CHARACTERIZATION OF DENTURE BASE POLY (METHYL METHACRYLATE) REINFORCED WITH ALUMINA/ZIRCONIA PARTICLES

By

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Thesis submitted in fulfillment of the requirements for the degree of Master of Science

May 2011

ACKNOWLEDGEMENT

In the name of Allah, The Most Beneficent, The Most Merciful

All praises and gratitude to Allah Almighty, the beneficent, the merciful, without whose will and help it was impossible for me to accomplish this research work.

At the onset I would like express my sincere and heartfelt gratitude to Prof. Hj. Zainal Arifin Ahmad for his understanding, support and generosity in sharing his expertise. Also, special thanks to Dean of School of Materials and Mineral Resource Engineering, USM, Prof. Ahmad Fauzi Mohd Noor for his kind assistance and support in providing all the facilities and to conduct experiments in my research area.

I am also thankful to all the colleagues who have made my life easier during the hard times of this work, to the School of Materials and Mineral Resource Engineering, and lab technicians for their tireless cooperation.

I want to express my gratitude to my beloved parents who had made it possible for me to overcome all the obstacles throughout this research work and their continuous support and constant encouragement that filled me with enthusiasm. My deepest love and appreciation for one and all that stood by me through all these challenging times.

Finally, I am greatly indebted to my brothers and my sisters for their love, support, understanding and encouragement throughout my studies. My special thanks to my elder brother, Mr. Mohammed Alhareb who helped me and encouraged me for pursuing studies.

My special thanks to Mr. Khalid Abdulal Yousif for his encouragement and advice during the course of this research.

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LIST OF ABBREVIATION

BPO	:	Benzoyl Peroxide
BIS-GMA	:	Bis-(2-HydroxypropyII)-Methacrylate
CAD	:	Computer-Aided Design
CAM	:	Differential Scanning Calorimetry
EDS	:	Energy Dispersive X-Ray Spectroscopy
EGDMA	:	Ethylene Glycole Dimethacrylate
FTIR	:	Fourier Transform Infra Red Spectroscopy
Al_2O_3	:	Alumina
ZrO_2	:	Zirconia
Y-TZP	:	Yttria-Stabilized Tetragonal Zirconia
PHEMA	:	Poly Hydroxy Ethyl-MethAcrylate
PMMA	:	Poly Methyl Meth Acrylic
Tg	:	Glass transition temperature
SBF	:	Simulated Body Fluid
FESEM	:	Field Emission Scanning Electron Microscopy
FRC	:	Glass Fiber Reinforced Composite
RRP	:	Rigid Rod Polymer
PAAm	:	Polyacrylamide
MMA	:	Methyl Meth Acrylic
ISO	:	International Standard Organization
γ-MPS	:	3-(methacryloxy) propyl trimethoxysilane
K_{IC}	:	Factor of Fracture Toughness
SBR	:	Styrene-Butadiene Copolymer
UHMWPE	:	Ultra High Molecular Weight Polyethylene
PP	:	Polypropylene
CVN	:	Charpy V-notch test
IS	:	Impact Strength
OD	:	Optical Density
LOI	:	The Value of Loss on Ignition
P/L	:	Powder to Liquid Ratio
SEN-B	:	Single Edge Notch Bending Test
TGA	:	Thermogravimetric Analysis
VHN	:	Vickers Hardness Number
XRD	:	X-Ray Diffraction
XRF	:	X-Ray Fluorescence
SiC	:	Silicon Carbide

LIST OF MAIN SYMBOLS

a	:	Notch Length
A_s	:	Surface Area of Indention
b	:	Width
c	:	Composite
t,d	:	Thickness of Specimen
E	:	Energy Value
b_n	:	Width of Specimen Without Notch
L	:	Length
r_n	:	The Angle Notch
Kgf	:	Kilogram-Force
KV	:	Kilo Volt
m	:	Tangent of the Initial Straight Line of load Versus Deflection Curve
M	:	Matrix
µm	:	Micrometer
MPa	:	Mega Pascal
P	:	Load
ρ	:	Density
pH	:	Acidity Measurement
t	:	Thickness
W_f	:	Weight Fraction
y	:	Correction Factor
ʎ	:	Wavelength
θ	:	Half of the Angle of Diffraction

PENCIRIAN TAPAK GIGI PALSU POLI (METILMETAKRILAT) DIPERKUAT DENGAN PERTIKEL ALUMINA/ZIRKONIA

ABSTRAKS

Sifat-sifat komposit matriks PMMA yang diisi dengan serbuk-serbuk alumina (Al_2O_3) dan zirkonia distabil ytria (Y-TZP) sebagai bahan tapak gigi dikaji. Kelemahan matriks PMMA adalah disebabkan oleh keliatan patahnya yang lemah. Serbuk PMMA telah dicampur dengan cecair monomer MMA dan distabilkan dengan 0.0025% hirokuinon. Benzoil peroksida (BPO) dan etilena glikol dimetakrilat (EGDMA) masing-masing telah digunakan sebagai bahan pemula dan agen sambung-silang. Kajian telah dibahagikan dibahagikan kepada dua peringkat. Dalam peringkat pertama, jumlah Al_2O_3/Y-TZP sebagai bahan pengisi telah ditetapkan pada 5% berat di dalam komposit matriks PMMA. Walau bagaimanapun, nisbah di antara Al_2O_3 dan Y-TZP diubah dari 0 ke 100. Dalam peringkat ini, jumlah optimum untuk kedua-dua pengisi tidak dirawat dan dirawat dengan silana (γ-MPS) telah dinilai berdasarkan ujian-ujian tegangan, pelenturan dan kekuatan pecah serta pemeriksaan mikrostruktur. Didapati bahawa nisbah optimum ialah 80/20 (Al_2O_3/Y-TZP). Komposit yang diisi dengan bahan pengisi dirawat menghasilkan sifat-sifat yang lebih baik. Dalam peringkat kedua, nisbah pengisi optimum (80/20) telah digunakan untuk mengkaji kesan jumlah kandungan pepejal di dalam komposit matriks PMMA. Jumlah kandungan pepejal telah diubah dari 0 dan 20%. Sifat-sifatnya dinilai berdasarkan sifat-sifat mekanikal, pemeriksaan mikrostruktur, kekerasan mikro Vickers, sifat terma, kesan pendedahan kepada cecair badan simulasi (SBF) dan ujian radiopasiti. Keputusannya menunjukkan bahawa 10% jumlah kandungan pepejal ialah yang terbaik

CHARACTERIZATION OF DENTURE BASE POLY (METHYL METHACRYLATE) REINFORCED WITH ALUMINA/ZIRCONIA PARTICLES

ABSTRACT

The properties of PMMA matrix composite incorporated with alumina (Al_2O_3) and yttria-stabilized zirconia poly crystal (Y-TZP) powders, as dental base material, was studied. The limitation of PMMA matrix is due to its weak fracture toughness. The PMMA powder was mixed with liquid MMA monomer and stabilized with 0.0025% hydroquinone. Benzoyl peroxide (BPO) and ethylene glycol dimethacrylate (EGDMA) were used as initiator and as cross-linking agent, respectively. The study was divided into two different stages. The first stage, the amount of Al_2O_3/Y-TZP as filler material was fixed at 5 wt% in the PMMA matrix composite. However, the ratio between Al_2O_3 and Y-TZP was varied from 0 to 100. In this stage the optimum amount for both untreated and treated fillers with silane (γ-MPS) was evaluated through their tensile, flexural and fracture toughness tests and microstructure examination. It was found that the optimum ratio is 80/20 (Al_2O_3/Y-TZP). Composites filled with treated filler produced superior properties. In the second stage, the optimum filler ratio (80/20) was used to study the effect of solid loading in the PMMA matrix composite. The solid loading was varied from 0 to 20 wt%. Their properties were evaluated based on their mechanical properties, microstructure examination, Vickers micro hardness, thermal properties, effect of simulated body fluid (SBF) exposure and radiopacity test. The results show that 10% solid loading is the best.

CHAPTER ONE
INTRODUCTION

1.1 Research Background

The field of material science seeks to explain the properties and performance of materials. It is a combination of chemistry, physics and engineering. In dentistry, a subgroup of material science has developed. This subgroup is known as dental materials (Gladwin et al., 1999). It provides a fundamental understanding of the materials on which dentistry depends, covering those aspects of structure and chemistry which govern the behavior and performance of materials in use. Nowadays, there is scarcely a dental restorative procedure that does not make use of dental materials. This field of dental materials has in the recent times developed into a full fledged research domain of considerable importance.

The major impetus in the study of characterization of dental materials and its applications is to enhance and prevent the mouth from diseases and inflammations. The science of dental materials involves the development, characterization, use and evaluation of the materials used to repair or replace of part of patient mouth (Ferracane, 2001). Therefore, it is very important to choose the right material and the correct procedure, considering all the mechanical and physical properties, quality, suitability and lifespan of these materials in patient mouth. Thus the field of dental material science includes the study of composite, properties of these materials and the environment with which they interact. Most of the dentist and the dental technicians require a considerable amount of time in selecting of appropriate materials to fabricate the removable dental prosthesis. The success or failure of the part inside the oral cavity of patient also affects the decision process. Therefore, the process of manipulation and combination is very important to obtain the best of the properties. The selection of materials is the main reason for success of the prosthesis in the patient mouth. There are many other factors that have significant impact on the development of dental prosthetic. The normal temperature variation in the mouth varies between 32°C to 37°C and therefore the dental material should be able to withstand this variation in temperature. Also the design of the prosthetic depends on whether the mouth is open or closed and the ingestion of hot or cold food or drink is also an important consideration in the choice of materials. The acidity and alkalinity of fluids with pH high or low should be considered in the choice of materials. In the oral patient, pH value varies from 4 until 8.5. Sometimes the intake of fruit juices extends the pH up to 11. Another factor that is of significant importance is the load bearing capacity of the dental prosthetic. The dental prosthetic construction influence due to load of the teeth during mastication automaticity (McCabe et al., 2008).

Several material properties must be considered when dental materials are selected for clinical use. These considerations include (1) Biocompatibility test to suit the material for mouth tissues, (2) Physical properties, (3) Handling characteristics, (4) Matching of the natural appearance of artificial part in the mouth and the tissues that surround the construction, and (5) Cost effectiveness of the materials used in artificial construction (Anusavice, 1996).

Polymer is considered to be a major component in dentistry constructions. Synthetic polymer is mostly used in both restorative and prosthetic dentistry. The use of polymer in dentistry applications involves the manufacture of artificial teeth, crown and bridges, implants and other removable prosthetics (denture base). Acrylic polymers are widely used in the removable prosthetics (Deb, 1998). There are many uses i.e.

impression materials such as alginates, polysulfides, silicones and hydrocolloids. Polymers are also being used in bone cements and orthodontic appliances. This polymer is an organic glass and is a very common material in dentistry for complete and partial dentures, artificial teeth, repairs and rebases dentures (Bhat et al., 2006).

The first man made polymer was produced in early mid 19^{th} century. Polymers are giant, long-chain organic molecules that have not been used extensively in dentistry as permanent structural materials. They are only used to make both the teeth and base of dentures, appliances that completely replace the teeth, gums, temporary restorative materials for single restorations and bridges to be worn while the permanent metallic or ceramic restoration is being fabricated in the laboratory (Ferracane, 2001).

The polymer came into prominence with the chance discovery of vulcanization by Charles Goodyear in the year 1840. Twenty years after this discovery ebonite and Vulcanite were developed as denture materials which were used with the porcelain teeth. These remained the principal denture based materials for the next 75 years. However, these materials had poor aesthetics, tasted seamy and had foul smell. In about 1868, John Hyatt invented the first plastic molding material called celluloid by discovering nitrocellulose (a cotton derivative) under pressure. The aim was to make a synthetic substitute for ivory billiard balls. Celluloid was tough and somewhat flexible and had better aesthetics than vulcanized rubber, but it too tested seamy, smelled foul, difficult to process and particularly unstable. In year 1909 Dr. Leo Bakeland discovered the phenol-formaldehyde resin which is used to make artificial shellac. This material was known as Bakelite, as a denture base but did not posses dimensional stability inside the mouth.

Since the mid-1940s, most denture base was fabricated from poly (methyl methacrylic). Denture base in removable prosthodontics was fabricated from PMMA and was considered the most popular material in denture constructions (El-Sheikh et al., 2006). PMMA is glass-like polymer and is occasionally used in this form for denture base construction. During 1930s and 1940s, acrylic resin was reported to be the best used material used for construction of dentures (Hassain, 2004).

PMMA resin exhibits better impact and mechanical and physical properties when compared to other polymeric materials. However, the material possesses poor mechanical and physical properties when used alone. It can be easily broken during accidents or when the patient applies high mastication force on the denture base (Hersek, et al., 2002). The patient may even accidentally ingest (swallow) these particles. Besides that, it is also radiolucent and cannot be different from soft tissues. Therefore, pure PMMA is not suitable to be used as a denture base. Incorporation of opaque filler such as metal or ceramic may be a solution to this problem.

In the 1930s, Walter Wright and the Vernon brothers at the Rohm and Haas Company in Philadelphia developed PMMA a hard plastic. Although many other materials were utilized for dental prosthetics none could come close to that of PMMA, and nowadays about 90 – 95% of denture base is mostly fabricated from acrylic resin (Ferracane, 2001). However, acrylic resin has weak mechanical properties and is soft and flexible.

The denture base materials should possess good aesthetics, biocompatibility, high strength with the available denture teeth, radiopacity, ease of repair, and must have adequate physical and mechanical properties. The denture base must be strong enough to allow the prosthesis to withstand functional and para-functional masticatory forces. In addition, since these prostheses are removable, it must also have good shock induced fracture resistance to withstand any sudden accidents. Earlier many materials were utilized such as bone, wood, ivory and vulcanized rubber. Currently, PMMA remains the most preferred material to fabricate the denture base (Meng and Latta, 2005).

Acrylic resin denture base has relatively poor resistance to fatigue fracture when subjected to masticator load. In 1997, it was estimated that over one million denture repairs were required in the UK alone due to poor impact strength of the material used. The dental technician needs for better understand of the causes and mechanisms of fracture as well as the development of improved materials (John et al., 2008).

Several studies have investigated the incidents and types of fracture of dentures. Hargreaves (1969) reported that 63% of dentures had broken within 3 years of their provision. Darbar (1994) in a survey distributed a questionnaire to three laboratories, and reported that 33% of the repairs carried out were due to de-bonded or detached teeth and 29% were repairs to midline fractures more commonly in dentures. The remaining 38% were other types of fractures, the majority of which were repair dentures.

The denture base is easy to break in the mouth of the patient due to accident or mastication force applied daily during eating. In dentistry, denture bases are commonly fabricated using acrylic resins. Overall, reinforcement is done in the base by ceramic filler. Denture-base polymers were reinforced with many types of fillers such as glass fiber, aramid, carbon fiber, barium particles and zirconia particles. Ceramic filler was used reinforcing such as hydroxyapatite and silica with denture base material (Chow et al., 2008). Some of the materials that were commonly used are acrylic resin, self-cured acrylic resin, epoxy resin, polystyrene, nylon, vinyl resin, polycarbonates, visible light curing acrylic and high impact acrylic. Among all these materials, PMMA was found to be the most preferred denture base material (Mittal et al., 2009).

1.2 Ideal Denture Base Materials Properties

The study of the properties of denture base materials is essential in order to further enhance these properties and make it more effective and patient friendly. An ideal denture base should be compatible with the natural appearance of the oral soft tissues. The polymer which is used to construct a denture base should have a value of glass transition temperature (T_g) high enough to prevent softening and distortion during use. Even though the normal temperature in the mouth varies only from 32°C to 37°C, the patients' consume hot drinks at temperature 70°C and also use very hot or oven boiling water to rinse their mouth (McCabe and Walls, 2008).

The base should have good dimensional stability and the shape of the denture should not change over a period of time. The denture base should also be radiopaque. Suddenly, the patients swallow dentures and may even inhale fragments of dentures if involved in violent accident such as car crashed. It should possess good mechanical properties. The denture base should be rigid, having high modulus of elasticity and elastic limit to ensure the stresses encountered during biting and mastication do not cause permanent deformation. The base should have sufficient flexural strength to resist fracture and should not break into fragments in the patient mouth. There is a possibility of fracture if the denture is accidentally dropped onto a hard surface. The ability of a denture base to resist such fracture is a function of impact strength of the material (John et al., 2008). The material should be insoluble in oral fluids and should not absorb water and solubility of simulated body fluid (SBF) and absorption. The denture base material has poor mechanical properties. Thus, with the incorporation of metal or ceramic as composite with polymer helps overcome these problems. On the other hand, Abu Kasim et al. (1998) reported that the PMMA polymer in denture base material by itself was not visible or not radiopacity hence difficult to detect this material using by X-rays technique. The denture base was breaking in the patient's mouth into multi pieces due to car accident or biting force. In this case, the patient will swallow some pieces of this material inside the stomach. The denture base materials incorporated with ceramic filler, glass powder and metal for visible this material under X-Ray technique (Chandler et al., 2004).

1.3 Problem Statement

PMMA denture base material still is the main material used in dentistry for denture base constructions. Even though there are many other polymeric materials which have been used for denture base but PMMA is better due to its stability in mouth and has better aesthetic appearance. Thus, PMMA remains the preferred material for removable prostheses, dental implants and other orthodontic appliances. It is consider as an ideal denture base material but is still restricted by a few intrinsic limitations.

One of the limitations is its weak in the fracture toughness value. The mechanical strength of the denture base is a concern due to fractures occurring intra-orally or when accidentally dropped. The fracture of acrylic denture base is a common problem in any dental laboratory manufacturing premises that made dental materials. Most PMMA resin denture base fractures result from two different types of forces, namely, flexural fatigue and impact. Flexural fatigue occurs after repeated flexing of the PMMA resin during clinical use. It is a mode of fracture whereby the denture base fails after being repeatedly subjected to mastication loads and usually occurs out of the mouth as a result of sudden blow or accidentally dropping on hard surface during cleaning, coughing or sneezing or by accident car, the patient may swallow some of these particles into stomach. This should be modified of the denture base material to invisible in X-ray image. Therefore, due to the incompatibility of the resin and the metal salt, the addition of heavy metal salt could not give the optimum properties.

Researchers have tried to solve these problems; however, the result is not improved very much. Addition of ceramic filler (Elshereksi et al., 2009) and glass (Vincenzini et al., 2006) has been reported in the literature. According to Hersek et al., (2002) the fracture problem of the denture base occurs due to accidentally dropping a denture on a hard surface resulting in an impact failure. Denture base fracture, particularly PMMA resin denture base material in removable dentures, is an unresolved problem in the dental industry by Rahamneh, et al. (2009). El-Sheikh and Al-Zahrani (2006) reported that fracture of PMMA resin denture base in clinical use is time consuming and costly to both patient and dental professionals. Also the affects of denture base material to exposure in artificial saliva and water on the mechanical properties (Santos et al., 2002; Elshereksi, 2009; Tham et al., 2010).

The addition the PMMA polymer with heavy metal salt is able to improve the radiopacity property (Vazquez et al., 2001). Some of the radiopacity materials that have been tried such as barium sulphate and zirconium are known to alter the mechanical and biological properties (Rudigier et al., 1977; Abboud et al., 2000). Chandler et al., (2004) developed a denture base composite using glass by additions of 30, 40 and 50 wt% of silane-treated, radiopaque, powdered glass as the reinforcing filler and PMMA. PMMA by itself is not visible using typical medical imaging techniques such as X-rays which is required to assess new bone formation surrounding the implant. PMMA with MgO particles and $BaSO_4$ particles decrease harmful exothermic reactions of PMMA and increase radiopacity (Webster et al., 2008). Radiopaque studies were done when addition of bromine containing composite of bone cement, was proved with increase in radiopacity of addition of bromine containing of acrylic bone cement by Rusu et al., (2008).

`The study of resistance of denture base material is exposed to an aqueous environment after immersion in artificial saliva and water. The fracture surface was rough by the cracking area which due to the poor filler-matrix interaction (Elshereksi, 2009). The flexural properties were reduced when the samples were exposed to water media and simulated body fluid (SBF), this is due to a weak in the interaction/debonding between the filler particles and the matrix (Tham et al., 2010).

Another important consideration will enhance the properties of denture base material. In order to improve the properties, the goal was mixed with alumina/zirconia (Al_2O_3/ZrO_2) to act as reinforcing filler in PMMA composite. The selection of Al_2O_3 and ZrO_2 as ceramic fillers is due to Al_2O_3 and ZrO_2 are bioceramic used in biomaterials and dental application (Santos et al., 2007). Al_2O_3/ZrO_2 composite combine high strength and toughness (Mangalarja et al., 2003; Xinjie et al., 2008). Whereby, Al_2O_3 and ZrO_2 have high hardness, flexural strength and fracture toughness, they were used as the femoral head of joint replacement (Zhou et al., 2008; Vuorinen et al., 2008). The fracture toughness of Al_2O_3 and ZrO_2 range from 2 to 6 MPa .$m^{1/2}$ (Xu et al., 1999) this range is suitable for denture base material. Al_2O_3 is high hardness while ZrO_2 improves both the flexural strength and fracture toughness, they suggested this type of ceramic filler is relatively suitable for dental restorations (Ayad et al., 2008). The radiopacity property was done by the incorporation of Al_2O_3/ZrO_2 composite filler compared to titanium. Yttria-stabilized tetragonal zirconia polycrystals (Y-TZP) showed higher radiopacity than titanium and aluminum. ZrO_2 exhibited high radiopacity because of its inherently high atomic number and density. Amongst the materials investigated, Al_2O_3 showed the most transparency against X-rays and ZrO_2 showed also the highest radiopacity (Okuda et al., 2010).

1.4 Research Objectives

The following are the three objectives that were investigated in this study of denture base reinforcement material:

- To investigate the effect of different ratios of Al_2O_3/Y-TZP and treated silane coupling treatment on the mechanical properties of Al_2O_3/Y-TZP filled PMMA composite.
- To study the limitations of Al_2O_3/Y-TZP as filler in PMMA matrix and its effects on the mechanical, physical and environmental properties.
- To study the effects of environmental conditions on composite properties whereby, the samples were exposed to solubility and simulated body fluid (SB) and study the absorption in the both the aqueous and simulated body fluid environmental conditions.

1.5 Structure of thesis

This thesis consists of five chapters. Chapter one is the review of the information about the material science in the field of dentistry and provides the historical overview of uses of polymer in denture base. In this chapter a brief outlook on some ideal properties of denture base and PMMA material are evaluated. The background of the research and objectives of the present study are also explained.

Chapter two is the literature review consisting of introduction to dental materials, dental prosthetics and biomaterial in dentistry field. Also, some studies on denture base material reinforcements and their properties are presented.

Chapter three provides the experimental procedures and methods for testing of specimens. The study also describes the details of material and equipments used in the current research work.

Chapter four is the results and discussion. It includes the results of alumina and zirconia as composite filler in different ratios, use of EDS to illustrate the additions of Al_2O_3 and Y-TZP and the study of filler content on the properties of denture base material. Also the results from scanning electron microscopy (SEM) on the morphology of the fracture surface and impact surface are presented.

Last chapter deals with the conclusion of this research and recommendations for future study.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction of Dental Materials

Dental materials are among the most extensively employed artificial material for incorporation in the human body. Thus, to repair or prevent any part or organ in the body, understanding of the physical and mechanical properties of materials used in dentistry is very essential. The materials used to replace missing portions of teeth are exposed to attack by oral environment and subjected to biting forces. Secondly, the restorative materials are cleansed and polished by various prophylactic procedures. Therefore, it is very important to select the materials with requisite properties to be used in particular dental procedures and restorations. Clinical experience and research have related clinical success to certain properties of materials that have been used as guides in the improvement of dental materials. Thirdly, the establishment of critical physical properties for various types of dental materials has led to the development of minimum standards or specifications (Craig et al., 2009). Thus, physical and mechanical properties are very important in selecting of the materials and use of materials designed for the oral cavity (Zahra et al., 2007).

In generally, dental materials are classified as preventive materials or restorative materials. While dental restorative materials are usually made up of materials such as metal, ceramic, polymer and composite. They are based on several factors such as the patient, dentist, material and its characteristics. The selection of the dental materials is as per the specifications provided by the manufactures of the dental components. Some of the important characteristics are strength, hardness, chemical resistance and esthetics appearance. The metals provide the strength and durability and many combinations such as amalgams, casting alloys and porcelain fused to metal restorations are used. The ceramic is important to incorporate with polymer or metal or as stand-alone. Ceramic materials are considered for aesthetic material in dental prostheses such as crowns and bridges, orthodontics and fixed and removable prosthodontics. Incorporation of polymer material is used as bone cements and as cavity fillings in conjunction with particulate ceramic filler materials (Bhaduri et al., 2009).

The use of polymers and ceramics has revolutionized the dentistry field. Many prostheses and implants made from polymers have been in use for the last three decades and there is a continuous search for more biocompatible and stronger polymer prosthetic materials. Several attempts have been made to combine the material properties of the polymers used in denture dentistry, with emphasis on the most widely used poly methyl methacrylate resin (PMMA). The denture base material was used successful by used PMMA (Bhola et al., 2010).

2.2 Definition of Dental Prosthetics (Dentures)

Dental prosthetics are replacement of natural teeth in the patient’s mouth but is not permanently fixed in the mouth. Prosthetics is that branch of dental art and science specifically deals with the replacement of missing dental and oral structure (McGivney and Castleberry, 1995). A removable prosthesis without artificial teeth attached to the base, replaces the masticatory surfaces and associated structures of maxillary or mandibular dental arch. The protection of the mouth tissue should be made the restorative to avoid the problems in the mouth bone and patient health. Dentures are artificial part of dental materials used to restore the missing part and replace the nature teeth in order to restore the normal functioning of the mouth. Removable prosthetics can be classified as full dentures or complete dentures and partial dentures as shown in Figure 2.1. This classification is based on the number of missing teeth. Additionally, dentures are also used to restore the oral tissues and protection of resorption of bone. A full denture consists of all the missing teeth of the mouth and is also known as complete prosthetic of either or both jaws, whereas the partial denture which includes replacement of two or three teeth of a patient's jaw is called as partial prosthetic. The prosthetic is fabricated from metal and acrylic resin as composite materials or only acrylic resin.

Due to the ravages of caries or periodontal disease, some people lose many or almost all of their teeth. If all of the teeth of an arch are missing, the teeth are replaced by a prosthesis known as complete denture. The prosthesis is an artificial device that replaces a lost part of organ or tissue. A denture on the other hand replaces missing teeth, bone and gingival after the teeth has been extracted. A complete denture is supported by and precisely rests on the mucosal tissue covering of the maxilla or mandible. The functions of complete denture include chewing food, proper speech and aesthetics. Also, dentures should be soaked over-night in commercial or home-made soaks to avoid the change in dimensions of denture. Dentures also help improve the patient's self-esteem, appearance and oral function. The supporting tissues are replaced with a plastic that simulates the appearance of gingival. As shown in Figure 2.1, the partial prosthesis has some teeth on an arch and has several metal clasps designs (Gladwin, 1999).

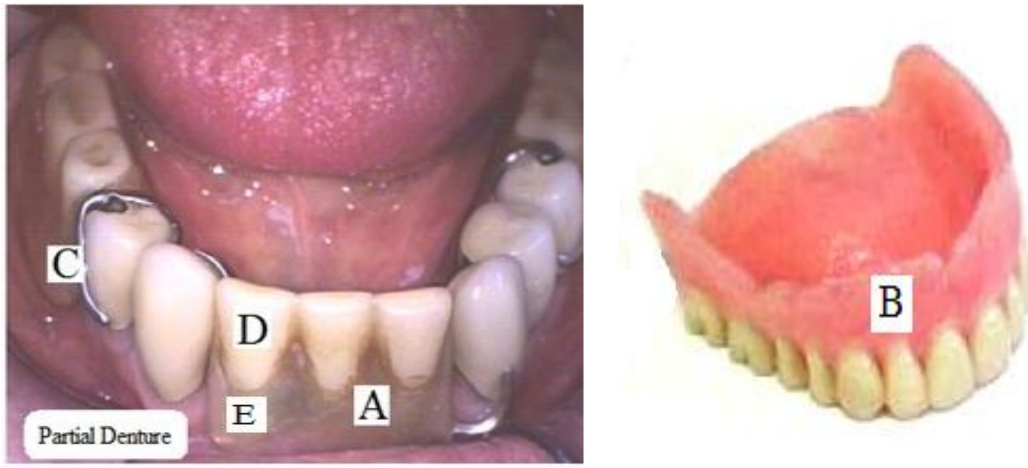

Figure 2.1: The compositions of the denture base; (A) Partial Denture; (B) Complete Denture; (C) Wire Metal; (D) Artificial Teeth; and (E) PMMA Denture Base Material

The benefits of dental prosthetics (dentures) on the health of the patient are enormous. It protects the alveolar bone that debenture on the prosthetic of the mouth tissue and thus the health of patient will improve with the restoration of the prosthetic in his mouth. Also, the prosthetic can restore appearance, by restoring the aesthetic of the face of patient and smiles to active the muscles that content it the face which to maintain the facial expressions which the function of labial flange of denture base to restore lost bone contours. Eating, speaking and retention of remaining teeth are all positive results obtained when a denture is worn to replace missing teeth. From another side, facial expressions, labial surface of denture base is support lips. The dentures also avoid the occurrence of inflammations in the tissues of the patient mouth. Some other important functions of removable prosthetics are attaching the prosthetic teeth to partial denture, transfer of occlusal forces that lie on artificial teeth directly into artificial denture base, and to provide bracing retention.

In the mouth cavity, dentures are considered as base that prevents misalignment between tooth and tissues that surround it. In oral environment, there are many obstructions such as oral fluids (saliva), maintaining the aesthetic aspect of the prostheses and also selection of the material to fabricate the denture in terms of its mechanical properties, reinforcement using ceramic filler, metal or glass fibers to carry the load force of the mastication during eating etc. Narva et al. (2005) estimated that the average load on the base of teeth during mastication is around 700 N.

2.3 Biomaterials

Biomaterials can be defined as synthetic materials which have been designed to induce a specific biological activity or the study of natural and synthetic materials used to fabricate artificial organs and tissues. Bronzino (2003) defined biomaterial as a synthetic material used to replace a part of the living system or to function in intimate contact with living tissue. Thus biomaterials are used to restore the function of denture base in the patient mouth and to improve the properties.

There is a big demand for biomaterials to assist or replace organ functions and to improve patients' quality of life. Generally the material options include metals, ceramics and polymers. Unfortunately, most of the conventional materials that are used are not specifically developed for biological applications. Interaction between biomaterials and natural tissues is an important subject for biomaterial science. Such information is essential to aid the design of new biomaterials. The goal of biomaterial is to improve human health by restoring the function of natural living tissue and organs in the body. It is essential to understand relationships among the properties, functions and structures of biological material (Park et al., 2007).

Generally, biomaterials are included as the dental restorative materials when a material is placed in or in contact with the human body. It is may be defined as a non-living material designed to interact with biological systems. There are three main areas of use of biomaterials:

● Dental restorative material such as metallic, composite filling materials, casting alloys, ceramics for fixed and removable intraoral prostheses.

●Structural implants, such as oral and maxillofacial implants and joint prostheses.

● Cardiovascular implants, e.g. catheters, prosthetic heart valves and blood vessels, and dialysis and oxygenator membranes.

In a historical introduction one can see an ongoing transformation from dental materials which once concerned itself with physical and mechanical properties of restorative materials to what may be described as dental biomaterials in which all aspects of biologic function are observed. This should be regarded as one part of biomaterials since many of the problems in dentistry are common to other areas of the body (Smith, 2010).

Dental biomaterials are that aspect of the subject, which considers materials for use in the mouth, as well as those employed in dental laboratory procedures (Combe et al., 1999).

2.3.1 Biomaterial for Dental Applications

Biomaterials science has expanded rapidly in the last few years, and is particularly evident in the orthopedic implants and dental materials. First generation material devices, originally manufactured for different industrial purposes and secondarily adopted for medical applications are being progressively replaced by biomaterials expressively made for specific surgical use, by taking into account criteria determined by bioengineering and biocompatibility testing. The outstanding advancement of tissue engineering science, with its complex multidisciplinary background of cell biology, molecular biology, physical chemistry, and nanotechnology, has added further inputs to understand and consider when choosing treatment options (Giunti et al., 2005).

Currently, the focus of dental materials and biomaterials is the replacement and enhancement of missing tissues as a result of disease or trauma to restore normal function. The use of appropriate materials and device has historically been a significant component of the practice of dentistry and thus knowledge of materials science and biomaterials has always been a rich component of dental research. In the areas of restorative dentistry and prosthethetics, all materials ranging from dental amalgams to ceramic restoration have undergone significant modifications in their composite and structure (Giannoble et al., 2010).

Biomaterials for dentistry applications have been developed in accordance with progress of the fields of medicine and material science. All the materials used in dentistry should be biocompatible. Notably, the major synthetic dental materials classifications involve into metal, ceramic, polymer and composite structures. These groups of dental biomaterials based on the importance of the aims; the fracture resistance of ceramics and optimum design of ceramic and metal ceramic prostheses, resin based composite the polymerization shrinkage. Mostly, the material engineers or scientists currently utilize synthetic biomaterials for use in implants (Ramakrishna et al., 2001). Thus, dental biomaterials can be classified as metal, polymer, ceramic and composite.

2.3.1 (a) Metal

Metal is one of classification of dental materials. It has many uses as denture base application and also used as crown or bridge as fixed prosthetics in the mouth. The metal alloys are widely used in dental applications. They are used in fabrication of denture bases for removal of dentures that are in contact with teeth and oral tissues (Craig et al., 2000).

They are generally used as with dental prosthesis in missing teeth or when it is necessary to simulate lost gingival tissues that surround missing teeth. In dental prosthesis, the metal clasps are an extension of the metal body or structural component of the removable partial denture. It provides the strength and stability inside the patient mouth. One of the popularly used metal alloys in dentistry is the stainless steel. This alloy is easily available and economically viable. Additionally it is strong, corrosion resistant, biocompatible and cleanable. Stainless steel denture base has high values of modulus of elasticity, ensuring that the patient retains a normal reflex reaction to hot and cold stimuli by McCabe and Walls (2008). Titanium and titanium alloys have been utilized as dental casting alloys that are used with porcelain in fixed prosthesis. Titanium has high melting point and excellent biocompatibility (Ferracane, 2001). Pure metals are not frequently used in dentistry. Occasionally pure gold (Au) although expensive is used as a high quality inlay. Even though Au is biologically well tolerated, it is too soft material. It is chemically very stable and does not corrode. For the prosthetic purposes, other metals are usually added to gold in order to get an alloy with better properties, especially harder and with higher melting point. The content of Au in gold alloys must be at least 65 %; the content of Ni must be less than 0.1 %; and Be, Cd must be less than 0.02 %. The addition of Cu to a gold alloy increases its hardness (Malbohan and Platenik, 2004).

Also alloy based on cobalt or nickel and containing a substantial amount of chromium are suitable for removable partial denture frameworks, full denture base and temporary tooth surgical and periodontal splints (McCabe and Walls, 2008). Cast metal plates also have been used to replace some parts of the denture and it increases the flexural and impact strength while its disadvantages are that it is very expensive and prone to corrosion. Moreover, metal reinforced denture may be unaesthetic as well. Vallittu, (1993b) has reported that the effect of placing metal strengtheners in different positions in the acrylic resin of the denture base material construction and reinforcement using bonding of metal wire to acrylic resin enhanced the fracture resistance. In dental industry, denture bases are commonly fabricated using acrylic resins or metal alloys (Kanie et al., 2004). During the 20th century, the constructions were made from metal alloy such as, gold, chromium and nickel, chromium and cobalt, and titanium in crowns, bridges and partial dentures (Gladwin et al., 1999).

It is necessary to fabricate the base of denture for strength and stability in oral patient. Fabrication of the base is incorporated by metal such as metal wire as reinforcement with polymer to provide better properties.

2.3.1 (b) Ceramics

The current, research pertaining to ceramics is focused on the technological advancement and more importantly, attempts to achieve an ideal reinforcement of different materials. Dental ceramics were first used in dentistry in the late 1700s and porcelain jacket crowns were developed in the early 1900s. Consequently, there are three types of porcelains which are commonly used in dentistry. One particular type is used to make denture teeth. This porcelain is called high fusing because it fuses at approximately 1300 to 1350 °C. First type of porcelain is known as low fusing porcelain and has a fusion range of 850 to 1050 °C and is used as a veneer for metal in dental restorations. A medium fusing porcelain (fusing point of 1100 to 1250 °C) is used for the anterior porcelain jacket crown and has properties intermediate between those of the low and high fusing porcelain types (Ferracane, 2001).

Dental ceramic is an inorganic compound with non metallic properties such as aluminum, calcium, titanium and zirconium that is formulated to produce the whole or as a part of a ceramic based dental prosthesis. Ceramics are defined as materials with regularly aligned mineral crystal molecules. This is quite an important consideration in using ceramic as implant material, for the regular atomic lattice is strongly related to it is biological compatibility without the ionic release that usually induces host immune reactions as well as it is biomechanical compatibility with extremely high strength , hardness and good mechanical bonding. In the 1960s, alumina (Al_2O_3) and Zirconia (ZrO_2) was first introduced as “bioceramic”. They are bioinert. Naturally, it was highly compressive but had low tensile strength and high brittleness (Suh, 1998).

Fixed partial denture using full ceramic has enhanced biocompatibility and aesthetics when compared to metal-ceramic restorations. Ceramics possess strength and aesthetics of the restorative. Generally, ceramics have three major applications in dentistry: (i) ceramic for ceramic-metal crowns and fixed partial dentures, (ii) full ceramic crowns, inlays, onlays and veneers, when aesthetics is a priority and (iii) ceramic denture teeth. Alumina-based ceramic, has high strength, high modulus of elasticity of about 350 MPa and high fracture toughness in the range of 3.5 to 4 MPa (Powers and Sakaguchi, 2006).

2.3.1 (c) Composite and Filler

Composite is a mixture of two or more materials from different categories and dental composites are a combination of a ceramic and a polymeric materials. Bhat and Nandish, (2006) defined composite as the compound of two or more distinctly different materials with properties that are superior or intermediate to those of individual components. Fillers are additives in matrix material such as polymer, metal or any other similar materials. Basically, a composite is considered to be any multiphase material that exhibit a significantly proportion of the properties of both constituent phases, matrix phase and dispersed phase, such that a better combination of properties is realized (Callister, 2000).

Modern technology places challenging demands on the performance capabilities of materials for new applications. The introduction of composite materials changed the world especially in the field of engineering. It is becauce most of composite materials have been created to show improved combinations of mechanical characteristics such as stiffness, toughness and high temperature strength that cannot be met by the conventional materials such as ceramics, metal or polymers (Callister, 2000).

Metal-ceramics popularly used in prosthodontics are characterized by their refractive nature, hardness, susceptibility to clinical fracture and chemical inertness. Metal ceramic restoration has metal substructures fused over with ceramic veneer that is mechanically and chemically bonded. The prosthesis possesses brittleness, lesser edge strength, high hardness and more impact. Logen in 1985 fused porcelain to platinum post to produce a metal ceramic crown. The most successful composite biomaterials used as restorative material or dental cement are BIS-GMA quartz/silica filler and PMMA-glass fillers. Also composite materials particularly polymeric material composite, are used in dental applications (Davis, 2003). Metal-ceramic restorations have a much lower risk of fracture in comparison with all other ceramic crowns and bridges. Further advantages include outstanding aesthetics and longevity. Metal-ceramic crowns and bridges show success rates of 97% during the first seven and a half years. After 10 years, 95% of the metal-ceramic restorations are still present in the oral cavity (Schmider, 1998). Inorganic fillers are typically used in filling composites and sometimes also in adhesive resins. Most commonly used fillers are silicon dioxide (SiO_2), zirconium dioxide (ZrO_2) and different silicates (Garcia et al., 2006).

Dental composite offer the best possibility for developing replacement materials by providing superior characterization and low cost compared with dental ceramic and metal alloy (Ruddell et al., 2002). Considering the benefits of the composite, Mangalaraja et al., (2003) developed composite from addition of zirconia to alumina in order to improve the fracture toughness of alumina since alumina has low fracture toughness and high hardness. Base metal alloys are more popular for removable partial denture base construction. This is due to their low cost and superior mechanical properties (Hassain, 2004).

Ceramic is also used in combination with acrylic and other polymers which helps improve the mechanical properties. McLean (1976) developed a stronger platinum bonded alumina crown (Hassain, 2004). According to Manappallil (2003) the ideal removable denture is usually made of a combination of metal and plastic. Ostrovoi et al., (2005) found that the strength and fracture toughness with the addition of composite such as metal-ceramic prostheses resulted in the significant improvement in the properties. Another study by Cylne and Jones (2007) using ceramic composite material also resulted in the increase in the toughness of the product. The study by Adrian et al., (2009) demonstrated that the main role in determining the composite's properties is played by the interface fiber-polymer or/and filler's particles polymer. Using fillers extends the material and reduces its cost (Concise Enclopedia of Polymer Science and Technology, 2007). Basically, dental composites comprise three phases (Mortensen, 2007; Bhat and Nandish, 2006);

i. An organic phase, the matrix.
ii. A dispersed phase, the filler, e.g. particles or fibers; and
iii. An interfacial phase, the coupling agents.

The properties and volume fraction of individual phases are important for composites. Usually the matrix phase is the continuous phase and the other phase is said to be the dispersed phase. Composites are often classified based on the shape or nature of the dispersed phase e.g., particle-reinforced, whisker-reinforced, or fiber-reinforced composites (Askeland and Phule, 2003).

Glass fiber reinforced composite (FRC) were introduced to dentistry in the late 1990s and were advertised as a universal aesthetic material for nearly every dental indication. Fiber reinforced materials combine the basically different mechanical properties of fibers and a matrix. The fibers demonstrate high tensile strength, a high tensile modulus and low shear strength, while the matrix is characterized by high toughness. In an optimum fiber reinforced material, the tensile strength of the fiber is combined with the high toughness of the matrix. Low weight combined with high strength is also required in removable denture prosthetics for PMMA resin have proved to be particularly suitable due to their resistance to the oral environment. Since complete dentures may fracture, glass-fiber reinforcements have been discussed by dental group for decades (Grotsch, 1965a; Grotsch, 1965b; Vallittu, 1996). Research mainly focused on the reinforcement of PMMA denture base materials by means of fibers. Most scientists found that the increased mechanical strength values can be achieved by means of reinforcement, with the fracture resistance enhancing with the increasing fiber content.

According to researchers Bhat and Nandish (2006) the size of filler in dental composite determines surface smoothness of the restorations depending on the category; concentration and particle size distribution of the filler used in composite materials which are also the major factors controlling properties. The properties that are improved by addition of fillers are:

- Mechanical properties such as compressive strength, tensile strength, modulus of elasticity, hardness, if the filler is chemically bonded to resin matrix (coupling agent).
- Reduction in coefficient of thermal expansion which reduces thermal shrinkage.
- Less heat evolved during polymerization.