INTRODUCTION

Heat-polymerizable polymethylmethacrylate (PMMA), has been the material of choice for the construction of denture bases for numerous reasons. Its low density, low cost, ease of manipulation and insolubility in the oral cavity are factors encouraging its use. (1) However, it is associated with some significant clinical limitations. Among these limitations are its low flexural strength, low fracture toughness, low impact strength and adherence to candida albicans which is the first step for development of denture stomatitis.(2,3) Fractures in acrylic dentures result from impact or bending forces. Impact forces typically are created during accidental fall. Bending forces are developed mainly during mastication because of poor adaptation of the denture to the underlying mucosa, improper occlusion, and morphology of the palate, excessive masticatory forces, or denture deformation during use. These bending forces in long-term can contribute to material fatigue. (4,5)

Several approaches had been pursued to elevate impact strength, flexural strength as well as fatigue strength to avoid recurrent fractures; including metal strengthening or reinforcing fibers, but the results of those attempts were limited. (6)

Several factors can contribute to the proliferation of candida albicans growth. Among these factors, surface roughness of prosthesis,(7) poor oral hygiene, local trauma, tissue integrity loss and systemic factors as malnutrition, diabetes mellitus, human immunodeficiency, viral infection and xerostomia.[8,9] Candida albicans has been shown to be an effective pathogen causing infection in the oral cavity and to be able to colonize acrylic materials.[8-10] Sodium hypochlorite with white vinegar for a cleaning routine may be instituted to prevent and remove accumulation of micro-organisms and to remove mucin, food remains, calculus and stains.[11]

An acrylic resin that can prevent adhesion of micro-organisms is currently unavailable. However, a study was conducted for the use of silver nanoparticles in polymethylmethacrylate material in an attempt to kill all pathogenic micro-organisms. [12]

Silver nanoparticles have been considered for research due to their antimicrobial effect in different biomedical applications. [13] Also, it has been used for modifying commercial acrylic resins for denture bases. Silver nanoparticles are also reported to be nontoxic to humans and very effective against bacteria, viruses and other eukaryotic micro-organisms at very low concentrations and without side effects. [14]

Although the literature reported various studies related to silver nanoparticles with antimicrobial applications in the medical field,[13] fewer studies concerning the application of silver nanoparticles in the dental field have been published.[15,16]

Thus, more investigations are needed to assess the effect of adding silver nanoparticles to acrylic resin denture base material mechanically as well as physically.

REVIEW OF LITERATURE

1. DENTURE BASE MATERIAL

The ideal denture base material should possess several characteristics including biocompatibility, good esthetics, radiopacity, ease of repair. In addition, the denture base material should possess adequate physical and mechanical properties. [1] It must be strong enough to allow the prosthesis to withstand functional and parafunctional masticatory forces.

Many different materials have been used for denture bases. Polymethylmethacrylate has become the most commonly used denture base material since the early 1940s. It is composed of prepolymerized polymethylmethacrylate powder particles mixed with the methylmethacrylate monomer, together with a cross-linking agent such as ethylene glycol dimethacrylate (EGDMA).[19,20] During the mixing and doughing periods, they penetrates the polymer particles giving rise to multiphase polymer system.[21,22] The properties that contributed most to the success of this material were excellent appearance, ease of processing, ease of repair and low cost.[23,24] They can reproduce surface details accurately and can be easily repaired. Although the properties of these materials are not ideal altogether, the desirable features mentioned above account for their popularity. [2-5] However, it has some limitations. With the use of polymethylmethacrylate as a denture base material, disadvantages such as relatively poor mechanical properties and the potential to elicit irritation, inflammation and allergic reaction in the oral mucosa. This was due to the released residual methyl methacrylate. It is considered as a principal factor affecting the biocompatibility and cytotoxic potential of acrylic resin denture bases.

Several investigations revealed regressive changes occurring in cell cultures with medium containing methyl methacrylate. These cultures showed signs of protoplasmic degeneration. [25-26] It was also proved that the reaction between methylmethacrylate and oxygen gave rise to further methylmethacrylate, methyl pyruvate and formaldehyde. Those products were also proved to be toxic compounds to the oral tissues. [20, 28, 29]

Polymethylmethacrylate denture bases are also characterized by some limitations concerning their mechanical properties. Certain studies estimated that a person bites on an average of 500,000 per year. [30] This may cause fracture of acrylic resin while service in mouth. Such fracture is known as flexural fatigue failure. It occurs most commonly at the midline of the maxillary than the mandibular dentures, as a result of acrylic flexural during the function. Midline fracture represented 29% of denture repairs carried out. Of these midline fractures, 68% were seen in upper dentures and 28% were seen in lower dentures.[36] Flexural fatigue failure is considered as one of the consequences of alveolar bone resorption, resulting in instability of the denture.[31]

The fracture mechanics approach is considered a more reliable indicator of the performance of brittle materials. Fracture toughness is the ability of a material to resists crack propagation and may more accurately determine the likelihood of fracture of polymethylmethacrylate in clinical practice. [32] Fractures in an acrylic denture base are a common clinical problem. Fatigue failure does not require strong biting forces as relatively small stresses caused by mastication over a period of time can eventually lead to the formation of a small crack, which propagates through the denture and results in a fracture. The maximal biting forces of a patient can reach up to 700 N, but these values are reduced (100–150 N) with the removal of teeth. Denture fractures are essentially due to stress concentration and increased flexing. [34] Denture fracture is generally related to faulty design, fabrication, and material choice. Zappini et al., compared the impact test results of seven heat-polymerised denture base resins with the results from fracture toughness tests and showed that impact testing is influenced by loading conditions and specimen geometry. Fracture toughness tests may be more suitable than impact strength measurements for demonstrating the effects of resin modifications.[35, 36]

Dentures can be made more resistant to fatigue failure by using few precautions. First, heat- polymerized resin is indicated as it is of higher strength and more resistant to such type of failure than auto- polymerized resins. [37] Second, fine polymer beads were proved to increase the fatigue strength several times. Finally, stress concentrators should be avoided as deep notches and prominent rugae patterns.[38] Any foreign particles act as stress concentrators, therefore acrylic resins should be fabricated in a relatively dust free atmosphere as that used for porcelain.[38,39]

Acrylic resin dentures may also fracture as a result of accidental dropping outside the mouth. The poor impact strength of acrylic resin contributes to such kind of failure. [40] Studies showed that the presence of very small surface defects (less than 16um) significantly reduced the impact resistance of polymethylmethacrylate. Such surface defects may be in the form of sharp irregular surfaces at the junction of the resin base with the undersurface of the resin-tooth. Scratches resulting from over-exuberant cleaning of the denture were also found to reduce the impact strength of acrylic denture bases. [41, 42] The need to produce high impact strength denture base material resulted in the use of impact modifiers. Rubber-like substances were added to acrylic resin allowing the absorption of greater amounts of energy before fracture. [43]

The type of processing could affect resin mechanical properties, such as surface roughness and hardness. The surface roughness of the denture base material is important, as it affects the oral health of the tissue in direct contact with the denture. Most microorganisms present intraorally, particularly those responsible for caries, periodontal disease and denture stomatitis, can only survive in the mouth if they adhere to a non-shedding oral surface and begin to form colonies.[44]The surface properties of any denture base material are of particular concern as studies of these materials have shown a direct link between the surface roughness, the accumulation of plaque and adherence of candida albicans.[45,46] the increased presence of candida species is reported in denture-related stomatitis.

A clinically acceptable threshold level of surface roughness (Ra) of 0.2 μm where no further reduction in plaque accumulation is expected in prosthetic and restorative dental materials. [47]

Acrylic hardness measurements will indicate the possibility of polymeric matrix degradation, which results in decrease acrylic hardness, and increases the possibility of fracture, diminishing the longevity of the denture base. Hardness provides a possible indication of the abrasiveness of the denture material. The surface properties of acrylic resin can be affected by hardness, which is characteristics of the easy of finishing the material as it is resistant to in-service scratching during cleaning. [48]

The exposure of acrylic resin denture base materials to the aqueous oral environments drew the attention to another limitation. This was the detriments effect of water sorption on these materials. Polymethylmethacrylate is formed of gigantic, polar polymeric chains, having a discontinuous empty chain in between. Water molecules ingress by the process of diffusion into the vacancies between the polymeric chains, pushing those polymeric chains apart. (49) These water molecules act as plasticizers, thus facilitating the movement of polymeric chains. One of the plasticizing effects is facilitating the relaxation of internal stresses built up in the polymeric chains during polymerization causing shape changes. (50) The plasticizing effect of absorbed water molecules also showed general decrease in mechanical properties of acrylic resin including its flexure strength. (51)

Two parameters were found to control water sorption of acrylic resin; - equilibrium uptake of water by the resin and the diffusion coefficient of water. These two parameters tend to govern the mechanical properties of the material in service together with its dimensional stability. (52,53) The American dental association (ADA) recommends that the increase in weight due to water sorption of the polymer shouldn't exceed 0.8mg/cm of the surface after immersion in water for 7 days at 37±1°C.(54) This limit ensures that no serious reduction in strength of the material occurs in service. It also ensures that the expansion associated with water sorption wouldn't overcompensate to a great extent the processing contractions. Such expansion cause poor adaptation of the denture base to the underlying denture bearing mucosa. (53)

Another parameter affecting the water sorption of acrylic resins is the type of crosslinking agents used. A certain cross-linking agent such as 1, 4- butanediol dimethacrylate (BDMA), 1, 6 hexanediol dimethacrylate (HDMA) and trimethylolpropane trimethacylate tend to decrease the water sorption. Those crosslinking agents form a close polymer network structure which doesn't swell easily with water sorption. [55] Whereas other cross-linking agents with ethoxy groups in dimethacrylate such as ethylene glycol dimethacrylate, diethylene glycol dimethacrylate and triethylene glycol dimethacylate tend to increase the water sorption. An explanation for that is the presence of oxygen in ethoxy groups. Attachment of water molecules to the polymer takes place by hydrogen bonding at oxygen. Such hydrogen bonding provides the hydrophilic property of these types of cross-linking agents. [55]

1.2. Reinforcement of polymethylmethacrylate:

Various approaches to strengthen acrylic resin prosthesis have been previously suggested. Such strengthening methods include either chemical modification of the resin structure or mechanical modification.

1.2.1. Chemical modification of polymethylmethacrylate:

Polymethylmethacrylate denture bases are subjected to high impact forces extra-orally as a result of accidental dropping of the prosthesis. Attempts were carried out to improve the impact strength of such material. Such attempts included the incorporation of rubber in the form of butadiene-styrene in acrylic resin. [49] This rubber could be incorporated up to 30% by weight in methylmethacrylate without deleterious effects on the handling characteristics such as an increase in viscosity.(36) This resin was described chemically as butadiene methacrylate copolymer with a secondary coating of PMMA. Those polymer beads are then mixed with the monomer in the usual way.

Several investigations showed the superiority of high impact resin over conventional heat-cured resin concerning impact strength. This was explained by the ability of grafted butadiene-styrene rubber to absorb greater amounts of energy before fracture. (56, 57)

Another investigation reported that fracture toughness tests may be more reliable than impact strength test in comparing conventional to high impact denture base resins. This study showed that impact strength and crack initiation were less affected by the presence of rubber resin modifiers. On the other hand, those resin modifiers seemed to play a decisive role in enhancing the toughness of denture base resins. Such enhancement was accomplished by rapidly slowing down the propagation of cracks leading to fracture. (58)

1.2.2. <u>Fiber reinforcement:</u>

Various types of fibers have been investigated to be used in dental polymers. Carbon fibers are lightweight, flexible, high strength material produced by pyrolysis of organic precursors such as polyacrylonitrile. (60) Carbon fibers were found to improve the flexural and impact strength, prevent fatigue fracture and increase fatigue resistance. Superior mechanical properties were attained by placing carbon fiber perpendicular to the applied force. [61,62,63] Despite that, carbon fibers showed some drawbacks, they had a dark colour, that might pose an esthetic problem.[25] On investigating their biological effect, carbon fiber-reinforced acrylic resin was found to be more cytotoxic than unreinforced acrylic resin. The proliferation of gingival fibroblasts decreased by approximately 20% as a result of its cytotoxic effect. [64]

Aramid is a generic term for wholly aromatic fibers called poly para-phenylene terephthalamide. Aramid fibers are marketed as Kevlar. [65] Aramid fibers have been shown to significantly increase the impact strength as well as the modulus of elasticity of the resin, but they are also unesthetic and their use is limited to certain intraoral applications. [65, 66] Aramid fibers showed tendency to buckle in compression, thus adversely affecting flexure properties in the final appliance.[67]

Silanated glass fiber showed good adhesion to dental acrylate polymer together with good esthetic qualities. Such properties made glass fiber widely used in dental applications.[71] Denture base polymers reinforced with glass fibers showed improved fatigue resistance, impact strength, as well as flexural strength.[73-76]

Polyethylene fibers have also been observed to increase the impact strength, Polyethylene fibers increase the modulus of elasticity and flexural strength and they are almost invisible in denture base acrylic resins. (69) Reinforcement of acrylic resin with polyethene fibers resulted in drastic reduction in the processing shrinkage, thus producing considerable improvement in the fitting accuracy. (70) However, the low surface energy and poor adhesion of polyethene fiber to the matrix adversely affected its reinforcing effect.

1.2.3. Metal reinforcement

Metal reinforcement was one of the most commonly used methods for reinforcing the acrylic resin. Such reinforcement was recommended in cases where dentures were porn to fracture. In mandibular denture with severe bone resorption, the buccolingual width was found to be 5mm or less. Such dimensions required metal reinforcement to resist fracture. (77) Metal reinforcements were also suggested as a method to reduce fracture problems of over-dentures.

Various studies were conducted to determine the strengthing effect of different solid metal forms embedded in the prosthesis. Such metal forms included different types of wires, either braided flat, with or without looped ends. The wires were placed close to tension side of acrylic sample and perpendicular to the anticipated line of the fracture to ensure superior strengthing.

2. NANOTECHNOLOGY AND SILVER NANOPARTICLES POWDER:

Nanotechnology as a rapidly growing branch of science has gained great concern based on producing nanoproducts and nanoparticles.[84] Silver nanoparticles (nanosilver) have attracted interest due to their unique physical, chemical and biological properties compared to their macro-scale counterparts. [85]

2.1. Synthesis of silver nanoparticles:

2.1.1. Chemical synthesis:

Chemical methods have been mostly used for the production of silver nanoparticles. Chemical methods provide an easy way to synthesize silver nanoparticles in solution. Monodisperse samples of silver nanocubes were synthesized in large quantities by reducing silver nitrate with ethylene glycol in the presence of polyvinylpyrrolidone, [86] this process called polyol process. In this case, ethylene glycol served as both reductant and solvent. It showed that the presence of PVP and its molar ratio relative to silver nitrate both played important roles in determining the geometric shape and size of the product. It suggested that it is possible to tune the size of silver nanocubes by controlling the experimental conditions.

Spherical silver nanoparticles with a controllable size and high monodispersity were synthesized by using the polyol process and a modified precursor injection technique. [87] In the precursor injection method, the injection rate and reaction temperature were important factors for producing uniform-sized silver nanoparticles with a reduced size. Silver nanoparticles with a size of 17±2 nm were obtained at an injection rate of 2.5 ml s^{-1} and a reaction temperature of 100 °C. The injection of the precursor solution into a hot solution is an effective means to induce rapid nucleation in a short period of time, ensuring the fabrication of silver nanoparticles with a smaller size and a narrower size distribution.

Nearly monodisperse silver nanoparticles have been prepared in a simple oleylamine-liquid paraffin system. [88] It was shown that the formation process of silver nanoparticles could be divided into three stages: growth, incubation and Ostwald ripening stages. In this method, only three chemicals, including silver nitrate, oleylamine and liquid paraffin, are employed throughout the whole process. The higher boiling point of 300 °C of paraffin affords a broader range of reaction temperature and makes it possible to effectively control the size of silver nanoparticles by varying the heating temperature alone without changing the solvent. Otherwise, the size of the colloidal silver nanoparticles could be regulated not only by changing the heating temperature, or the ripening time, but also by adjusting the ratio of oleylamine to the silver precursor.[87, 88]

Chemical synthesis process of the silver nanoparticles in solution usually employs the following three main components:

metal precursors, reducing agents and stabilizing/capping agents. The formation of colloidal solutions from the reduction of silver salts involves two stages of nucleation and subsequent growth. (88) It is also revealed that the size and the shape of synthesized silver nanoparticles are strongly dependent on these stages. Furthermore, for the synthesis of monodispersed silver nanoparticles with uniform size distribution, all nuclei are required to form at the same time. In this case, all the nuclei are likely to have the same or similar size, and then they will have the same subsequent growth. The initial nucleation and the subsequent growth of initial nuclei can be controlled by adjusting the reaction parameters such as reaction temperature, pH, precursors, reduction agents (ethylene glycol, glucose) and stabilizing agent sodium oleate. (89-91)

2.1.2. Physical synthesis:

For a physical approach, the metallic nanoparticles can be generally synthesized by evaporation-condensation, which could be carried out by using a tube furnace at atmospheric pressure. However, in the case of using a tube furnace at atmospheric pressure, there are several drawbacks such as a large space of tube furnace, great consumption energy for raising the environmental temperature around the source material and a lot of time for achieving thermal stability. Therefore, various methods of synthesis of silver nanoparticles based on the physical approach have been developed.