from the teeth of the deceased or animal teeth such as oxen and hippopotamus. In 1774, apothecary François Duchateau suggested the dentist Dubois De Chermont replace the teeth with porcelain in order to solve the problems of yellowing and foul odor [3].

One of the greatest advances in complete removable prosthesis was the discovery of vulcanized rubber by Charles Goodyear in 1840. This hardened rubber was called ebonite, subsequently vulcanite from 1855. It is a composite material based on gutta percha, vulcanized rubber, silica, and sulfur. Vulcanite will remain the reference material for the non-metallic removable prosthetic bases until the introduction of resinous materials. Resins, particularly acrylic-based resins (Polymethyl methacrylate PMMA), were developed by Kulzer in 1937 and replaced vulcanite because of their various qualities (ease of processing,

physical, mechanical, aesthetic properties, etc.). Other resinous materials based on polycarbonate or even nylon since have been developed.

1.2 Acrylic resin: -

 Polymethylmethacrylate (PMMA) is currently the most commonly used material for denture bases since its introduction in 1937 [4]. These resins must meet the specifications defined by the ADA and are controlled by the ISO 20795-1: 2013 standard which establishes the classification of polymers and copolymers (table 1).

Type 1: Thermo-polymerizable polymers	Polymerization temperature> 65 ° C
Type 2: Chemo-polymerizable polymers	Polymerization initiated by chemical means and not requiring a temperature> 65 ° C
Type 3: Thermoplastic materials	Heat-modulable polymers Curing by
Type 4: Light-curing materials	ultraviolet radiation and / or visible light
Type 5: Materials polymerizable by Thermal polymerization system with microwave	

Table 1: Classification and properties of dental base materials according to the ISO standard 20795-1 2013

 The American Dental Association (ADA) No. 12 for denture base polymers, includes tests on color stability, water absorption, water solubility, and cross deflection (Table 2). This specification carefully standardizes sample depth, temperature, atmospheric conditions, and strain rate to avoid any variations between the samples tested.

TYPE	Resistance to bending minimum (MPa)	Flexural modulus minimum (MPa)	Solubility maximum (mg / cm2)
Type 1, 3, 4, 5	65	2000	0.01
Type 2	60	1500	0.041

Table 2: ADA characteristics n ° 12

1.3 Composition: -

 In dentistry, the most widely used resin is Polymethyl Methacrylate. It is in the form of a powder/liquid mixture.

 The powder

The powder contains the methyl methacrylate polymer in the form of small spheres of a few hundredths or tenths of a millimeter. These spheres are obtained from the monomer heated and stirred in a non-polymerizable medium such as soap and water, or talc and gelatin.

We also find [5]:

1. A polymerization initiator which forms free radicals under the effect of heat or by chemical activation. The most widely used is Benzoyl Peroxide.

2. Pigments are incorporated into the spheres either during the initial polymerization, or by impregnation in a second step. In the latter case, the allergic reactions are more important.

3. Opacifiers such as zinc oxide (ZnO) or titanium dioxide (TiO2) reduce the transparency of polymethyl methacrylate in the pure state.

4. A plasticizer such as dibutyl phthalate accelerates the dissolution of the polymer into the monomer. The neutralization of the secondary bonds prevents the molecules from sliding against each other, which decreases the softening time. It is also possible to use a copolymer of polymethyl methacrylate of lower molecular weight, such as poly ethyl acrylate.

5. In some cases, red nylon threads stimulate the gingival capillaries.

6. Emulsion residues during the preparation of the polymer, such as talc and gelatin.

The liquid

1. The liquid essentially contains the methyl methacrylate monomer. It is a transparent liquid with a boiling point of 100.8 ° C [6].

2. In order to facilitate the conservation and storage of the monomer, the manufacturers add a stabilizer (0.003 to 0.1%) which prevents the activation of the polymerization by heat, oxygen, or light. It is generally hydroquinone or rarely, pyrogallol [5].

3. The liquid can also contain a crosslinking agent such as divinyl benzene or glycol di methacrylate molecules, which have two polymerizable bonds, allowing the constitution of a three-dimensional macromolecular network (annular or crosslinked polymer). This formation provides the advantages of high molecular weight resins over low molecular weight resins; that is, increased dimensional stability, increased strain temperature, and greater strength.

4. In the case of chemo polymerizable resins, a polymerization activator, dimethyl para-toluidine, is added, the action of which only occurs in contact with a catalyst (peroxide) contained in the powder [7].

2. POLYMERIZATION: -

Polymerization is a chemical reaction during which low molecular weight molecules (monomers) react with each other to form higher molecular weight molecules (polymers).

There are also two types of polymerization reaction: by condensation or by addition. All the resins currently used in dentistry come from addition polymerization [8]. This consists of the formation of covalent bonds between the monomers by the opening of one of their double bonds. It is a very rapid and exothermic reaction composed of three phases characterized by variations in temperature and volume within the resin.

2.1 Initiation: -

Also called the induction phase, this first step corresponds to the formation of free radicals by the opening of unsaturated double bonds present in the molecules of monomers (figure 1). Free radicals result from the dissociation of the initiator (benzoyl peroxide) under the influence of the activator (chemo polymerizable resins) or heat (60 ° C-73 ° C for thermo-polymerizable resins) [5].
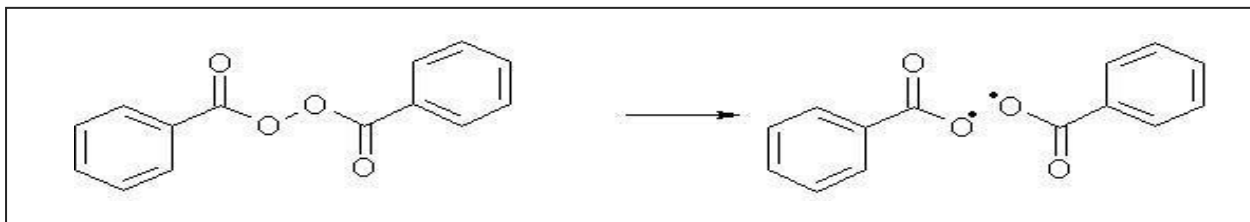

Figure 1: Activation of Benzoyl Peroxide

Once released, the free radicals bind to other free radicals from adjacent monomers and thus create a bond (Figure 2). During this first step, the resin undergoes expansion due to the temperature rise to 60 ° C. In practice, the walls of the muffle limit this expansion. This phase is endothermic and requires 16 to 29 kcals per mole of energy.
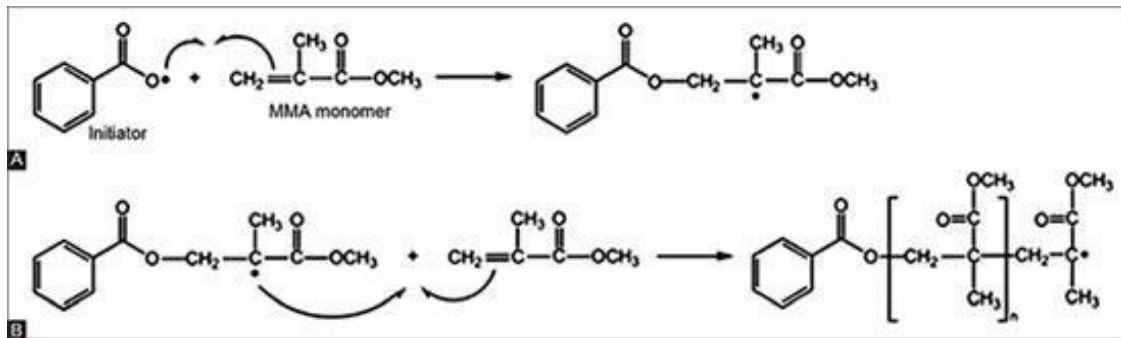
Figure 2: Reaction of Benzoyl Peroxide with MMA Monomer and Propagation

2.2 Spread: -

This is the exponential elongation phase of polymers. It is characterized by a thermal peak caused by the release of 5 K to 8 K Calories per mole per molecule during polymerization. It is therefore an exothermic reaction, rapid and sudden, the peak of which depends on the initial cooking temperature. The latter must be less than 100.8 ° C to avoid boiling of the monomer.

The multiplication of covalent bonds during this phase decreases the intermolecular distance and causes a theoretical contraction of 5.25% by volume or 1.71% linearly. In practice, this contraction is limited by the thermal expansion which continues and by the adhesion to the walls of the muffle [5].

These chain reactions are supposed to continue until the monomer is exhausted, but practically, the polymerization is never complete.

2.3 Cut: -

It occurs when two polymer chains interact to form a single, longer chain or become deactivated through the exchange of a hydrogen atom. This phase is characterized by a new contraction due to cooling and a return to room temperature. The average final contraction is 0.50% [5].

3. Acrylic resins "modified and the outlook for new materials": -

The acrylic resins constituting the removable prosthetic bases can be modified by the inclusion of macroscopic elements (metal wires in particular) in the acrylic resin base, by modifying the very structure of the material by the addition of fibers, polymers, or nanoparticles, or finally by surface treatment.

3.1 Inclusion of metallic wires

Historically, one of the most common strengthening techniques is the use of sub metals (cobalt-chromium or silver/copper/aluminum alloy) [9] into the prosthetic base. These metal additions can be considered in the form of wires, plates, or threads incorporated into the areas of the prosthesis subjected to the heaviest tensile stresses. This method therefore does not modify the structure of the resin itself.

The thickness and the position of the reinforcement in the resin thus modify the mechanical properties of the prosthetic base. According to [10], the optimum diameter for increasing resistance to transverse force is a circular wire of 1.3 mm in diameter. These wires would allow an 85% increase in the resistance of the base.

Semicircular steel wires would allow an average increase in flexural strength of 22 to 110%. By comparison, a braided metal plate, made of three individual metal wires braided together and flattened, affects the transverse strength of the base by 28%. The value was obtained by integrating the metal plate across the fracture line [10].

However, many attempts to reinforce the acrylic resin base in this way have failed because the stress concentration occurs around the embedded materials. Various approaches have therefore been used to improve the metal/acrylic bond, such as creating mechanical retention or lamination and use of adhesives/surface treatments. The mechanical retention of PMMA on the surface of a metal is caused by the penetration and locking of the resin into the macro-irregularities or micro-irregularities

of the metal. These irregularities can be obtained by processes such as grinding, sandblasting, and electrolytic or chemical etching. Making loops at the end of the wire can be used as macroscopic retention.

Mechanical retention can also be increased when the wires are sandblasted beforehand. The grain size of the sand (50 μm or 250 μm) does not seem to affect the strength. Finally, the bond between the metal reinforcements and the matrix can be chemically improved by surface treatments such as 4 Meta [11]. The other problem with its reinforced resins is the difficulty of repairing them in case of fracture due to outgoing wires.

4. MATERIAL PROPERTIES: -

4.1. Physicochemical properties of materials: -

I. Hardness

Hardness is a mechanical parameter that allows us to characterize a material. It can be defined as a measure of the resistance to localized plastic deformation induced by either mechanical indentation or abrasion. Hardness, therefore, indicates how easily the material is scratched or abraded. In the case of removable prostheses, it must be sufficient so that the prosthetic surface is not damaged during mechanical brushing, during handling or even during daily use of the prostheses in the oral cavity. Insufficient hardness compromises surface roughness and promotes plaque retention and pigmentation, potentially compromising the aesthetic appearance and longevity of the denture [12].

Materials	Hardness
Pressed resin	18 to 22 VHN
Injected resin	13.48±1.4 VHN
Chemo polymerizable resin	16 to 18 VHN
Photopolymerizable resin	30.59 ± 1.778 VHN
Polycarbonate	20 VHN
Nylon	7.45 ± 1.0 VHN
Pressed resin	18 to 22 VHN

Table 3: Comparison of acrylic, polycarbonate and nylon resin hardness

Based on (R. Ogolnik, B. Picard, I. Denry 1992; Yunus et al. 2005; Nadia A Badr, Amal M Ibrahim, Gehan F Mohamed 2008; Murthy and Murthy 2015)

II. Flexural strength

Bending can be defined as the deformation of an object which results in a curvature on either side of the applied force. The bending test is therefore used to measure the bending or curvature properties of a material. Sometimes called a "crossbar test", it involves placing a sample between two points or supports and throwing a load using a third point or two additional points, which are called the 3-point bending test and the 4-point bending test, respectively. It allows comparison of prosthetic base materials because it reflects the complex stresses applied to the prosthesis during chewing and provides an accurate indication of the stiffness of the material [13].

Base polymers in prostheses can fail clinically due to flexural fatigue. Flexural strength tests should therefore be used as a method to assess optimum polymerization. In fact, the greater the degree of polymerization, the greater the flexural strength. As bending properties may vary with sample depth, length of support spans, temperature, atmospheric conditions, and rate of strain, test procedures are carefully standardized to American specifications. Dental Association (ADA) No. 12 for basic denture polymers. According to these (equivalent ISO 1567, IS 6887), prosthetic base materials must have a flexural strength of at least 65 MPa (6.628 kg/mm2) to qualify as prosthetic resin [14].

Although the flexibility of a material is crucial for energy absorption (e.g. when the prosthesis falls), the same property raises the question of whether the prosthesis is rigid enough to distribute forces evenly across the body and dental arch. A removable prosthesis must therefore be a compromise between these two mechanical properties. Therefore, a lower flexural modulus (increased flexibility) is often a clinical disadvantage. According to ISO 20795-1, the flexural modulus of the treated modulus must not be less than 2 GPa [15]. The flexural modulus reflects the stiffness of the material and the stress distribution within a sample [16].

Materials	Flexural strength (MPA)
Pressed resin	88.9 ± 15.1
Injected resin	63.7
Chemo polymerizable resin	69.79
Photopolymerizable resin	122.6± 13.7
Polycarbonate	105 ± 14.6
Nylon	78.3
Nylon	78.3

Table 4: Comparison of flexural strength between different acrylic resins, polycarbonate, and nylon

Based on (Ali et al. 2008; Nadia A Badr, Amal M Ibrahim, Gehan F Mohamed 2008; Mumcu et al. 2011; Ucar et al. 2012; Hashem et al. 2014).

III. Dimensional stability

Dimensional stability is a key feature for integration biomechanics of a removable prosthesis. It improves masticatory efficiency, increases patient comfort, and prevents injuries to the osteomucosal support tissues. The dimensional variations result from the handling of the resins during the polymerization step. They depend not only on the material used but also on more technical parameters such as the polymerization shrinkage or the stresses generated by the cooling of the resin, or even the biological and chemical stresses applied at the level of the prosthesis, such as the treatment procedures/cleaning of prostheses, physiological (pH, diet, etc.) and anatomical (bone resorption) conditions of the oral cavity [17], [18].

Experimental results have shown that, PMMA resins are very sensitive to these dimensional variations. However, the injected techniques make it possible to limit them [4] [19]. In fact, injection molding allows compensation for the polymerization shrinkage due to the pressure exerted during the injection of the acrylic resin. This also seems valid for polycarbonate resins, which exhibit interesting dimensional stability by combining the dimensional precision provided by the injection process without undergoing polymerization shrinkage associated with PMMA from thermopolymerisable resins [19]. Finally, the resins polymerized by microwaves would make it possible to obtain a better adaptation to the bearing surface than the prostheses obtained by the technique of resin in a water bath [20] [16].

IV. Surface condition

Porosities can compromise the physical, aesthetic, and biological properties of prostheses. A rougher surface can indeed cause patient discomfort, discoloration of the prosthesis, and contribute to microbial and biofilm formation, it can also result in high internal stresses and vulnerability to deformation and warping of the prosthetic base. Many technical factors can be the cause, such as trapping air during mixing, presence of residual monomers, monomer contraction during polymerization, monomer vaporization associated with exothermic reaction, insufficient monomer mixing, and polymer and initiator concentration [21] [23]. There are several methods in place to measure the porosity of cured acrylic resin. Microscopic observation remains the standard method, but other techniques, such as measuring the weight before and after immersion in water, volume and density, can calculate water and air trapped in the pores. Mercury porosimeter is also a routine porosity measurement method [22].

There are big differences between the materials, Water bath thermopolymerisable resins have a porosity similar to microwave thermopolymerisable resins [23]. Chemo polymerizable resins have greater porosity due to the air dissolved in the monomer, which is insoluble in the polymer at room temperature [5]. Nylon-based resins have a clinically higher porosity. Finally, if we compare the roughness of the surface of polyamide resins with PMMA resins, we see that the polyamide samples have a rougher surface than PMMA, both before and after the polishing process [24].

4.1.2 Biological properties

These relate to allergic and toxic reactions related to materials.

I. Hypersensitivity reactions

Allergic tests performed on the skin have shown that acrylic bases can be responsible for allergic reactions. Contact allergy observed in denture wearers is the result of a delayed hypersensitivity reaction. Most common indicators of which are pain associated with a burning sensation in the palate, tongue, oral mucosa, and/or oropharynx. In the event of an immediate or

delayed reaction, patch tests, blood tests, or specific allergen IgE tests may be performed [25]. Constituents such as dyes (metal oxides and organic dyes), plasticizers, pyrogallol (antioxidant) and amines, in the case of chemo polymerizable resins (activator), can be the cause of irritation or allergies [7].

Photopolymerizable resins have been developed to limit allergic contact reactions (type IV), particularly for patients sensitive to methyl methacrylate. UDMA materials are less allergenic than other acrylates.

II. Toxic reactions

When preparing the resins, care is also needed for the laboratory technicians. During the handling of acrylic resins, vaporization of the MMA monomer occurs, which may cause irritation of lung tissue and affect the central nervous system. Methyl methacrylate monomers can also penetrate the skin and cause irritation and direct neurotoxic effects. It is therefore recommended that the resin be handled in a well-ventilated room with gloves.

In the oral cavity, the presence of saliva in the oral cavity provides an essential defensive barrier by diluting harmful antigens before their penetration into the oral mucosa. The effect of penetrated irritants is also reduced due to the high vascularity of the oral mucosa [25]. The polymerization of resins is based on an addition reaction which involves the activation of an initiator. The polymerization reaction results in the conversion of MMA to PMMA during which the monomer molecules are converted into polymers. However, this polymerization reaction of acrylic resins is never complete. There is a variable number of free monomers, called residuals, which have not reacted during the polymerization. These can then spread in saliva, causing cytotoxic effects on the oral cavity. The greater the quantity of residual monomer, the more deleterious the effect [25]. The amount of residual monomer depends on the polymerization method and the powder/liquid ratio [26] [27]. Resins prepared with a high proportion of polymer (5: 3) exhibit significantly lower levels of residual monomer than those prepared with a lower ratio (4: 3) [28]. However, it is important to note that changes in powder/liquid ratios can result in an acrylic resin mixture that is too stiff or too fluid for clinical use. It is therefore important to follow the instructions for use.

The polymerization temperature is also an essential parameter for the cytotoxic effects. When the polymerization time is prolonged, the amount of unreacted monomer is significantly reduced and, therefore, the chances of cytotoxic effects are reduced. To obtain an optimal conversion of the monomer, it is recommended to incubate the newly polymerized prostheses for 7 hours in water at 70 ° C, followed by an incubation of 1 hour in water at 100 ° C [25]. Automated resin injection systems offer programs ensuring varying degrees of polymerization (Ivo base injector, Ivoclar Vivadent), and could vary the degree of residual monomer on the surface of the polymerized bases. It is also recommended that once polymerized dental bases be stored in water for 1 to 2 days before being delivered to patients to allow residual monomers to propagate out of the prosthesis and decrease allergic reactions.

Chemo polymerizable acrylic resins release higher amounts of residual monomer than thermo-polymerizable resins [7] [27] [25]. A greater quantity of methyl methacrylate is indeed detected in the saliva of individuals who have a prosthesis with a chemo-polymerizable base [27]. The risks of chemo toxic reactions due to residual monomers are therefore higher.

UDMA resin bases are non-toxic and unpolymerized monomers have lower toxicity [13]. A 20-minute microwave polymerization also exhibits a reduced amount of residual monomer compared to resins which undergo other processing processes.

5. Addition of fibers to improve PMMA properties: -

Several types of fibers, such as carbon fibers, glass fibers, and carbon fibers polyethylene, are added to resinous mixtures. However, the ability of the fibers to strengthen the base of the prosthesis is dependent on various individual properties of the fibers and resins, their impregnation, adhesion, volume in the matrix, and orientation and location in the prosthesis.

5.1 Nylon fibers

A solution to improve the mechanical properties of acrylic resins would consist of adding small-diameter nylon fibers (10-15mm) to the PMMA polymer mixture. The main advantage of nylon is its resistance to impact and repeated stress. However, water absorption affects its mechanical properties. The bases of acrylic resin reinforced by the addition of nylon fibers have a higher breaking strength than those of PMMA.

There are currently no commercially available prepreg nylon fibers to improve adhesion with PMMA. To ensure proper bonding of nylon fibers with acrylic resin, it is advisable to moisten them with methyl methacrylate monomer for 10 minutes [29].

Nylon fibers can also be used to mimic blood capillaries. These do not have mechanical objectives and have a smaller diameter (8-10mm). Nylon fibers therefore make it possible to improve the mechanical properties, despite the fact that their fiber/acrylic bond needs to be improved.

5.2 Carbon fibers

The use of carbon fibers is supposed to improve the strength of prosthesis bases as reported by Larson et al in1991, Carbon fibers are produced by different companies, such as Courtaulds (Coventry, UK) [30]. The bulk of carbon fibers are created by heating poly-acrylonitrile to 200 ° C-250 ° C followed by heating in an inert atmosphere to 1200 ° C in order to remove hydrogen, nitrogen, and oxygen, and leaving only chains of carbon atoms and carbon fibers [9]. These fibers exist in different forms, such as strand form, woven mat form, layered, random, longitudinal, and perpendicular to the applied force. The addition of carbon fibers allows a significant improvement in impact resistance and modulus of elasticity of the reinforced acrylic resin base with woven carbon fibers [31]. The strand fiber shape would have a higher transverse force resistance than the mat-like fiber. Longitudinally oriented fibers would also increase flexural strength more than randomly arranged fibers. The fibers placed perpendicular to the direction of the stress would finally constitute the most favorable combination for bending resistance and fatigue.

While there are limited studies on the biological characteristics of resinous materials reinforced with carbon fibers, the cytotoxicity of carbon fibers is considered to be a problem with a risk of skin irritation. Their use is relatively restricted because of their potential toxicity, but also because of their handling, the difficulty of polishing and their color [9]. It is, for example, necessary to use a silane coupling agent to provide good adhesion between the fibers and the PMMA resin.

5.3 Aramid fibers

The trade name for aramid fiber is Kevlar. These fibers are produced by various companies, such as DuPont (Wilmington, Delaware) [32]. Kevlar fibers are popular because they have interesting mechanical properties from a mechanical point of view. Acrylic resin bases reinforced with a content of Aramid Fibers up to 2% and with unidirectional orientation show greater resistance to impact and fatigue [9]. In addition, acrylic resins reinforced by the addition of aramid fibers are biocompatible and show no signs of toxicity [31].

However, these fibers are not widely used due to their yellow tint and rough resin surface, making them difficult to polish, and poor adhesion between fibers and acrylic resin [9].

5.4 Polyethylene fibers

The addition of ultra-high molecular weight Polyethylene fibers to blends of PMMA polymer seems particularly interesting for reinforcing prosthetic bases in acrylic resin since these fibers have high ductility, neutral color, low density and excellent biocompatibility. They come in mono filament or can be woven. These fibers are marketed by various companies for direct addition, such as Lotus Polytwist (India), Stealth SI Concrete System (USA) [33]. The adhesion between the fibers and the PMMA resin can be promoted by an electric plasma treatment, which strips the surface of the fibers in which the resin is impregnated and creates a mechanical bond [9].

The concentration, orientation, and length of the fibers strongly influence the mechanical properties of polyethylene in PMMA reinforced resins. Fiber concentration of less than 3% and treated with electric plasma significantly improves resistance. In addition, it has also been observed that concentrations as low as 1% can significantly improve impact resistance. The bases reinforced by the inclusion of polyethylene fiber would thus have impact resistance and a significantly higher modulus of elasticity than conventionally polymerized PMMA resins [31]. However, a concentration greater than 3% of these fibers makes the mixture of PMMA polymer unworkable [31].

Finally, the etching process, preparation and positioning of the fibers make their use impractical for the laboratory.

5.5 Fiberglass

The inherent disadvantages of carbon and aramid fibers, such as difficulty in polishing, unsightly appearance, and complex surface treatments of polyethylene, have prompted researchers to develop new fibers such as glass fibers. There are different shapes: short stalk, loose stick or even continuous, like a woven leaf. These fibers are sold by various companies, such as Saint Gobain Vetrotex International (Chambéry, France) or Ahlstrom-Munksjö (Karhula, Finland) [32].

These fibers are characterized by an excellent aesthetic appearance and improved mechanical properties [34]. While they are not very resistant to impact forces, their strength can still be improved by using many unidirectional glass fibers or by using woven glass fibers. Short fiberglass reinforcement rods provide interesting reinforcement and are the easiest to use in the press technique [35]. Continuous fibers also provide high strength but are more difficult to set up and it is difficult to orient them during the manufacturing process [9]. In fact, an heterogeneous distribution of the fibers can be caused during the pressing, which causes an uneven lateral spread of the fibers in the polymer matrix.

The mechanical properties of these reinforced resins depend on the strength of adhesion between the glass fibers and the matrix; a silane coupling agent is therefore applied to the fibers before their positioning. A silane preparation thus makes it possible to obtain a transverse strength and a higher tensile strength than resins with untreated glass fibers [35].

The resistance imparted by the glass fibers also depends on their position and their concentration. The impact resistance increases significantly when the fibers are placed parallel to the longitudinal axis of the sample and perpendicular to the direction of the impact forces [34]. Similarly, the amount of reinforcing fibers influences flexural strength and impact resistance.Finally, the most favorable fiber content would be equal to 5% [36] and the incorporation of glass is limited to 20% due to the deleterious effects on the properties of the pulp above 5% [11]. Research is needed to determine if fiberglass is carcinogenic, attracts more plaque, or increases gum disease. However, reinforced acrylic resins are more cytotoxic than conventional acrylic resins .

5.6 Jute fibers

There is limited data on this material, but some authors suggest strengthening the prosthetic bases by adding chopped jute fibers to improve flexion [9]. However, as no significant improvement in flexural properties was observed, the authors suggested further studies on the surface and appearance of the jute fiber be used. *The following table summarizes the characteristics of these fibers:*

	Nylon fiber	Carbon fiber	Aramid fiber	Polyethylene fiber	Fiberglass
Benefits	Improved resistance to repeated shocks and stresses	Increased resistance to shocks and module elasticity	Improved impact resistance	Improved mechanical properties	- Improvement of mechanical properties
	- Superior breaking strength		- Biocompatibility	- Neutral color	- Aesthetics
				- Low density	
				- Biocompatible	
Disadvantages	- Poor adhesion e fiber / resin	- Toxicity potential	- Yellow tint	- Process of engraving, preparation, positioning of difficult fibers	- Requires a better fiber / resin bond
		- Handling and polishing	- Rough surface		- Plate
		- Color	- Difficulty polishing		- Increased cytotoxicity
			- Poor adhesion fiber / resin		
			- Difficulty polishing		

Table5: Advantages and disadvantages of the different fibers

6. Conclusion: -

Polymethyl methacrylate is the most common material used for prosthesis bases. Despite its risks of fracture, imprecision, distortion, and dimensional variation, it meets the clinical requirements of a removable prosthesis. Likewise, resins polymerizable by microwaves are easier to handle and allow a significant saving of time (3 minutes against 9 hours!), as well as better adaptation and sensitivity to residual monomers, but their flexural modulus is less important. Photopolymerizable resins are characterized by an improvement in physical (flexural modulus and hardness) and aesthetic properties, whereas chemo polymerizable resins are characterized with limited utility. Their physical (hardness, flexion), aesthetic and biological (porosity, allergy) properties are less good than those of conventional resins. Finally, nylon and polycarbonate resins, developed to reduce sensitivity reactions to residual monomers, do not exhibit significant mechanical improvement.

The ideal resin would therefore be a mixture of ease of use and dimensional stability of injected PMMA resins, the saving of time and the sensitivity to monomers of microwave resins, physical and aesthetic properties of photopolymerizable resins.

Despite the improvement in flexural strength, the incorporation of metal wires generates some drawbacks, such as stresses in the wires, insufficient metal/acrylic bond, repair difficulties and a decrease in aesthetics.

Photopolymerizable resins have an average flexural strength value which is significantly higher than polycarbonate resins (Table 4), which are themselves superior to heat-polymerized resins [16]. All of these resins meet the criteria set by "Revised American Dental Association Specification No. 12."

References: -

1. AL-BAKRI I, HARTY D, AL-OMARI W, SWAIN M, CHRZANOWSKI W, ELLAKWA Surface characteristics and microbial adherence ability of modified polymethylmethacrylate with fluoridated glass fillers. Aust Dent J. 1 2014; 59 (4): 482-9.

2. RAJAEE N, VOJDANI M, SADAF, the effect of food stimulating agents on the flexural strength and surface hardness of denture base acrylic resins.2014; 13 (4): 1041-7.

3. LEFEBURE C.A History of Dental Art. Toulouse: Privat; 2001.

4. GHARECHAHI J, ASADZADEH N, SHAHABIAN F, GHARECHAHI M. Dimensional Changes of Acrylic Resin Denture Bases: Conventional Versus Injection-Molding Technique. J Dent Tehran, Iran. July 2014; 11 (4): 398-405.

5. OGOLNIK R, PICARD B, DENRY I. Methacrylic resins. Dental biomaterials notebook: Organic materials. Masson; 1992. p. 30-46.

6. SKINNER EW, PHILLIPS RW. Dental material science. 6th ed. Paris: Prelate; 1971

7. NALLY JN. Dental materials and alloys: composition, applications, and techniques. Paris: Prelate; 1964.

8. DESAUTELS, O'BRIEN, RYGE. Acrylic polymers and BIS-GMA. Dental materials: precise and selection guide. 1982, p. 92-8.

9. RAMA KRISHNA ALLA SS. Influence of Fiber Reinforcement on the Properties of Denture Base Resins. 2013; 4 (1): 91-7

10. VALLITTU PK. A Review of Methods Used to Reinforce Polymethyl Methacrylate Resin. Sep 1, 1995; 4 (3): 183-7.

11. JAGGER DC, HARRISON A, JANDT KD. The reinforcement of dentures, March 1999; 26 (3): 185-94.

12. FARINA AP, CECCHIN D, SOARES RG, BOTELHO AL, TAKAHASHI JMFK, MAZZETTO MO, et al. Evaluation of Vickers hardness of different types of acrylic denture base resins with and without glass fiber reinforcement. Gerontology. 2012; 29 (2): e155-60.

13. HASHEMM, ALSALEEM A comparative study of the mechanical properties of light-cure and conventional denture base resins. Oral Health Dent Manag. June 2014; 13 (2): 311-5.

14. MURTHY SS, MURTHY GS. Argon Ion Laser Polymerized Acrylic Resin: A Comparative Analysis of Mechanical Properties of Laser Cured, Light Cured, and Heat Cured Denture Base Resins. J Int Oral Health JIOH. June 2015; 7 (6): 28-34.

15 UCAR Y, AKOVA T, AYSAN I. Mechanical Properties of Polyamide versus Different PMMA Denture Base Materials: Polyamide as a Denture Base Material. April 2012; 21 (3): 173-6

16. NADIA A BADR, AMAL M IBRAHIM, GEHAN F MOHAMED. The effect of the curing mode on the clinical performance and properties of acrylic resin overdenture bases. Cairo Dent J. May 2008; 2 (24): 259-71.

17. CONSANI RLX, DOMITTI SS, RIZATTI BARBOSA CM, CONSANI S. Effect of commercial acrylic resins on dimensional accuracy of the maxillary denture base. Braz Dent J. 2002; 13 (1): 57-60.

18 ARAFA KAO. The Effect of Different Denture Base Materials and Changed Mouth Temperature on Dimensional Stability of Complete Dentures. Int J Dent. 2016 (4): 1-5

19. PARVIZI A, LINDQUIST T, SCHEINDER R, WILLIAMSON D, BOYER D, DAWSON DV. Comparison of the dimensional accuracy of injection-molded denture base materials to that of conventional pressure-pack acrylic resin. J Prosthodont Off J Am Coll Prosthodont. June 2004; 13 (2): 83-9.

20. KIMURA H, TERAOKA F, OHNISHI H, SAITO T, YATO M. Applications of microwave for dental technique (part 1). Dough-forming and curing of acrylic resins. J Osaka Univ Dent Sch. Dec 1983; 23:43-9.

21. JEROLIMOV V, BROOKS SC, HUGGETT R, BATES JF. Rapid curing of acrylic denture-base materials. Dent Mater. January 1, 1989; 5 (1): 18-22.

22. YANNIKAKIS S, ZISSIS A, POLYZOIS G, ANDREOPOULOS A. Evaluation of porosity in microwave-processed acrylic resin using a photographic method. J Prosthetic Dent. June 2002; 87 (6): 613-9.

23. SINGH S, PALASKAR JN, MITTAL S. Comparative evaluation of surface porosities in conventional heat polymerized acrylic resin cured by water bath and microwave energy with microwavable acrylic resin cured by microwave energy. Clin Dent. April 2013; 4 (2): 147-51.

24. ABUZAR MA, BELLUR S, DUONG N, KIM BB, LU P, PALFREYMAN N et al. Evaluating the surface roughness of a polyamide denture base material in comparison with poly (methyl methacrylate).2010; 52 (4): 577-81.

25. RASID H, SHEIKH Z, VOHRA F. Allergic effects of the residual monomer used in denture base acrylic resin. Eur J Dent. December 2015; 9 (4): 614-9.

26. KEDJARUNE U, CHAROENWORALUK N, KOONTONGKAEW S. Release of methyl methacrylate from heat- cured and auto polymerized resins: cytotoxicity testing related to residual monomer. Dent J. March 1999; 44 (1): 25-30.

27. GOIATO MC, FREITAS E? DOS SANTOS D, DE MEDEIROS R, SONEGO M. Acrylic Resin Cytotoxicity for Denture Base-Literature Review. Adv Clin Exp Med Off Organ Wroclaw Med Univ. August 2015; 24 (4): 679-86.

28. JORGE JH, GIAMPAOLO ET, MACHADO AL, VERGANI CE. Cytotoxicity of denture base acrylic resins: a literature review. J Prosthetic Dent. August 2003; 90 (2): 190-3.

29. LADHA K, SHAH D. An In-Vitro Evaluation of the Flexural Strength of Heat-Polymerized Poly (Methyl Methacrylate) Denture Resin Reinforced with Fibers. J Indian Prosthodont Soc. December 2011; 11 (4): 215- 20.

30. VALLITTU PK, LASSILA VP, LAPPALAINEN. Acrylic resin-fiber composite part I: The effect of fiber concentration on fracture resistance. J Prosthet Dent. June 1, 1994; 71 (6): 607- 12.

31. UZUN G, HERSEK N, TINCER T. Effect of Five Woven Fiber Reinforcements on the Impact and Transverse Strength of a Denture Base Resin. J Prosthet Dent. 1999; 81 (5): 616- 20.

32. JOHN J, GANGADHAR SA, SHAH I. Flexural strength of heat-polymerized polymethyl methacrylate denture resin reinforced with glass, aramid, or nylon fibers. J Prosthet Dent. October 2001; 86 (4): 424- 7.

33. MOWADE TK, DANGE SP, THAKRE MB, KAMBLE VD. Effect of fiber reinforcement on impact strength of heat polymerized polymethyl methacrylate denture base resin: in vitro study and SEM analysis. J Adv Prosthodont. February 2012; 4 (1): 30- 6.

34. GOGUTA L, MARSAVINA L, BRATU D, TOPALA F. Impact strength of acrylic heat curing denture base resin reinforced with E-Glass Fibers. Temporomandibular Jt Disord. 2006; 56 (1): 88- 91.

35. VOJDANI M, KHALEDI A. Transverse Strength of Reinforced Denture Base Resin with Metal Wire and E-Glass Fibers. J Dent Tehran Univ Med Sci. 2006; 3 (4): 159- 66.

36. UNALAN F, DIKBAS I, GURBUZ O. Transverse strength of polymethylmethacrylate reinforced with different forms and concentrations of EGlass fibers. OHDMBSC. 2010; 9 (3): 144- 7.