A STUDY ON THE EFFECT OF α-CORDIERITE CERAMIC POWDER AS A FILLER IN DENTURE BASE POLY (METHYL METHACRYLATE)

BY

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TABLE OF CONTENTS

		Page
ACKNOWLEDGEMENTS		ii
TABLE OF CONTENTS		iii
LIST OF TABLES		ix
LIST OF FIGURES		x
LIST OF ABBREVIATIONS		xiv
LIST OF MINE SYMBOLES		xvi
ABSTRAK		xvii
ABSTRACT		xviii
	CHAPTER 1: INTRODUCTION	
1.0	Background	1
1.1	Ideal Denture Base Materials	2
1.2	Problem Statement	4
1.3	Research Objectives	7
1.4	Arrangement of The Thesis	8
	CHAPTER 2: LITERATURE REVIEW	
2.0	Background	10
2.1	History and Development of Denture Base Materials	10
2.2	Classes of Materials Used in Dentistry	18
	2.2.1 Metals and Alloys	19

2.2.2 Ceramics 20

2.2.3 Composites 20

2.2.4 Polymer 22

2.3 Types of Denture Base Materials 22

2.3.1 Composition of Type 1 and Type Materials 23

2.3.2 Structure of Acrylic Resin MMA and PMMA 26

2.3.2 (a) Methyl Methacrylate (MMA) 26

2.3.2 (b) Poly (Methyl Methacrylate) (PMMA) 27

2.4 Fillers 28

2.5 Silane Coupling Agent and The Effect on Fillers 31

2.6 Molecular Weight 33

2.7 Cross-linking 34

2.8 Mixing and Curing (Heat Curing Materials) 35

2.8.1 Mixing of Dental Base Materials 35

2.8.2 Curing of Dental Base Materials 37

2.9 Reinforcing of PMMA 38

2.9.1 The Reinforcing of PMMA with Fiber 39

2.9.2 The Reinforcing of PMMA with Ceramic Powder 41

CHAPTER 3: RESEARCH METHADOLOGY

3.0 Background 44

3.1 First Stage: Preparation of α-cordierite Ceramic Powder 44

	3.1.1 Raw Materials	44
	3.1.2 Method	45
3.2	Second Stage: Incorporating of The α-Cordierite Powders as Filler Into PMMA Powder	48
	3.2.1 Matrix	48
	3.2.2 Reinforcing Filler	48
	3.2.3 Coupling Agent	48
3.3	Methodology	49
	3.3.1 α-Cordierite Filler Treatment	49
	3.3.2 Sample Preparation	49
3.4	Physical and Mechanical Characterizations	50
	3.4.1 Physical Properties	50
	3.4.1 (a) Filler Particle Size and Distribution Analysis	50
	3.4.1 (b) X-ray Diffraction	51
	3.4.1 (c) Scanning Electron Microscopy (SEM) and Energy – Dispersive X-ray (EDX)	51
	3.4.1 (d) X-ray Fluorescence	51
	3.4.1 (e) Weight and Volume Fraction Determination Ashing Test	52
	3.4.1 (f) Determination of Composites and Filler Densities	53
	3.4.1 (g) Fourier Transform Infra Red Spectroscopy FTIR	53
3.4.2	Mechanical Properties	54

	3.4.2 (a) Fracture Toughness	54
	3.4.2 (b) Tensile Test	56
	3.4.2 (c) Flexural Test	56
3.5	Vickers Hardness Test (VHN)	57
3.6	Environmental Properties	59
	3.6.1 Water Absorption	59
	3.6.2 Simulated Body Fluid (SBF) Absorption	59
	3.6.3 Solubility in Simulated Body Fluid (SBF)	61
	3.6.4 Effect of Water Absorption	61
	3.6.4.1 Flexural Properties	61
	3.6.5 Effect of Simulated Body Fluid (SBF) Absorption	61
	3.6.5 .1 Flexural Properties	61
3.7	Thermal Properties	62
	3.7.1 Thermo Gravimetric Analysis (TGA)	62
3.8	Radiopacity Test	62
	CHAPTER 4 : RESULTS AND DISCUSSION	
4.1	Analysis on the Synthesized of α-Cordierite Ceramic Powder as Reinforcement Filler	64
	4.1.1 Filler Particle Size Analysis	64
	4.1.2 Scanning Electron Microscopy & EDX	67
	4.1.3 X-Ray Fluorescence (XRF)	69

4.2	Analysis of PMMA / α-Cordierite Composite	69
	4.1.1 Determination of Filler Content by Ashing	69
	4.2.2 Effect of Filler Content on The Density of The PMMA Composite	70
	4.2.3Confirmation of Silane Coupling Agent Treatment by FTIR	71
4.3	The Effect of Filler Content and Silane Coupling Agent on mechanical Properties of α-Cordierite Filled PMMA Matrix	73
	4.3.1 Fracture Toughness	74
	4.3.2 Tensile Properties	76
	4.3.3 Flexural Properties	80
	4.3.4 Scanning Electron Microscopy (SEM)	83
4.4	Hardness	89
4.5	Thermal Characterization	90
4.6	Environmental Properties	92
	4.6.1 Water Absorption	92
	4.6.2 Absorption of Simulated Body Fluid (SPF)	95
	4.6.3 Solubility in Simulated Body Fluid (SPF)	98
4.7	Effect of Environmental Exposure on Mechanical Properties	100
	4.7.1 Effect of Water Exposure on Flexural Strength	100
	4.7.2 Effect of Simulated Body Fluid (SBF) Exposure on Flexural Strength	102
	4.7.3 Scanning Electron Microscopy (SEM)	103

4.8 Radiopacity Evaluation Test 110

CHAPTER 5 : CONCLUSION AND RECOMMENDATION

5.1 Conclusions 112

5.2 Recommendations 113

REFERENCES 114

Appendix 1 126

LIST OF TABLES

Table 2.1	Classification of composites according to filler particle size.	21
Table 2.2	Classification of denture base polymers according to ISO1567.	23
Table 2.3	Composition of acrylic denture base materials.	24
Table 3.1	Raw Materials for the Preparation of α-cordierite ceramic powder.	44
Table 3.2	The chemical composition of the sodium lactate compound (SBF) as provided by the supplier.	60
Table 4.1	The results of the XRF analysis of α-cordierite.	69
Table 4.2	Filler content of various composite formulations.	70
Table 4.3	Effect of filler content on the density of the PMMA composite compared to that of the PMMA matrix.	71
Table 4.4	The effect of filler loading on the tensile properties of PMMA/ α-cordierite composite	77
Table 4.5	The effect of incorporating treated and untreated filler composite on hardness surface	90
Table 4.6	The Solubility values of α-cordierite filled PMMA matrix compared to that of the PMMA matrix after 28 days immersion in SBF at 37 ˚C	100

LIST OF FIGURES

Figure 2.1	A set of the dentures made from wood.	11
Figure 2.2	Ivory denture with human teeth.	12
Figure 2.3	Ivory denture, C1760.	12
Figure 2.4	Prosthesis carved by hand in the late1700s- early 1800s.	13
Figure 2.5	The plate of these dentures are made of hippopotamus Ivory, the interior teeth are human teeth.	13
Figure2.6	Front and rear view of gold partial upper denture with carved ivory teeth reputedly made by William Duke.	14
Figure 2.7	Upper and lower gold dentures with Porcelain anterior tube teeth fitted over posts Soldered into the plates, with ivory posterior Masticating surface and with gold spring.	15
Figure 2.8	Porcelain teeth with soft silver base, retained by springsc 1850.	16
Figure 2.9	Partial dentures made from Aluminium latter half of the 19th century.	16
Figure 2.10	Full upper denture made from vulcanite.	17
Figure 2.11	Cobalt chromium denture.	18
Figure 2.12	Complete acrylic denture.	18
Figure 2.13	Partial upper acrylic denture.	18
Figure 2.14	The structural formula of benzoyl peroxide, a general used initiator.	24
Figure 2.15	Structure formula of MMA.	27
Figure 2.16	Structure formula of PMMA.	28
Figure 2.17	Diagram for the crack propagation passing around the equator of the unsilanized filler compared with the crack process for the silanized specimen.	33

Figure 2.18	The structural formula of ethylene glycol dmethacrylate (EGDMA).	34
Figure 3.1	Heating time function of mixed powder to form frit.	45
Figure 3.2	Calcination time of milled powder to form α-cordierite.	46
Figure 3.3	Flow chart shows preparation of the α-cordierite powders	47
Figure 3.4	Ashing test temperature profile.	53
Figure 3.5	Representation of SEN-B Specimen.	55
Figure 3.6	Samples tested by X-ray radiography for Radiopacity.	63
Figure 4.1	a) Frit with pieces of alumina crucible after quenching in distilled water. b) Frit (prior subjected to two milling processes to produce powder).	64
Figure 4.2	Result analysis report of α-cordierite particle size.	66
Figure 4.3	The micrograph of α-cordierite ceramic powder at 1000x shows the particle size.	68
Figure 4.4	The EDX graph of α-cordierite ceramic powder.	68
Figure 4.5	FTIR Spectra of α-cordierite ceramic powder; (B) Before Silane Treatment (A) After Silane Treatment.	72
Figure 4.6	The effect of filler loading and coupling agent on the fracture toughness of α-cordierite filled PMMA matrix.	74
Figure 4.7	SEM Micrograph of the irregular shapes of filler particles.	78
Figure 4.8	The effect of filler loading and coupling agent on the flexural strength of α-cordierite filled PMMA matrix.	82
Figure 4.9	The effect of filler loading and coupling agent on the flexural modules of α-cordierite filled PMMA matrix.	82
Figure 4.10	SEM micrograph of the fracture surfaces of the PMMA matrix at1000x magnification.	85

Figure 4.11: (a)	SEM micrograph of the fracture surface of the 5 w% (α-cordierite -filled) PMMA matrix at1000x magnifications.	85
Figure 4.11:(b)	SEM micrograph of the fracture surface of the 5 w% (treated α-cordierite -filled) PMMA matrix at 1000x magnification.	86
Figure 4.11:(c)	SEM micrograph of the fracture surfaces of the 5 w% (untreated α-cordierite-filled) PMMA matrix at 1000x magnification.	86
Figure 4.12:(a)	SEM micrograph of the fracture surfaces of the 10 w% (treated α-cordierite-filled) PMMA matrix. At 1000x magnification.	87
Figure 4.12:(b)	SEM micrograph of the fracture surfaces of the 10 w% (untreated α-cordierite -filled) PMMA matrix.	87
Figure 4.13:(a)	SEM micrograph of the fractured surface of the 15 wt% (treated α-cordierite -filled) PMMA matrix.	88
Figure 4.13:(b)	SEM micrograph of the fracture surfaces of the 15 w% (untreated α-cordierite -filled) PMMA matrix.	88
Figure 4.14	TGA Curves showing the thermal degradation temperature of the PMMA composites compared to PMMA matrix.	92
Figure 4.15	Water absorption curves of α-cordierite filled PMMA matrix compared to that of the PMMA matrix after 28 days immersion at room temperature.	95
Figure 4.16	SBF absorption curves of á-cordierite filled PMMA matrix compared to that of the PMMA matrix after 28 days immersion at 37 ˚C.	98
Figure 4.17	Effect of water absorption on flexural strength of PMMA matrix and PMMA α-cordierite composites compared to the same samples before exposure.	101
Figure 4.18	Effect of SBF exposure on flexural strength of PMMA matrix and PMMA α-cordierite composites compared to the same samples before exposure.	103
Figure 4.19	SEM micrograph of fracture surface of PMMA matrix after 28 immersion days at different magnifications.	106

Figure 4.20	SEM micrograph of fracture surface of α-cordierite 5 wt% filled PMMA matrix after 28 immersion days at different magnifications.	107
Figure 4.21	SEM micrograph of fracture surface of α-cordierite 10 wt% filled PMMA matrix after 28 immersion days at different magnifications.	108
Figure 4.22	SEM micrograph of fracture surface of α-cordierite 15 wt% filled PMMA matrix after 28 immersion days at different magnifications.	109
Figure 4.23	X-ray image of the flexural samples compared to the aluminium plate. (A) Aluminium plate (B) PMMA matrix (C) PMMA + α-cordierite 5 wt % (D) PMMA + α-cordierite 10 wt % (E) PMMA + α-cordierite 15 wt %	111

LIST OF ABBREVIATIONS

ASTM	American Society for Testing and materials
$BaTiO_3$	Barium Titanate
BIS-EMA	An ethoxylated bisphenol a glycoldimethacrylate
BIS-GMA	Bis-(2-Hydroxypropyl)-Methacrylate
BPO	Benzoyl Peroxide
EDX	Energy Dispersive X-Ray Spectroscopy
EGDMA	Ethylene Glycole Dimethacrylate
FTIR	Fourier Transform Infra Red Spectroscopy
h	Hour
HA	Hydroxyapatite
HDPE	High Density Poly ethylene
ISO	International Standardization Organization
Min	Minute
MMA	Methyl Methacrylate
MW	Molecular Weight
ODP	Opaque Dental Porcelain
PBM	Planetary Ball Milling
PBR	Powder to Ball Ratio
PCDMA	Polycarbonate dimethacrylate

P/L	Powder to Liquid Ratio
PMMA	Poly (methyl methacrylate)
RPM	Rotation per Minute
SBF	Simulated Body Fluid
SEM	Scanning Electron Microscope
SEN-B	Single Edge Notch Bending Test
SG	Specific Gravity
TA	Thermal Analysis
TGA	Thermogravimetric Analysis
VHN	Vickers Hardness Number
XRD	X-Ray Diffraction
Wt	Weight
ZO_2	Zirconium Oxide

LIST OF MINE SYMBOLES

γ-MPS	[3-(methacryloxy) propyl trimethoxysilane]
ρ	Density
ρ_c	Density of composite
ρ_f	Density of filler
ρ_w	Density of water
a	Notch length
b	Specimen width
d	Specimen thickness
GPa	Gegapascal
K_{IC}	The stress intensity factor
L	Support span
MPa	Megapascal
P	Load
V_f	Volume fraction
W_1	Sample weight in air
W_2	Sample weight in water
Y	Geometrical correction factor

Kajian ke atas Kesan Serbuk α-Kordierit Sebagai Pengisi di dalam Tapak Gigi Palsu Poli (Metil Metakrilat)

ABSTRAK

Tujuan penyelidikan ini ialah untuk mengkaji kesan serbuk seramik α-kordirit sebagai bahan pengisi penguat dalam poli metil metakrilat (PMMA). Dalam kajian ini formulasi yang digunakan termasuklah PMMA, serbuk seramik α-kordirit, benzoil peroksida (BPO) sebagai bahan pemula, metil metakrilat sebagai monomer dan etilena glikol dimetil akrilat (EGDMA) sebagai agen sambung-silang. α-kordirit telah dirawat dengan agen pengkupel silana (γ-MPS) sebelum dicampur dengan serbuk-serbuk komponen (PMMA, BPO). Sampel-sampel disediakan berdasarkan piawaian penggunaan makmal pergigian. Dari keputusan, kemasukan pengisian α-kordirit ke dalam matriks PMMA menghasilkan peningkatan modulus tegangan, kekuatan fleksural, dan modulus keliatan dengan penurunan sedikit kekuatan tegangan. Formulasi yang mengandungi bahan pengisi terawat dengan γ-MPS menunjukkan sifat mekanikal yang lebih tinggi berbanding yang tidak dirawat. Kesan kandungan bahan pengisi terhadap kekerasan permukaan telah dikaji. Keputusannya menunjukkan peningkatan kekerasan permukaan sampel komposit PMMA. Penyerapan dan kelarutan di dalam air dan cecair jasad simulasi (SBF) mendedahkan bahawa sampel berbahan pengisi menunjukkan penyerapan sedikit lebih tinggi berbanding sampel tanpa pengisi. Walau bagaimanapun, sampel-sampel berpengisi menunjukkan kelarutan yang lebih rendah daripada sampel tanpa pengisi. Selain dari itu, kekuatan fleksural adalah berkurangan sebagai fungsi tempoh rendaman di dalam air dan SBF. Akhirnya, keradiopasiti komposit PMMA adalah meningkat dengan bertambahnya pengisi yang dimasukkan.

A STUDY ON THE EFFECT OF α-CORDIERITE CERAMIC POWDER AS FILLER IN DENTURE BASE POLY (METHYL METHACRYLATE)

ABSTRACT

The aim of this research is to investigate on the effect of α-cordierite ceramic powder reinforcement filler in poly methyl methacrylate (PMMA). In this study the formulation used include PMMA, α-cordierite ceramic powder, benzoyl peroxide (BPO) as the initiator, methyl methacrylate as the monomer and ethylene glycol dimethyl acrylate (EGDMA) as the cross-linking agent. The α-cordierite was treated with a silane coupling agent (γ-MPS) before it was mixed with the powder components (PMMA, BPO). The samples are prepared according to the standard dental laboratory application. The incorporation of α-cordierite filler into PMMA matrix resulted in an increase tensile modulus, flexural strength and modulus and fracture toughness with slightly reduction in tensile strength. The formulations which contained treated filler with γ-MPS had shown much higher mechanical properties than that of the untreated samples. Also, the results showed an improvement on surface hardness of PMMA composite. Absorption in water and simulated body fluid (SBF) revealed that the filled samples showed slightly higher absorption as compared to the unfilled samples. However, the filled samples showed lower solubility than the unfilled samples. Apart from that, the flexural strength was decreased as a function of the period of immersion in water and SBF. Finally, the radiopacity of PMMA composite was improved when the filler percentage increased.

CHAPTER 1
INTRODUCTION

1.0 Background

When an oral tissue is lost, dental professionals will attempt to replace it with a dental material. The replacement material mimics the function of the lost oral tissue and must withstand the same harsh environment. However, theses artificial parts would have to replace its appearance as well. In the case of losing the teeth either by illness or accident, esthetics and function requirements are very important. And it is for this reason that dentists are trying, in various ways and means to satisfy patients (Gladwin and Bagby, 2000).

Removable denture is commonly used to replace missing teeth and its base materials have always been a matter to the dentists in their research and studies (Khindria et al., 2009). Denture based material should have many key physical characteristics. Some of these properties include good esthetics, biocompatibility, radiopacity, ease of repair, high bond strength with available denture teeth and should possess suitable physical and mechanical properties. In addition the denture base must be strong enough to allow the prosthesis to withstand functional and parafunctional masticators forces (Meng and Latte, 2005).

There are many definitions for denture base. McCabe and Walls, (2008) defines denture base as the part of the denture that covers the soft tissue of the mouth. It is commonly made of resin or a combination of resins and metal, also called saddle and does not include the artificial teeth.

Poly (methyl methacrylate) PMMA has replaced prior denture materials such as vulcanite, nitrocellulose, phenol formaldehyde, vinyl plastics, and porcelain. By 1935, PMMA resin was introduced as a material for removable dentures bases and remained the most commonly used denture material because of its higher physical, biological, and esthetic properties. Pure PMMA resin is a colorless and transparent solid. It may be colored to give any shade and degree of translucency, as suitable esthetics for dental applications. A denture base made from PMMA has good dimensional stability, and adequate strength. In addition, it matches the appearance of normal soft tissues (Cheng and Chow, 1999 & Radzi et al., 2007).

Although PMMA's is considerably used as a denture base material, the fracture of acrylic denture base is still a matter of concern. One of the factors that can lead to the fracture of acrylic denture base material is the low resistance to impact, flexural or fatigue or poor manufacturing procedure. These factors necessitate one to enhance the strength of denture base materials and to produce dentures with better properties, in order to increase the clinical longevity. There are many approaches, which can be used to improve the strength of PMMA (Geramipanah et al., 2008). One of the approaches is through the addition of a cross-linking agent such as polyethylene glycol dimethacrylate to produce a poly-functional monomer. Another approach is by reinforcing of the denture base with rubber, metal phase and metal wire, or fiber (Hamza et al., 2004).

1.1 Ideal Denture Base Materials

In the 21st century, dentist and material scientists complete their studies for the ideal restorative material. And they found that the ideal denture base materials are supposed to provide the mechanical, physical, chemical, biological and miscellaneous properties.

- **Mechanical properties**

  Fit material to construct denture base should be rigid so it must has high value of modulus of elasticity. The denture base should have enough flexural strength to resist fracture. Fracture of denture base occurs by a fatigue mechanism, sometimes small crack in denture resulting in fracture. Therefore, the denture base material should have an adequate fatigue life and a high value of fatigue limit. There is a danger of fracture if the denture is accidentally dropped on a hard surface or by a violent accident involving the facial area. The material should have a resistance to impact fracture (Chandra et al., 2000).

- **Physical properties**

  An ideal denture base material should be capable of matching the appearance of natural oral soft tissues. A polymer which is used to make a denture base should have a value of glass transition temperature which is high enough to prevent softening and distortion during use. While a normal temperature in the mouth varies only from 32˚C to 37˚C, account must be taken of the fact that patients take hot drinks at temperature up to 70˚C and sometimes clean dentures in boiling or very hot water. The base should have good dimensional stability in order that the shape of the denture does not change over a period of time. The denture should also be as light as possible so, the material should have a low value of specific gravity (McCabe and Walls, 2008).

- **Chemical properties**

  A denture base material should be insoluble in oral fluids and should not absorb water or saliva because this may change the mechanical properties of the material and cause the denture to become unhygienic (Koudi and Patil, 2007).

- **Biological properties:**

  In the unmixed or uncured states the denture base material should not be harmful to the technician involves in its handling. Also it should be non-toxic and irritant to the patient.

- **Miscellaneous properties**

  An ideal denture base material should be inexpensive and have a long shelf life, easy to manipulate and enable to fabricate without having to resort to using expensive processing equipment and it should be easy to repair (McCabe and Walls, 1998).

1.2 Problem Statement

As mentioned previously, the most commonly used material for the fabrication of removable dentures base is poly (methyl methacrylate) PMMA. This is because of its attractive advantages which include simple processing technique, optical properties, economy, color stability, adequate strength, free from toxicity, pigmented and other physical properties which make it the material of choice for the fabrication of denture base (Narva et al., 2005 & Khindria et al., 2009). Although it is popular, PMMA is still far from ideal denture base materials requirements (Marei, 1999). It showed that poor mechanical requirements of prosthesis (Jagger et al., 1999). Once inside the mouth, poly methyl methacrylate denture base is at risk of facing a lot of different kinds of stresses. For example, repeated masticatory forces, which guide to fatigue phenomena. Thus, fracture of denture base often occurs as a result of fatigue mechanism and small flexural stresses through a period of time (Elshereksi et al., 2009).

Several studies have investigated on the incidence of dentures fracture. Many methods in improving PMMA's strength and toughness have been investigated. Most of these methods have not been adopted yet due to the need for specialized processing equipment or increased laboratory time due to more complicated procedure and the cost was so expensive (Franklin et al., 2004).

Many researchers reported that the incorporation of ceramic powder as filler can enhance the properties of denture base material. Elshereksi (2006) studied on the effects of barium titanate ceramic powder as filler in PMMA denture base and concluded that ceramic filler improved in most the mechanical properties of denture base material. Another research made by Mohamed (2005) who studied the effect of ceramic fillers incorporation in the PMMA and which improved the mechanical properties of the composite. Gladwin and Bagby (2000) reported that, ceramic materials are chosen as fillers for their special properties. The strong hard ceramic materials have low coefficients of thermal expansion (CTE). When they are mixed with polymers, the resulting dental composites have coefficients closer to tooth structure than the polymers on which they are based. Because a composite has percentage of polymers in the system, there is a reduction of polymerization shrinkage when the material sets. In addition, the material used to make a denture base should have a low specific gravity value as the denture base should be as light as possible (McCabe and Walls, 2008).

Filler contains of glass and ceramic particles that give radiopacity to the composite. These particles may differ significantly in their concentration and composition, and hence the radiopacity of composites can be improved (Tirapelli et al., 2004). Based on the above mentioned reasons, therefore, α-cordierite can also be used. It has exclusive properties (Shi et al., 2001). The α-cordierite is hard, nonmagnetic, thermal and electrical insulators, oxidation resistant, chemically stable, high melting point, very low CTE, low specific gravity (~ 2.5 g/cm^3), excellent thermal shock resistance and stable at elevated temperature (Camerucci et al., 2001, Yamuna et al., 2004 and Banjuraizah et al., 2009) .

In the present study, the goal is to find ways for improving the mechanical, physical properties and radiopaque of denture base material, namely through the incorporation of α-cordierite ceramic as a reinforcement filler. The target of this inclusion is to improve the ability of PMMA to absorb x-ray for achieving sufficient level of radiopacity. Moreover, the usage of α-cordierite ceramic in denture base as reinforcement has never used before.

1.3 Research Objectives

Denture base polymer should have suitable resilience and strength for biting and chewing impact forces and be stable under all condition of service, including loading and thermal shocks. In addition, not only it should be very light in weight but also it must maintain the appearance and its color without changing even for the long time of uses (Bhola et al., 2010).

Although PMMA is preferred material to produce denture base, it is still need to address some problems such as fatigue failure, impact failure, residual monomer, porosity and water sorption. These problems has led to several ways to improve PMMA‘s mechanical properties (Radzi et al., 2007).

The objective of this research is to fabricate a polymer denture base with improved properties and in the same time it should be suitable for the patient requirements. The study will focus on these following lines:

1- To prepare α-cordierite ceramic powder via glass crystallization methods.
2- To investigate the effect of α-cordierite content and silane coupling agent treatment on the mechanical properties of α-cordierite ceramic filled PMMA composite.
3- To study the physical and thermal properties of α-cordierite ceramic filled PMMA composite.
4- The effect of filler loading on water and SBF absorption, solubility into simulated body fluid (SBF) will be investigated. Moreover, study the effect of water and SBF exposure on the flexural properties of denture base materials.
5- To investigate the effect of α-cordierite ceramic powder on the radiopacity of denture base material.

1.4 Arrangement of the Thesis

Chapter 1 includes the basic information about denture base materials like definition, classification, the characterization of ideal denture base material, over view on the history of fabrication of denture base, problem statement, research objectives and the general flow of the whole research program were also outlined.

Chapter 2 explains the evolution of dental materials. And all the types of materials used in dentistry. In addition, study the effect of some factors which could apply to improve fillers properties. Apart from that most of the information regarding polymer especially used with removable denture base and the influence some of the factors on PMMA properties. It provides and looks at various literatures on denture base materials and especially that are closely related to this research steps.

Chapter 3 details of all work steps on the methodology followed in the research project. In addition several charts, pictures, methods, tests as well as all experimental techniques employed in the study were given.

Chapter 4 aims to explain and discuss all the results through laboratory work in this research. All data graphs and charts are depicted here as a result from the effect of several factors on polymer matrix. It depicts the effect of filler content of α-cordierite on the mechanical and thermal properties of the composite compared to the PMMA matrix. Scanning electron microscopy (SEM) photographs and discussing all analysis would be carried out based on the data collated. FTIR analysis was reported to investigate the effect of treated coupling agent on the filler surface. Furthermore, it reports the effect of filler loading on absorption of water and (SBF), solubility in SBF and the effect of environmental exposure on flexural strength. The influence of ceramic filler on the radiopacity of denture base would be determined and compared with that of the aluminium sheet.

Chapter 5 draws the conclusion on the advantages and disadvantages of the method, and some suggestions for future work.

CHAPTER 2

LITERATURE REVIEW

2.0 Background

In recent years novel technology depends on materials, which are substances of which something is composed or made. Some of the commonly encountered materials used are concrete, steel, glass, paper, rubber, copper, wood, plastic, aluminum, and brick (Smith, 1990). The science of dental materials is involved in a study of the composition and properties of materials and the way in which they interact with the environment in which they are placed (McCabe and Walls, 2008). Dental materials science is a basic science, which deals with mechanical, biological and physical properties of dental materials (Hussain, 2004). It is like a bridge between the basic and clinical sciences. While dental materials are used in the production of dental bases, restorations, impressions, prostheses, etc (Ferracane, 2001).

Nallaswamy (2003) defines dentures base as a part of the denture which rests on the oral mucosa and to which teeth are attached. Usually, it is made of acrylic resin. The denture base forms the foundation of the denture. It helps to distribute and transmit all the forces action on the denture teeth to the basal tissues. It is the part of the denture, which is responsible for retention and support.

2.1 History and Development of Denture Base Materials

In 8^{th} century, the Japanese made the first wooden denture. They were carved from a single piece of wood, box and cherry were used at that time because of it has sweet smelling with natural teeth were fixed with the help of screws. Figure 2.1 shown set of the dentures made from wood.

Figure 2.1: A set of the dentures made from wood.
http://www.namibiadent.com/History/HistoryDentistry.html

By the 17th century, Pierre Fauchard developed many prosthetic methods, used human teeth or teeth made from elephant ivory or hippopotamus in the denture. Also, he carved dentures from ivory or bone. Bone showed superior dimensional stability than wood. While ivory was stable in oral environment, and offered significant esthetics but it was very expensive. Fauchard made a denture by measuring individual arches with a compass and cutting bone to fit these arches. In other techniques a piece of wax was partially carved and molded to the desired shape, so it reproduced missing teeth and fit closely against ridge and palate. By craftsman, this model was used for reproducing bone or ivory denture and it was a long time just to carve a denture from ivory or bone (Gladwin and Bagby, 2000). Figures 2.2 - 2.4 show ivory dentures with human teeth, upper denture set made from hippopotamus ivory and prosthesis carved by hand, respectively. While, figure 2.5 shows dentures are made of hippopotamus ivory and human teeth.

Figure 2.2: Ivory denture with human teeth.
http://www.namibiadent.com/History/HistoryDentistry.html

Figure 2.3: Ivory denture, C1760. This upper denture set is made from hippopotamus ivory.
http://www.namibiadent.com/History/HistoricPictures.html

Figure 2.4: Prosthesis carved by hand in the late1700s- early 1800s.
http://www.namibiadent.com/History/HistoricPictures.html

Figure 2.5: The plate of these dentures are made of hippopotamus Ivory, the interior teeth are human teeth.
http://www.namibiadent.com/History/HistoricPictures.html

Khindria et al. (2009) mentioned about the development of more successful impression process by Pfaff and Frederick. Their method was to take wax impression then it removed. After that the plaster casts were made from them. This method appears to have been unknown even to Fauchard, who followed Pfaff techniques. Uses of pigment, was by Tomes when a block of ivory was shaped with a drill and engraving blade, using a pigment to detect high spots as a base was made to fit the casts also Tomes invented his a patented machine.

A century later, French dentist Etienne Bourdet (1755) made the first gold base punctuated with small holes like the sockets of teeth. The gold did not sit on the crest of the ridge as the recent denture base however, was formed as a shallow cup. After discovery of the impression technique using softened wax and plaster of Paris, models were fabricated and gold plates could be hammered and swaged to get more correct adaptation (Donaldoson, 1980). Figure 2.6 show gold partial dentures with carved ivory teeth made by William Duke.

Figure 2.6: front and rear view of gold partial upper denture with carved ivory teeth reputedly made by William Duke (Donaldoson, 1980).

In the year 1774 Alexis Duchateau made the first denture from porcelain, because of he was not a dentist so his effort unsuccessful. After that he teamed up with Parisian Nicholas who contained manufacture of denture from porcelain in 1788. Porcelain denture had several advantages over animal substances. Nicholas denture was popular until 1808 when an Italian dentist Giuseppangeio made teeth attached to the gold denture by a small platinum hook. It was the most significant event in the history of dentistry (Donaldoson, 1980). Figure 2.7 shows upper and lower gold dentures with porcelain teeth.

Figure 2.7: the upper and lower gold dentures with Porcelain anterior tube teeth fitted over posts Soldered into the plates, with ivory posterior Masticating surface and with gold spring (about 1865) (Donaldoson, 1980).

Many discoveries and continued with the experiences of many different materials were used. Figure 2.8 shows porcelain teeth with silver base retained by springsc in 1850. Moreover, Loomis 1854 made the first porcelain denture with artificial teeth. Around 40 years later, Charles (1890) fabricated porcelain dentures with platinum bases. In 1962 Alexander made dentures from one piece of porcelain.

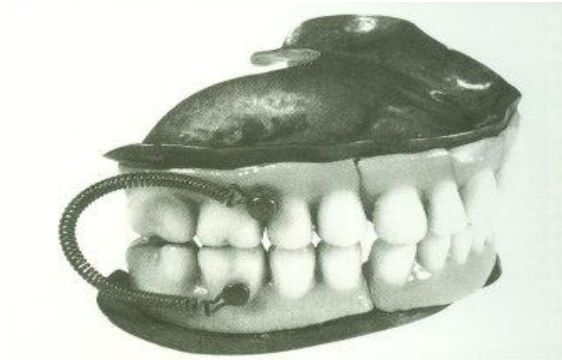

Figure 2.8: Porcelain teeth with soft silver base, retained by springsc 1850.
http://www.doctorspiller.com/Dentures.htm

By 19th century, there were many materials used to make dentures such as, gutta percha (1851), rose pearl (1860) and aluminum (1867). Figure 2.9 shows partial dentures made from aluminium later half of the 19th century. In 1839, Nelson Goodyear invented a process for making hard rubber called vulcanite. A vulcanite denture was fixed to the ridges of a patient and more accurate than previous dentures. Therefore, it was almost the solution to the dentist's problems in fabrication of dentures. Later on, in 1854 Thomas Evan made vulcanite as a denture base material (Khindria et al., 2009). Figure 2.10 show upper dentures made from vulcanite.

Figure 2.9: Partial dentures made from Aluminium.
http://www.namibiadent.com/History/HistoricPictures.html

Figure 2.10: full upper denture made from vulcanite.
http://www.namibiadent.com/History/HistoryDentistry.html

Vulcanite remained the essential denture base material for the next 75years until the introduction of PMMA (poly methyl methacrylate) in 1930 (Soratur, 2002). In 1850 C. F. Harrington introduced the first thermoplastic denture base material. Six years later, Alfred Blandy used a low fusing alloy of silver, bismuth and antimony. Moreover, dentures made of this low fusing alloy were called cheoplastic dentures. In the following year, Dr. Bean made the first casting of a complete aluminium base. In 1870, a celluloid material was used as denture base material by John Wesley Hyatt.

In the 20th century, there were many materials used as denture base such as, bakelite (1909), stainless (1921), cobalt chromium (1930), acrylic resin (1937), polystyrene (1951), high impact acrylic (1967) and pure titanium (1998). Figure 2.11 show lower partial denture made from cobalt chromium.

Figure 2.11: Cobalt chromium denture.
http://www-personal.umich.edu/~sbayne/dental-materials/RPD-Acrylic-HO.pdf

In 1937, PMMA was clinically evaluated by Wright and found that PMMA has most requirement of an ideal denture base material (Craig, 1985 & Khindria et al., 2009). Figures 2.12 and 2.13 show acrylic dentures.

Figure 2.12: Complete acrylic denture. Figure 2.13: Partial upper acrylic denture.
http://www.fotosearch.com/photos-images/dentures.html

2.2 Classes of Materials Used in Dentistry

In recent times four groups of materials are used in dentistry: metals, ceramics, polymers and composites.

2.2.1 Metals and Alloys

Metals are a category of electropositive elements that usually have a shiny surface, hammered into thin sheets, are generally good conductors of heat and electricity, and can be melted or fused, or drawn into wires. Typical metals form salts with nonmetals, basic oxides with oxygen.

Alloy is a solid mixture of metal with one (or) more metals or with non-metals. In dentistry, the mainly general casting alloys used for dental appliances and prostheses are based on a majority of one of the following elements: gold, iron, cobalt, palladium, nickel, silver and titanium (Hussain, 2004). Metals and alloys have many uses in dentistry. One of the oldest dental applications was based on aesthetics, rather than masticatory ability was gold. The use of gold in dentistry still remains very important today. In conservative and restorative dentistry, as well as in orthodontics, gold is used either as a pure metal, or alloyed together with noble metals and base metals, gold alloys and alloys containing chromium are used for construction crowns, denture bases and inlays. Steel alloys are usually used for making of instruments and of orthodontics and the most commonly used as dental filling material is dental amalgam (Rebeka et al., 2008).

Metals are generally strong, hard, and lustrous at ambient temperature and can be readily formed into practical shapes. Moreover, metals are opaque and good conductors of both electricity and heat. Most metals are white, (e.g. silver, aluminum, nickel) gray excluding for copper, which is reddish, and gold which is yellow (Ferracane, 2001 & McCabe and Walls, 2008).

2.2.2 Ceramics

The word ceramic comes from the Greek word "keramos" which means "burnt stuff". However, it has come more from material specially produced by burning or firing. A ceramic is a compound contained in the union of a metallic and a non-metallic element. Many researchers studied the ceramic materials it found that they attained excellent aesthetic result properties with ceramics and beneficial to dentistry. For this reason ceramics have been used as veneers or coatings to improve the aesthetics of metallic dental restorations or as stand-alone veneers for anterior teeth (Sukumaran and Bharadwaj, 2006). Recent applications of ceramics in dentistry include dental restorations, crowns, veneers, implants and orthodontic brackets (Sivakumar and Valiathan, 2006).

There are many types of ceramics. In general, porcelain is a particular type of ceramic used largely in dentistry. In addition, there is also glass ceramics which are used as filler, or strengthening agents, for dental composites. Among the most important properties of ceramics: thermal insulators, hard, wear-resistant, brittle, electrical insulators, refractory are nonmagnetic, oxidation resistant, prone to thermal shock, chemically stable, high melting points, and very brittle materials (Ferracane, 2001 & Sukumaran and Bharadwaj, 2006).

2.2.3 Composites

Composites consist of the compound of two or more distinctly different material (reinforcing elements, fillers, and composite matrix binder) with properties that are superior to those of the individual components. Composites have corrosion resistance, hardness, strength, and conductivity.

Dental composites are extremely cross-linked polymeric materials reinforced by a distribution of crystalline, glass, or short fibres bound to the matrix by silane coupling agents and/or resin filler particles. Dental composites are consisting of three phases:

- Organic phase (Resin phase) – Matrix A plastic resin material that forms a continuous phase and binds the filler particles.
- Inorganic phase (Filler particles) - Dispersed in resin matrix to increase strength.
- Interfacial phase (Coupling or keying agent) – Adhesive agent that promotes adhesion between filler and resin matrix by chemical bonding (Anusavice, 2003) & (Bhat and Nandish, 2006). According to Bhat and Nandish (2006) table 2.1 show classification according to filler particle size.

Table 2.1: Classification of composites according to filler particle size (Bhat and Nandish, 2006)

Category	Filler particle size
Macrofilled composite (conventional/ traditional composite)	8-12 µm
Small particle composite	1-5 µm
Microfilled composite	0.04-0.4 µm
Hybrid composite	0.6-1 µm

2.2.4 Polymers

The term polymer literally means "many parts. It is a big molecule produced of repeating structural units usually connected by covalent chemical bonds. Ferracane (2001) & Bhat and Nandish (2006) explained the meaning of polymer, as a long-chain organic molecule. It is formed by the reaction of many smaller molecules called monomers, or mers. For example polyvinylchloride, polyethylene and poly methylmethacrylate, etc. The starting material for the production of a polymer is the “monomer” (Noort, 2002).

PMMA has been in dentistry since 1930s as denture materials (Vuorinen et al., 2007). Different types of polymers are used in dentistry as denture liners or tissue conditioners, custom trays for impressions, dentures bases and artificial teeth, temporary restoratives, composite restoratives and pit and fissure sealants, impression materials, maxillofacial prostheses, die materials, orthodontic functional appliances, space maintainers, and adhesives.

2.3 Types of Dentures Base Materials

Acrylic resin is the most frequently used material for manufacture of dentures. Table 2.2 show polymeric denture base materials are classified into five groups. Types 1 and 2 are the most common used product.

Table 2.2: Classification of denture base polymers according to ISO 1567-2001

Types	Class	Description
1	1	Heat-processing polymers, powder and liquid
1	2	Heat-processing (plastic cake)
2	1	Auto-polymerized polymers, powder and liquid
2	1	Auto-polymerized polymers, (powder and liquid pour types resin)
3	-	Thermoplastic blank or powder
4	-	Light-activated materials
5	-	Microwave-cured materials

2.3.1 Composition of Type 1 and Type 2 Materials

Details of the composition are given in table 2.3 which it is shown that the most materials are supplied as a powder and liquid. Most element of the powder is beads of polymethylmethacrylate with diameters up to 100µm. These are produced by a process of suspension polymerization in which methylmethacrylate monomer, containing initiator, is suspended as droplets in water. Starch or carboxymethylcellulose can be used as suspension stabilizers and thickeners however have the disadvantage of potentially contaminating the polymer beads. The temperature is raised in order to decompose the peroxide and bring about polymerization of the methylmethacrylate to form beads of polymethylmethacrylate which, after drying, form a free flowing powder at room temperature.

Table 2.3: Composition of acrylic denture base materials (McCabe and Walls, 1998)

Material form		Chemical composition
powder	polymer	PMMA beads
	initiator	BPO (≈0.5%)
	pigment	Salts of cadmium, iron or organic dyes (≈0.1%)
liquid	Monomer	MMA
	Cross-linking agent	EGDMA (~10%)
	Inhibitor	Hydroquinone (trace)
	Activator	NN –dimethyl-p-toluidine (≈1%)

The initiator present in the powder may consist of peroxide remaining unreacted after the production of the beads, in addition to extra peroxide added to the beads after their manufacture. The initiator releases free-radical for example, benzoyl peroxide releases free-radicals to bring about polymerization in acrylic resin. It is a commonly used initiator in acrylic resins (Callister, 2006). Figure 2.14 show the structural formula of benzoyl peroxide.

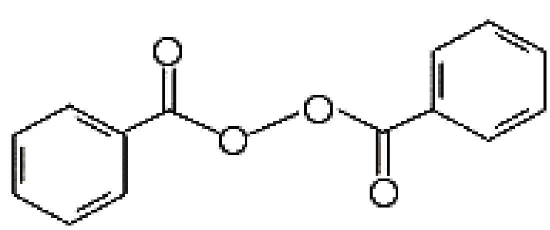

Figure 2.14: The structural formula of benzoyl peroxide.

Polymethylmethacrylate is a clear, glass-like polymer and is occasionally used in this form for denture base construction. It is more normal, however, for manufacturers to incorporate pigments and opacifiers in order to produce a more lifelike denture base. Sometimes, small fibres coated with pigment are used to give a veined appearance. Traditionally, the pink pigments used in denture base resin are salts of cadmium. These pigments have good colour stability and been shown to leach cadmium from the denture base in only minute amounts. Fears over the toxicity of cadmium compounds, however, have lead to the gradual replacement of cadmium salts with other ‘safer’ substance.

The major component of the liquid is methylmethacrylate (MMA) monomer. This is a clear colourless, low-viscosity liquid with a boiling point of 100.3˚C and a distinct odour exaggerated by a relatively high vapour pressure at room temperature. MMA is one of a group of monomers which are susceptible to free radical addition polymerization. The substance most commonly used in this procedure is ethylene glycol dimethacrylate. This compound is used to advance the physical properties of the set material.

An inhibitor, hydroquinone, is used to extend the shelf life of the liquid component. In the absence of this inhibitor, polymerization of monomer and cross linking agent would occur slowly, even at room temperature and below, due to the random occurrence of free radicals within the liquid. The source of these free radicals is uncertain, but once formed they cause a slow increase in viscosity of the liquid and may eventually cause the liquid component to solidify. The inhibitor works by reacting rapidly with radical’s formec within the liquid to form stabilized radicals which are not capable of initiating polymerization. One way of decreasing the amount of unwanted