

TABLE OF CONTENTS

TITLE PAGE	i
ABSTRACT	ii
ACKNOWLEDGEMENT	iv
TABLE OF CONTENTS	vi
LIST OF FIGURES	xvii
LIST OF TABLES	xxi
LIST OF ABBREVIATIONS	xxiv
CHAPTER 1 INTRODUCTION	1
1.1. Backgrounds	1
1.2. Objectives	6
1.3. Rationales of study	7
CHAPTER 2 LITERATURE REVIEW	9
2.1. Masticatory system	9
2.1.1. Temporomandibular joint (TMJ)	9
2.1.1.1. Functional anatomy of TMJ	9
2.1.1.1.1. Articular disc	9
2.1.1.2. Movement at TMJ	12
2.1.2. Masticatory muscle	14
2.1.2.1. Functional anatomy of masseter and temporal muscle	14
2.1.2.1.1. Masseter muscle	14
2.1.2.1.2. Temporal muscle	15
2.1.2.2. Neuromuscular system of the masticatory system	16
2.1.2.2.1. Muscle fibers	16

2.1.2.2.2.	Neurological structures	16
2.1.3.	Biomechanics of mandible	18
2.1.3.1.	Analysis of forces	18
2.1.3.2.	Condylar force	20
2.2.	Terminology of temporomandibular disorders	22
2.2.1.	Terminology	22
2.2.2.	History of terminology	22
2.3.	Epidemiology	24
2.3.1.	Prevalence	25
2.3.2.	Age and sex distribution	26
2.3.3.	Social and psychological factors	27
2.3.4.	Relationship between the signs and symptoms of TMD and occlusion	28
2.4.	Classification of TMD	30
2.4.1.	History of classifications of TMD	30
2.4.2.	Masticatory muscle disorders	32
2.4.3.	Temporomandibular joint disorders	33
2.5.	Pathogenesis of TMD	35
2.5.1.	Etiology of TMD	35
2.5.1.1.	Trauma	35
2.5.1.1.1.	Direct trauma	35
2.5.1.1.2.	Indirect trauma	36
2.5.1.1.3.	Microtrauma	36
2.5.1.1.3.1.	Functional overloading	36
2.5.1.1.3.1.1.	Parafunctional habits	37
2.5.1.1.3.1.2.	Adverse usage	39

2.5.1.1.3.1.3.	Magnitude and duration of force	40
2.5.1.2.	Anatomical factors	41
2.5.1.2.1.	Structural relationship of the joint	41
2.5.1.2.2.	Occlusal relationship	42
2.5.1.3.	Pathophysiologic factors	43
2.5.1.3.1.	Systemic factors	43
2.5.1.3.2.	Local factors	43
2.5.1.4.	Psychosocial factors	45
2.5.2.	Development of TMD	46
2.5.2.1.	Interrelationship between muscle disorders and disc derangement	47
2.6.	Examination and diagnosis	49
2.6.1.	Examination	49
2.6.1.1.	Complaint and history taking	49
2.6.1.2.	Examination of the masticatory muscle	49
2.6.1.3.	Examination of TMJ	50
2.6.1.3.1.	Range of movement	50
2.6.1.3.2.	TMJ tenderness	51
2.6.1.3.3.	TMJ sound	51
2.6.1.3.4.	Radiographs	52
2.6.1.4.	Examination of occlusion	53
2.6.1.4.1.	Incisor classification	53
2.6.1.4.2.	Anterior guidance	54
2.6.1.4.3.	Non-working side interferences	54
2.6.1.4.4.	Signs of bruxism	54
2.6.2.	Diagnosis	55

2.6.2.1.	Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD)	55
2.6.2.2.	Summarized RDC/TMD Axis I criteria list	56
2.7.	Treatment of TMD	61
2.7.1.	Objective of treatment	61
2.7.2.	Principles of TMD management	61
2.7.3.	Treatment modalities	63
2.7.3.1.	Patient education and self-care	63
2.7.3.2.	Cognitive behavioural intervention	64
2.7.3.3.	Pharmacologic therapy	64
2.7.3.3.1.	Analgesics	65
2.7.3.3.2.	Nonsteroidal anti-inflammatory drugs (NSAIDs)	65
2.7.3.4.	Physical therapy	65
2.7.3.5.	Occlusal therapy	66
2.7.3.5.1.	Reversible occlusal therapy	66
2.7.3.5.1.1.	Occlusal appliance therapy	66
2.7.3.5.1.1.1.	Stabilization splint (hard splint)	67
2.7.3.5.1.1.2.	Soft splint	69
2.7.3.5.1.1.3.	Soft splint versus hard splint	70
2.7.3.5.1.1.4.	Mechanism of action of the splint	71
2.7.3.5.1.1.4.1.	Sensory changes in masticatory system	71
2.7.3.5.1.1.4.2.	Increased vertical dimension	72
2.7.3.5.1.1.4.3.	Reduction of parafunctional activity	72
2.7.3.5.1.1.4.4.	The pivoting effect of the splint	73
2.7.3.5.2.	Irreversible occlusal therapy	74
2.7.3.6.	Surgery	75

2.8.	Electromyography (EMG)	76
2.8.1.	Device	77
2.8.2.	Types of EMG	78
2.8.3.	Application	79
2.8.4.	Reliability and validity	80
2.8.5.	Uses of EMG in TMD	81
2.8.6.	EMG acquisition setup	81
2.9.	Splint and electromyography in TMD	83
2.9.1.	The effect of the splint on muscles activities	83
2.9.1.1.	The effect of the soft splint on muscles activities	83
2.9.1.2.	The effect of the hard splint on muscles activities	84
2.9.1.2.1.	The effect of the hard splint on TMD patients	85
2.9.1.2.2.	The effect of the hard splint on healthy subjects	86
2.9.1.2.3.	The effect of the hard splint on muscles activities after long-term hard splint therapy	88
2.9.1.2.4.	EMG activity of muscles after long-term hard splint therapy	88
2.9.2.	TMD patients versus healthy subjects	89
2.9.2.1.	Reliability of EMG study comparing TMD patients and healthy subjects	89
2.9.2.2.	EMG activity of TMD patients versus healthy subjects	90
2.9.3.	Anterior temporal muscle versus masseter muscle	92
CHAPTER 3	METHODOLOGY	93
3.1.	Sampling	95
3.1.1.	Selection of the experimental subjects	95
3.1.1.1.	Inclusion criteria	95
3.1.1.2.	Exclusion criteria	96

3.1.1.3.	Experimental group	96
3.1.2.	Selection of the control subjects and the control group	97
3.2.	Examination and treatment	98
3.2.1.	Complaint and history taking	98
3.2.2.	Examination	98
3.2.3.	Treatment for subjects	100
3.3.	EMG Instrumentation	101
3.3.1.	EMG machine and acquisition setup	101
3.3.1.1.	Electrode placement	101
3.3.1.2.	EMG recording duration	102
3.3.1.3.	Calibration of EMG measurements	105
3.3.2.	Electrode and cable	106
3.4.	Step-by-step EMG measurement procedure	107
3.5.	Data analysis	113
3.5.1.	EMG test analysis before conservative treatment	113
3.5.1.1.	Analysis for experimental group	113
3.5.1.2.	Analysis for control group	114
3.5.2.	EMG test analysis after six weeks of conservative treatment	114
3.5.2.1.	Analysis for experimental group after six weeks of conservative treatment	114
3.5.2.2.	Analysis for TMD patients with resolved and unresolved pain after six weeks of conservative treatment	115
3.5.2.3.	Analysis for TMD patients with resolved and unresolved pain before conservative treatment	115
3.5.3.	Analysis for effectiveness of conservative treatment	116

3.5.4.	Analysis for demographic data, dentition characteristic and functional overloading	116
CHAPTER 4	RESULTS	117
4.1.	EMG test before conservative treatment	117
4.1.1.	EMG test for experimental group before conservative treatment	117
4.1.1.1.	Paired t-Test for EMG activity of experimental group (n=18)	120
4.1.1.1.1.	Postural	120
4.1.1.1.2.	Maximum clenching	120
4.1.2.	EMG test for control group	122
4.1.2.1.	Paired t-Test for EMG activity of control group (n=10)	124
4.1.2.1.1.	Postural	124
4.1.2.1.2.	Maximum clenching	124
4.2.	EMG test for experimental group after six weeks of conservative treatment	126
4.2.1.	Paired t-Test for EMG activity of experimental group after six weeks of conservative treatment	129
4.2.1.1.	Postural	129
4.2.1.2.	Maximum clenching	129
4.2.2.	Paired t-Test for EMG activity of TMD patients with resolved and unresolved pain after six weeks of conservative treatment	131
4.2.2.1.	Paired t-Test for EMG activity of TMD patients with resolved pain (n=13)	131
4.2.2.1.1	Postural	131
4.2.2.1.2.	Maximum clenching	131
4.2.2.2.	Paired t-Test for EMG activity of TMD patients with	133

	unresolved pain (n=5)	
4.2.2.2.1.	Postural	133
4.2.2.2.2.	Maximum clenching	133
4.2.3.	Paired t-Test for EMG activity of TMD patients with resolved and unresolved pain before conservative treatment	135
4.2.3.1.	Paired t-Test for EMG activity of TMD patients with resolved pain (n=13)	135
4.2.3.1.1.	Postural	135
4.2.3.1.2.	Maximum clenching	135
4.2.3.2.	Paired t-Test for EMG activity of TMD patients with unresolved pain (n=5)	137
4.2.3.2.1.	Postural	137
4.2.3.2.2.	Maximum clenching	137
4.3.	TMD sign and symptoms distribution	139
4.3.1.	Signs and symptoms before conservative treatment (Table 4.3.1)	139
4.3.1.1.	Muscle pain	139
4.3.1.2.	Joint pain	139
4.3.1.3.	Muscle and joint pain	139
4.3.1.4.	Joint click	139
4.3.1.5.	Limitation of mouth-opening	140
4.3.1.6.	Limitation of lateral mandible movement	140
4.3.1.7.	Mandible deviation during mouth-opening	140
4.3.2.	Signs and symptoms after six weeks of conservative treatment (Table 4.3.2)	140
4.3.2.1.	Muscle pain (n= 14)	140

4.3.2.2.	Joint pain (n= 10)	140
4.3.2.3.	Muscle and joint pain (n= 18)	141
4.3.2.4.	Joint click (n= 13)	141
4.3.2.5.	Limitation of mouth-opening (n= 9)	141
4.3.2.6.	Limitation of lateral mandible movement (n= 10)	141
4.3.2.7.	Mandible deviation during mouth-opening (n= 14)	141
4.3.3.	Effectiveness of conservative treatments	144
4.3.3.1.	Patient's comments on the usefulness of splint	144
4.4.1.	Demographic distribution	145
4.4.1.1.	Sex	145
4.4.1.2.	Race	145
4.4.1.3.	Age	145
4.4.2.	Dentition characteristic	148
4.4.2.1.	Incisor relationship	148
4.4.2.2.	Anterior guidance	148
4.4.2.3.	Deep overbite	148
4.4.2.4.	Deviated occlusal plane	148
4.4.2.5.	Crowding	148
4.4.2.6.	Interference on lateral excursion	148
4.4.3.	Functional overloading	150
4.4.3.1.	Parafunctional habits	150
4.4.3.2.	Adverse usage	150
CHAPTER 5	DISCUSSION	152
5.1.	The effect of splint on masticatory muscles activities	152
5.1.1.	EMG variability	152
5.1.2.	The effect of the soft splint on the masseter and anterior	153

	temporal muscles activities	
5.1.2.1.	The study by Okeson (1987) versus this study	153
5.1.2.2.	The study by Al-Quran and Lyons (1999) versus this study	155
5.1.3.	The effect of the splint on TMD patients compared to healthy subjects	156
5.1.4.	The effect of the soft splint in this study compared to hard splint	157
5.1.5.	Reduction of parafunctional activity by the splint	159
5.2.	The effect of the soft splint on TMD patients after 6 weeks of conservative treatment	161
5.2.1.	Experimental group after 6 weeks of conservative treatment	161
5.2.2.	TMD patients with resolved and unresolved pain after six weeks of conservative treatment	162
5.2.3.	TMD patients with resolved and unresolved pain before conservative treatment	163
5.3.1.	Signs and symptoms before and after conservative treatment	164
5.3.1.1.	Muscle pain	164
5.3.1.2.	Joint pain	165
5.3.1.3.	Muscle and joint pain	165
5.3.1.4.	Joint click	165
5.3.1.5.	Limitation of mouth-opening	166
5.3.1.6.	Limitation of lateral mandible movement	167
5.3.1.7.	Mandible deviation during mouth-opening	167
5.3.2.	Conservative treatments	168
5.3.2.1.	Assessing effectiveness of conservative treatments	168

5.3.2.2.	Effectiveness of conservative treatments	170
5.3.3.	Patients' personal comments on the usefulness of soft splint	171
5.3.4.	Effectiveness of soft splint in reducing dysfunction	172
5.4.1.	Demographic distribution	173
5.4.1.1.	Sex	173
5.4.1.2.	Race	174
5.4.1.3.	Age	175
5.4.2.	Dentition characteristic	176
5.4.2.1.	Incisor relationship	176
5.4.2.2.	Anterior guidance	177
5.4.2.3.	Deep overbite	177
5.4.2.4.	Deviated occlusal plane	177
5.4.2.5.	Crowding	178
5.4.2.6.	Interference on lateral excursion	178
5.4.3.	Functional overloading	179
5.4.3.1.	Parafunctional habits	179
5.4.3.2.	Adverse usage	180
5.5.	Limitation of this study	181
CHAPTER 6	CONCLUSION	183
6.1.	Clinical Implication	184
REFERENCES		186
APPENDIX 1:	Patient information sheet	197
APPENDIX 2:	Consent by patient for clinical research	198
APPENDIX 3:	Consent by responsible relative for clinical research	199
APPENDIX 4:	Patient examination form	200

LIST OF FIGURES

Figure 2.1.1.1(a)	Line drawing of TMJ representing a Jockey's cap	10
Figure 2.1.1.1(b)	Line drawing showing the cross section of TMJ	10
Figure 2.1.1.1(c)	Superior aspect of the TMJ	11
Figure 2.1.1.1(d)	Lateral aspect of the TMJ	11
Figure 2.1.1.1(e)	Form, subdivisions and thickness variations of the intra-articular disc in the TMJ, in sagittal section.	11
Figure 2.1.1.2(a)	Normal functional movement of the condyle and disc during the full range of opening and closing	12
Figure 2.1.1.2(b)	Changing relationships of the condyle of the mandible, the articular disc and the articular surface of the temporal bone during one complete opening (A-D) and closing (D-A) cycle of the mouth	13
Figure 2.1.2.1.1	Masseter muscle	14
Figure 2.1.2.1.2	Temporal muscle	15
Figure 2.1.3.1(a)	The human mandible functioning as a lever during biting along the first molar	19
Figure 2.1.3.1(b)	Forces acting along the mandible in the frontal projection	19
Figure 2.1.3.2(a)	Class II lever	21
Figure 2.1.3.2(b)	Class III lever	21
Figure 2.1.3.2(c)	Biomechanics of the mandible in lateral projection during biting along the first molar and central incisor	21
Figure 2.3.2	Age and sex distribution of 3,428 TMD patients presenting with TMD at a Seattle-based health maintenance organization of 360,000 enrollees	27

Figure 2.4.1(a)	Classification system used for diagnosing TMD (Okeson, 1998)	31
Figure 2.4.1(b)	Recommended diagnostic classification for TMD by AAOP (Okeson, 1996)	31
Figure 2.4.3(a)	Functional movement at the TMJ with disc displacement	33
Figure 2.4.3(b)	Functional movement at the TMJ with disc dislocation with reduction	34
Figure 2.4.3(c)	Functional movement at the TMJ with disc dislocation without reduction	34
Figure 2.5.2.1(a)	Masticatory muscle model	48
Figure 2.5.2.1(b)	Various states of internal derangement of the temporomandibular joint	48
Figure 3	Flow chart of methodology	94
Figure 3.2.2(a)	Orthopantomograph showing the dentition, maxilla and mandible	99
Figure 3.2.2(b)	Standard transcranial oblique lateral radiograph at open and closed positions of the TMJ	99
Figure 3.2.3	Soft splint made of polyvinyl with uniform thickness, made by vacuum forming technique	10
Figure 3.3.1(a)	Five-channel system EMG equipment	10
Figure 3.3.1(b)	Two of the major components of EMG equipment	3
Figure 3.3.1(c)	Acquisition setup of Channel 1	10

		4
Figure 3.3.1(d)	Summary of acquisition settings of all 4 channels	10
		4
Figure 3.3.1(e)	The plinth under the notebook is a central data acquisition unit that links together the computer, amplifier and control panel	10
		5
Figure 3.3.1(f)	Acquisition of data through notebook computer	10
		5
Figure 3.3.2(a)	A, disposable electrodes; B, lead cable	10
		6
Figure 3.3.2(b)	A, bipolar electrodes with the front and back view; B, ground electrodes with the front and back view	10
		6
Figure 3.4(a)	Scheme showing the position of the double electrodes on the analyzed muscles in the study by Ferrario et al. (1991)	10
		8
Figure 3.4(b)	Electrodes placement and the cables connection to the EMG machine at the side and frontal views	10
		9
Figure 3.4(c)	Positioning of the subject	11
		0
Figure 3.4(d)	Recording of postural muscle activity showing continuous recordings of 1000 ms duration each	10
		11
		2
Figure 3.4(e)	Recording of clenching muscle activity showing continuous recordings of 1000 ms duration each	4
		11
		2
Figure 4.1.1(a)	Boxplot for postural EMG activity of experimental group before conservative treatment	11
		9
Figure 4.1.1(b)	Boxplot for maximum clenching EMG activity of experimental group before conservative treatment	11
		9

Figure 4.1.2(a)	Boxplot for postural EMG activity of control group	12
		3
Figure 4.1.2(b)	Boxplot for maximum clenching EMG activity of control group	12
		3
Figure 4.2(a)	Boxplot for postural EMG activity of experimental group after six weeks of conservative treatment	12
		8
Figure 4.2(b)	Boxplot for maximum clenching EMG activity of experimental group after six weeks of conservative treatment	128
Figure 4.4.1(a)	Sex distribution of TMD patients, number of patients (percentage); mean of age in year (SD)	147
Figure 4.4.1(b)	Race distribution of TMD patients, number of patients (percentage); mean of age in year (SD)	147

LIST OF TABLES

Table 2.3.1	Signs and symptoms of TMD in investigated populations	26
Table 2.3.4	Studies that investigated the relationship between the signs and symptoms of TMD and occlusion (Okeson, 1998)	28
Table 4.1.1(a)	Postural EMG activity of experimental group before conservative treatment	117
Table 4.1.1(b)	Maximum clenching EMG activity of experimental group before conservative treatment	118
Table 4.1.1.1.1	Paired t-Test for postural EMG activity of experimental group before conservative treatment	121
Table 4.1.1.1.2	Paired t-Test for maximum clenching EMG activity of	121

	experimental group before conservative treatment	
Table 4.1.2(a)	Postural EMG activity of control group	122
Table 4.1.2(b)	Maximum clenching EMG of control group	122
Table 4.1.2.1.1	Paired t-Test for postural EMG activity of control group	125
Table 4.1.2.1.2	Paired t-Test for maximum clenching EMG activity of control group	125
Table 4.2(a)	Postural EMG activity of experimental group after six weeks of conservative treatment	126
Table 4.2(b)	Maximum clenching EMG activity of experimental group after six weeks of conservative treatment	127
Table 4.2.1.1	Paired t-Test for postural EMG activity of experimental group after six weeks of conservative treatment	130

Table 4.2.1.2	Paired t-Test for maximum clenching EMG activity of experimental group after six weeks of conservative treatment	130
Table 4.2.2.1.1	Paired t-Test for postural EMG activity of TMD patients with resolved pain after six weeks of conservative treatment	132
Table 4.2.2.1.2	Paired t-Test for maximum clenching EMG of TMD patients with resolved pain after six weeks of conservative treatment	132
Table 4.2.2.2.1	Paired t-Test for postural EMG activity of TMD patients with unresolved pain after six weeks of conservative treatment	134
Table 4.2.2.2.2	Paired t-Test for maximum clenching EMG activity of TMD patients with unresolved pain after six weeks of conservative treatment	134
Table 4.2.3.1.1	Paired t-Test for postural EMG activity of TMD patients with resolved pain before conservative treatment	136
Table 4.2.3.1.2	Paired t-Test for maximum clenching EMG activity of TMD patients with resolved pain before conservative treatment	136
Table 4.2.3.2.1	Paired t-Test for postural EMG activity of TMD patients with unresolved pain before conservative treatment	138
Table 4.2.3.2.2	Paired t-Test for maximum clenching EMG activity of TMD patients with unresolved pain before conservative treatment	138

Table 4.3.1	Signs and symptoms of TMD patients before conservative treatment	142
Table 4.3.2	Signs and symptoms of TMD patients after six weeks of conservative treatment	143
Table 4.3.3	Effectiveness of conservative treatment and patient's comment towards splint therapy	144
Table 4.4.1(a)	Sex and race distribution of TMD patients	146
Table 4.4.1(b)	Age distribution of TMD patients	146
Table 4.4.2	Dentition characteristic of TMD patients	149
Table 4.4.3	Parafunctional habit and adverse usage of the masticatory system of the TMD patients	151

LIST OF ABBREVIATIONS

AAOP	American Academy of Orofacial Pain
CNS	Central nervous system
EMG	Electromyography
NSAIDs	Nonsteroidal anti-inflammatory drugs
RDC/TMD	Research Diagnostic Criteria for Temporomandibular Disorders
SD	Standard deviation
TMD	Temporomandibular disorders
TMJ	Temporomandibular joint