PROSPECTIVE EVALUATION OF FACIAL AND MASTICATORY MUSCLES ACTIVITY IN DIFFERENT MALOCCLUSION PATIENTS: AN ELECTROMYOGRAPHY STUDY

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بِسْمِ اللهِ الرَّحْمٰنِ الرَّحِيْمِ

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TABLE OF CONTENTS

ACKNOWLEDMENTS		ii
TABLE OF CONTENTS		iii
LIST OF TABLES		xii
LIST OF FIGURES		xviii
LIST OF ABBREVIATIONS		xxiii
LIST OF SYMBOLS		xxiv
ABSTRAK		xxv
ABSTRACT		xxvii
CHAPTER 1: INTRODUCTION		1
1.1	Background of the study	1
1.2	Problem statement	4
1.3	The Rationale of the study	8
1.4	Objectives	11
	1.4.1 General objectives	11
	1.4.2 Specific objectives	11
1.5	Research questions	12
1.6	Hypothesis	13
	1.6.1 Alternative hypotheses	13
CHAPTER 2: LITERATURE REVIEW		15
2.1	Definition of malocclusion	15
2.2	Prevalence of malocclusion	15
2.3	Classification of malocclusion	18

2.3.1 Class I malocclusion 20

2.3.2 Class II malocclusion 21

2.3.3 Class III malocclusion 24

2.4 Etiology of malocclusion 26

2.5 Lateral cephalogram in malocclusion management 29

2.6 Treatment of malocclusion 31

2.6.1 Extraction 32

2.6.2 Non- extraction 33

2.6.3 Orthodontic brackets 34

2.6.4 Laser 37

2.7 Tooth movement 41

2.8 Muscles 43

2.8.1 Masticatory muscle 45

2.8.1(a) Masseter muscle 47

2.8.1(b) Temporalis muscle 49

2.8.2 Facial muscles 51

2.8.2(a) Buccinator muscle 53

2.8.2(b) Orbicularis oris muscle 55

2.9 Electromyography (EMG) 57

2.9.1 Uses of EMG 59

2.9.2 EMG types 60

2.9.3 Surface Electromyography (sEMG) 64

2.9.3(a) Procedure 64

2.9.3(b) Advantages of sEMG 70

2.9.3(c) Limitations 70

CHAPTER 3: MATERIALS AND METHODS 71

3.1 Study design 71

3.2 Population and sample 71

3.2.1 References population 71

3.2.2 Source of population 71

3.3 Sampling frame 72

3.3.1 Inclusion criteria 72

3.3.2 Exclusion criteria 72

3.4 Sample size calculation 73

3.5 Patient selection 82

3.6 Diagnosis of malocclusion 82

3.7 Sampling method and randomization 86

3.8 Variables 86

3.8.1 Dependent variables 86

3.8.2 Independent variables 86

3.9 Research tools 87

3.9.1 For EMG purpose: 87

3.9.1(a) Electromyography device 87

3.9.1(b) Electromyography recording cable 89

3.9.1(c) Single patient surface electrode 90

3.9.1(d) EMG software 91

3.9.1(e) Alcohol swabs 92

3.9.1(f) Hand sanitizer 93

3.9.1(g) Chewing gum 94

3.9.1(h) Whistle 95

3.9.2 Routine orthodontic records before treatment 96

3.9.2(a) History and examination record sheet 96

3.9.3 Orthodontic apparatus to conduct the research 96

3.9.4 For laser application 97

3.10 Ethical approval 98

3.11 Data collection procedure 98

3.11.1 EMG procedure 100

3.11.1(a) Calibration procedure 100

3.11.1(b) Patients' position 100

3.11.1(c) Patients' instructions 101

3.11.1(d) Electrode placement 102

3.11.1(e) Recording 110

3.11.1(f) EMG signal analysis 127

3.11.2 Measurement of orthodontic variables 131

3.12.1(a) Overjet 131

3.12.1(b) Overbite 132

3.12.1(c) Face profile 133

3.12.1(d) Face morphology 134

3.12.1(e) Lip competency 134

3.12 Laser application 135

3.13 Statistical analysis 136

CHAPTER 4: RESULTS 142

4.1 Demographic data analysis 143

4.2 Calibration result 143

4.3 Objective 1: To determine the facial and masticatory muscles activity measured via sEMG in Class I, Class II (division 1 and division 2) and class III malocclusion patients 145

4.4 Objective 2: To determine the facial and masticatory muscles activity measured via sEMG in different malocclusion patients with different overjet, overbite, facial profile, facial morphology and lip competency 156

4.4.1 Muscle activity (masseter, temporalis, buccinator and orbicularis oris) with different overjet 157

4.4.2 Muscle activity (masseter, temporalis, buccinator and orbicularis oris) with different overbite 166

4.4.3 Muscle activity (masseter, temporalis, buccinator and orbicularis oris) with different face profile 174

4.4.4 Muscle activity (masseter, temporalis, buccinator and orbicularis oris) with different face morphology 182

4.4.5 Muscle activity (masseter, temporalis, buccinator and orbicularis oris) with different lip competency 189

4.5 Objective 3: To compare the effect of facial and masticatory muscles activity measured via sEMG in malocclusion patients treated by extraction and non-extraction in conventional bracket system pre and at six months of the orthodontic treatment 195

4.5.1 Masseter muscle activity (chewing and clenching) in extraction and non-extraction groups 194

4.5.2 Temporalis muscle activity (chewing and clenching) in extraction and non-extraction groups 198

4.5.3 Buccinator muscle activity (chewing, blowing and smiling) in extraction and non-extraction groups 201

4.5.4 Orbicularis muscle activity (blowing and smiling) in extraction and non-extraction groups 206

4.6 Objective 4: To determine the effects of facial and masticatory muscles activity measured via sEMG between different bracket types (conventional, self-ligating and ceramic bracket) in orthodontic patients pre and at six months of the orthodontic treatment 206

4.6.1 Masseter muscle activity (chewing and clenching) in different bracket groups 209

4.6.2 Temporalis muscle activity (chewing and clenching) in different bracket groups 211

4.6.3 Buccinator muscle activity (chewing, blowing and smiling) in different bracket groups 213

4.6.4 Orbicularis muscle activity (blowing and smiling) in different bracket groups 215

4.7 Objective 5: To investigate and compare the effect of facial and masticatory muscles activity measured via sEMG in Class II division 1 malocclusion treated by LLLT and without LLLT in conventional bracket system pre and at six months of the orthodontic treatment 214

4.7.1 Masseter muscle activity (chewing and clenching) in laser and non-laser groups 217

4.7.2 Temporalis muscle activity (chewing and clenching) in laser and non-laser groups 219

4.7.3 Buccinator muscle activity (chewing, blowing and smiling) in laser and non-laser groups 221

4.7.4 Orbicularis muscle activity (blowing and smiling) in laser and non-laser groups 223

4.8 Objective 6: To investigate and compare the effect of facial and masticatory muscles activity measured via sEMG in Class II division 1 malocclusion treated by LLLT and without LLLT in self-ligating bracket system pre and at six months of the orthodontic treatment 223

4.8.1 Masseter muscle activity (chewing and clenching) in laser and non-laser groups 228

4.8.2 Temporalis muscle activity (chewing and clenching) in laser and non-laser groups 231

4.8.3 Buccinator muscle activity (chewing, blowing and smiling) in laser and non-laser groups 233

4.8.4 Orbicularis muscle activity (blowing and smiling) in laser and non-laser groups 235

4.9 Objective 7: To investigate the effect of facial and masticatory muscles activity measured via sEMG in Class II division 1 malocclusion treated by LLLT between conventional and self-ligating bracket system pre and at six months of the orthodontic treatment 232

4.9.1 Masseter muscle activity (chewing and clenching) in conventional and self-ligating brackets with LLLT 238

4.9.2 Temporalis muscle activity (chewing and clenching) in conventional and self-ligating brackets with LLLT 239

4.9.3 Buccinator muscle activity (chewing, blowing and smiling) in conventional and self-ligating brackets with LLLT 241

4.9.4 Orbicularis muscle activity (blowing and smiling) in conventional and self-ligating brackets with LLLT 243

CHAPTER 5: DISCUSSION 239

5.1 sEMG activity in different malocclusion patients 240

5.2 sEMG activity with different overjet, overbite, facial profile, facial morphology and lip competency 243

5.3 sEMG activity in malocclusion patients with extraction and non-extraction treatment 246

5.4 sEMG activity in different orthodontic brackets (conventional, self-ligating and ceramic bracket) 248

5.5 sEMG activity in malocclusion with LLLT and without LLLT 249

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS 253

6.1 Conclusions 253

6.2 Clinical significances 254

6.3 Limitations 255

6.4 Recommendations 256

REFERENCES 257

APPENDICES

APPENDIX A Ethical Clearance Letter from Universiti Sains Malaysia (USM) Ethics Committee

APPENDIX B Informed Consent Form (Malay Version)

APPENDIX C Informed Consent Form (English Version)

APPENDIX D Patient Record Sheet or Proforma

APPENDIX E Turnitin Report

APPENDIX F Patients’ Position and sEMG Recording

APPENDIX G Pairwise Comparison of Muscle Activity in Different Bracket Groups

APPENDIX H List of Publications

APPENDIX I List of Presentations

APPENDIX J USM Fellowship Offer Letter

LIST OF TABLES

		Page
Table 2.1	Reported prevalence of malocclusion in different countries	16
Table 2.2	Electromyographic procedure in different muscles (literature survey)	65
Table 3.1	Study population for extraction patients' group	75
Table 3.2	Study population for non-extraction patients' group	75
Table 3.3	Study population for conventional bracket patients' group	76
Table 3.4	Study population for self-ligating bracket patients' group	78
Table 3.5	Study population for ceramic bracket patients' group	78
Table 3.6	Study population for conventional bracket with laser group	79
Table 3.7	Study population for conventional bracket with non-laser group	80
Table 3.8	Study population for self-ligating bracket with laser group	81
Table 3.9	Study population for self-ligating bracket with non-laser group	81
Table 3.10	BSI (British Standard Incisor) classification of malocclusion	84
Table 4.1	Intra-examiner ICC values of scoring	144
Table 4.2	Inter-examiner ICC values of scoring	145
Table 4.3	sEMG activity of masseter and temporalis muscles in different malocclusion patients	148
Table 4.4	sEMG activity of buccinator and orbicularis oris muscles in different malocclusion patients	151
Table 4.5	sEMG activity of Masseter and Temporalis muscles with different overjet	160

Table 4.6	sEMG activity of Buccinator and Orbicularis oris muscles with different overjet	162
Table 4.7	sEMG activity of Masseter and Temporalis muscles with different overbite	167
Table 4.8	sEMG activity of Buccinator and Orbicularis oris muscles with different overbite	170
Table 4.9	sEMG activity of Masseter and Temporalis muscles with different Face profile	175
Table 4.10	sEMG activity of Buccinator and Orbicularis oris muscles with different face profile	178
Table 4.11	sEMG activity of Masseter and Temporalis muscles with different face morphology	183
Table 4.12	sEMG activity of Buccinator and Orbicularis oris muscles with different face morphology	185
Table 4.13	sEMG activity of Masseter and Temporalis muscles with different lip competency	190
Table 4.14	sEMG activity of Buccinator and Orbicularis oris muscles with different lip competency	192
Table 4.15	sEMG activity of Masseter muscle during chewing between extraction and non-extraction groups	196
Table 4.16	sEMG activity of Masseter muscle during clenching between extraction and non-extraction groups	197
Table 4.17	sEMG activity of Temporalis muscle during chewing between extraction and non-extraction groups	199

Table 4.18 sEMG activity of Temporalis muscle during clenching between extraction and non-extraction groups 200

Table 4.19 sEMG activity of Buccinator muscle during chewing between extraction and non-extraction groups 202

Table 4.20 sEMG activity of Buccinator muscle during blowing between extraction and non-extraction groups 203

Table 4.21 sEMG activity of Buccinator muscle during smiling between extraction and non-extraction groups 205

Table 4.22 sEMG activity of Orbicularis oris muscle during blowing between extraction and non-extraction groups 207

Table 4.23 sEMG activity of Orbicularis oris muscle during smiling between extraction and non-extraction groups 208

Table 4.24 sEMG activity of Masseter muscle during chewing between different bracket types 210

Table 4.25 sEMG activity of Masseter muscle during clenching between different bracket types 210

Table 4.26 sEMG activity of Temporalis muscle during chewing between different bracket types 212

Table 4.27 sEMG activity of Temporalis muscle during clenching between different bracket types 212

Table 4.28 sEMG activity of Buccinator muscle during chewing between different bracket types 214

Table 4.29 sEMG activity of Buccinator muscle during blowing between different bracket types 214

Table 4.30 sEMG activity of Buccinator muscle during smiling between different bracket types 214

Table 4.31 sEMG activity of Orbicularis oris muscle during blowing between different bracket types 216

Table 4.32 sEMG activity of Orbicularis oris muscle during smiling between different bracket types 216

Table 4.33 sEMG activity of Masseter muscle during chewing between laser and non-laser groups of conventional bracket 218

Table 4.34 sEMG activity of Masseter muscle during clenching between laser and non-laser groups of conventional bracket 219

Table 4.35 sEMG activity of Temporalis muscle during chewing between laser and non-laser groups of conventional bracket 220

Table 4.36 sEMG activity of Temporalis muscle during clenching between laser and non-laser groups of conventional bracket 220

Table 4.37 sEMG activity of Buccinator muscle during chewing between laser and non-laser groups of conventional bracket 222

Table 4.38 sEMG activity of Buccinator muscle during blowing between laser and non-laser groups of conventional bracket 222

Table 4.39 sEMG activity of Buccinator muscle during smiling between laser and non-laser groups of conventional bracket 222

Table 4.40 sEMG activity of Orbicularis oris muscle during blowing between laser and non-laser groups of conventional bracket 224

Table 4.41 sEMG activity of Orbicularis oris muscle during smiling between laser and non-laser groups of conventional bracket 226

Table 4.42 sEMG activity of Masseter muscle during chewing between laser and non-laser groups of self-ligating bracket 229

Table 4.43 sEMG activity of Masseter muscle during clenching between laser and non-laser groups of self-ligating bracket 230

Table 4.44 sEMG activity of Temporalis muscle during chewing between laser and non-laser groups of self-ligating bracket 232

Table 4.45 sEMG activity of Temporalis muscle during clenching between laser and non-laser groups of self-ligating bracket 233

Table 4.46 sEMG activity of Buccinator muscle during chewing between laser and non-laser groups of self-ligating bracket 234

Table 4.47 sEMG activity of Buccinator muscle during blowing between laser and non-laser groups of self-ligating bracket 234

Table 4.48 sEMG activity of Buccinator muscle during smiling between laser and non-laser groups of self-ligating bracket 234

Table 4.49 sEMG activity of Orbicularis oris muscle during blowing between laser and non-laser groups of self-ligating bracket 236

Table 4.50 sEMG activity of Orbicularis oris muscle during smiling between laser and non-laser groups of self-ligating bracket 237

Table 4.51 sEMG activity of Masseter muscle during chewing in laser groups between conventional and self-ligating brackets 239

Table 4.52 sEMG activity of Masseter muscle during clenching in laser groups between conventional and self-ligating brackets 239

Table 4.53 sEMG activity of Temporalis muscle during chewing in laser groups between conventional and self-ligating brackets 240

Table 4.54	sEMG activity of Temporalis muscle during clenching in laser groups between conventional and self-ligating brackets	240
Table 4.55	sEMG activity of Buccinator muscle during chewing in laser groups between conventional and self-ligating brackets	242
Table 4.56	sEMG activity of Buccinator muscle during blowing in laser groups between conventional and self-ligating brackets	242
Table 4.57	sEMG activity of Buccinator muscle during smiling in laser groups between conventional and self-ligating brackets	242
Table 4.58	sEMG activity of Orbicularis oris muscle during blowing in laser groups between conventional and self-ligating brackets	244
Table 4.59	sEMG activity of Orbicularis oris muscle during smiling in laser groups between conventional and self-ligating brackets	244

LIST OF FIGURES

		Page
Figure 2.1	Angle's classification of malocclusion	20
Figure 2.2	Angle's Class I malocclusion	21
Figure 2.3	Angle's Class II malocclusion	23
Figure 2.4	Angle's Class III malocclusion	25
Figure 2.5	Congenital factors for malocclusion	28
Figure 2.6	Oral habits causing malocclusion	29
Figure 2.7	Lateral cephalogram for orthodontic treatment	30
Figure 2.8	Components of fixed orthodontic treatment	35
Figure 2.9	Metal and Ceramic brackets of fixed orthodontic treatment	37
Figure 2.10	Low-level laser therapy (LLLT) in orthodontics	39
Figure 2.11	Graphic diagram of tooth movement	43
Figure 2.12	The muscles of mastication that move the mandible during mastication and speech	46
Figure 2.13	Lateral view of a skull showing that the origin of the masseter muscle is from the lower edge of the zygomatic arch and insert into the angle of the mandible	48
Figure 2.14	The temporalis muscle has a wide origin from the temporal fossa	50
Figure 2.15	Muscles of facial expressions	52
Figure 2.16	The buccinator muscle origin from pterygomandibular raphe and merger with the fibers of the orbicularis oris at the angles of the mouth	54
Figure 2.17	Orbicularis oris muscles encircling the mouth	56

Figure 2.18	Apparatus used in the recording of electromyography	58
Figure 2.19	Surface electromyography (sEMG) during recording	62
Figure 2.20	Intramuscular electromyography	63
Figure 3.1	MyoTrac infiniti 2 Channel sEMG device used to record muscle activity in the study (A and B)	88
Figure 3.2	Electromyography recording cable used to connect with the sEMG device	89
Figure 3.3	The surface electrode used in the study	90
Figure 3.4	BioGraph infiniti software used in the study	91
Figure 3.5	Alcohol swabs used for skin preparation in the study	92
Figure 3.6	Hand sanitizer used in the study before sEMG recording	93
Figure 3.7	Chewing gum used in the study	94
Figure 3.8	Plastic whistle used in the study	95
Figure 3.9	Laser device used in the study	97
Figure 3.10	View of the pre-gelled electrodes showing the interelectrode distance used in the study	102
Figure 3.11	Surface electrode placement over the masseter muscle during sEMG recording in the study	104
Figure 3.12	Surface electrode placement over the temporalis muscle during sEMG recording in the study	106
Figure 3.13	Surface electrode placement over the buccinator muscle during sEMG recording in the study	108
Figure 3.14	Surface electrode placement over the orbicularis muscle during sEMG recording in the study	109

Figure 3.15 sEMG of the right masseter muscle activity during chewing {graphical view: yellow color representing the right side and blue one representing left side} 111

Figure 3.16 sEMG of the left masseter muscle activity during chewing {graphical view: yellow color representing the right side and blue one representing left side} 112

Figure 3.17 sEMG recording showing together action of the right and left masseter muscles clenching activity {graphical view: yellow color representing the right side and blue one representing left side} 113

Figure 3.18 sEMG of the right temporalis muscle activity during chewing {graphical view: yellow color representing the right side and blue one representing left side} 115

Figure 3.19 sEMG of the left temporalis muscle activity during chewing {graphical view: yellow color representing the right side and blue one representing left side} 116

Figure 3.20 sEMG recording showing together action of the right and left temporalis muscles clenching activity {graphical view: yellow color representing the right side and blue one representing left side} 117

Figure 3.21 sEMG of the right buccinator muscle activity during chewing {graphical view: yellow color representing the right side and blue one representing left side} 119

Figure 3.22	sEMG of the left buccinator muscle activity during chewing {graphical view: yellow color representing the right side and blue one representing left side}	120
Figure 3.23	sEMG recording showing together action of the right and left buccinator muscles blowing activity {graphical view: orange color representing the right side and blue one representing left side}	121
Figure 3.24	sEMG recording showing together action of the right and left buccinator muscles smiling activity {graphical view: orange color representing the right side and blue one representing left side}	122
Figure 3.25	sEMG recording showing together action of the upper and lower orbicularis oris muscles blowing activity {graphical view: orange color representing the right side and blue one representing left side}	123
Figure 3.26	sEMG recording showing together action of the upper and lower orbicularis oris muscles smiling {graphical view: orange color representing the right side and blue one representing left side}	124
Figure 3.27	Muscle activity recording procedure with different actions (chewing, clenching, blowing and smiling) in sEMG	125
Figure 3.28	Raw sEMG trace showing the noise-free recording (green box) of muscle during blowing	126
Figure 3.29	sEMG tracing represents the onset, peak and offset point of the muscle activity event. In the graph onset and offset point	128

	showing the baseline during resting phase. Peak points from (5 seconds to 15 seconds) showing the chewing activity of the muscle	
Figure 3.30	Peak points for every 2.5 seconds were detected by placing the red line in the target area of sEMG signal graph	130
Figure 3.31	Overjet of teeth in a malocclusion	131
Figure 3.32	Overbite of teeth in a malocclusion	132
Figure 3.33	Different face profile (convex, straight and concave) of malocclusion patient	134
Figure 3.34	Lip competency of malocclusion patient	135
Figure 3.35	Flow chart of the study for objective 1 and 2	139
Figure 3.36	Flow chart of the study for objective 3	140
Figure 3.37	Flow chart of the study for objective 4	141
Figure 3.38	Flow chart of the study for objective 5, 6 and 7	142

LIST OF ABBREVIATIONS

ATP	Adenosine triphosphate
BSI	British Standard Institute
CI	Confidence Interval
df	Degree of freedom
EMG	Electromyography
sEMG	Surface electromyography
HUSM	Hospital Universiti Sains Malaysia
HREC	Human Research Ethics Committee
IEC	International Electrotechnical Commission
ICC	Interclass correlation coefficient
LLLT	Low level laser therapy
MUAP	Motor unit action potential
MVIC	Maximum voluntary isometric contraction
MVC	Maximum voluntary clenching/contractions
PDL	Periodontal ligament
RANKL	Receptor activator of nuclear factor kappa-B ligand
RMS	Root mean square
SPSS	Statistical Package for the Social Sciences
SD	Standard deviation
TMJ	Temporomandibular joint
TMD	Temporomandibular disorder
TMJD	Temporomandibular joint disorder
WHO	World Health Organization

LIST OF SYMBOLS

Hz	Hertz
et al.	And other workers
%	Percentage
n	Number of subjects
mm	Millimetre
μV	Microvolts
<	Less than
>	More than
=	Equal to
≤	Equal or less than
≥	Equal or more than
°C	Degree Celsius
e.g.	For example

PENILAIAN PROSPEKTIF AKTIVITI OTOT-OTOT MUKA DAN KUNYAHAN BAGI PELBAGAI JENIS PESAKIT MALOKLUSI: SATU KAJIAN ELEKTROMIOGRAFI

ABSTRAK

Proses pengunyahan melibatkan aktiviti otot seperti memamah, menelan dan menghadam makanan dengan menghancur dan memecahkan makanan pejal oleh permukaan oklusal gigi. Telah diketahui bahawa pesakit maloklusi mengalami penurunan dalam kemampuan mengunyah berbanding orang normal. Tujuan kajian ini dijalankan adalah untuk menyiasat dan membandingkan kesan aktiviti otot fasial (buksinator dan orbikularis oris) dan otot pengunyahan (maseter dan temporalis) melalui elektromiografi permukaan (sEMG) sebelum dan semasa 6 bulan selepas rawatan ortodontik. Pesakit berbangsa Melayu dengan pelbagai tahap maloklusi (Kelas I, II div 1, II div 2 dan III) telah dipilih melalui penyaringan oleh pakar daripada Klinik Pakar Ortodontik, Hospital Universiti Sains Malaysia. Setiap pesakit diambil keizinan melalui pengisian borang yang kemudiannya dibahagikan secara rawak melalui kaedah loteri konvensional dan perancangan rawatan ditentukan berdasarkan diagnosis akhir. Bagi memenuhi objektif dan saiz sampel, pesakit dibahagikan kepada beberapa kumpulan iaitu kumpulan *laser* dan *non-laser*; kumpulan cabutan dan tanpa cabutan; dan tiga lagi kumpulan braket berbeza (braket konvensional, braket ligate-sendiri dan braket seramik). Kaedah sEMG otot telah dijalankan dengan menggunakan alat dwi-saluran elektromiografi yang disertakan dengan pra-gel dan elektrod bilateral lekat-sendiri. Aktiviti sEMG otot maseter, temporalis, buksinator dan oris orbikularis telah direkodkan bagi setiap aktiviti berbeza (memamah, mengetap, meniup dan senyum) sebelum dan selepas enam bulan rawatan ortodontik tetap diberikan. Berdasarkan analisis statistik, Kelas II div 1 maloklusi menunjukkan aktiviti otot tertinggi berbanding Kelas I, Kelas II div 2 dan Kelas III maloklusi. Juga terdapat perbezaan ketara terhadap aktiviti memamah oleh otot maseter kanan (*P*= 0.025) dengan pelbagai overjet. Selain itu, pesakit maloklusi dengan pelbagai overbite memberikan nilai perbezaan yang ketara kepada aktiviti meniup oleh orbikularis oris bawah semasa tiupan pertama (*P*=0.007), tiupan kedua (*P*=0.005), puncak tinggi tiupan pertama (*P*=0.014) dan puncak tinggi tiupan kedua (*P*=0.011). Hasil kajian juga menunjukkan perbezaan signifikan bagi aktiviti otot buksinator kanan semasa senyuman pertama (*P*= 0.040) dengan profil muka berbeza. Walau bagaimanapun, aktiviti senyum oleh orbikularis oris atas menunjukkan perbezaan signifikan semasa rehat (*P*= 0.048), senyuman kedua (*P*= 0.038), puncak tinggi senyuman pertama (*P*= 0.041) dan puncak tinggi senyuman kedua (*P*= 0.032) dengan kemampuan bibir berbeza. Berdasarkan analisis berulang ANOVA, keputusan menunjukkan perbezaan bererti bagi aktiviti otot dengan prosedur rawatan cabutan dan tanpa cabutan. Pesakit yang menerima rawatan ortodontik braket konvensional menunjukkan aktiviti EMG yang lebih baik berbanding dengan pesakit dari kumpulan rawatan braket pasang-sendiri dan braket seramik. Pesakit Kelas II div 1 maloklusi yang dirawat dengan sistem braket konvensional dan menerima LLLT (terapi laser tahap rendah) menunjukkan aktiviti otot yang lebih baik beranding dengan sistem braket ligate-sendiri.

PROSPECTIVE EVALUATION OF FACIAL AND MASTICATORY MUSCLES ACTIVITY IN DIFFERENT MALOCCLUSION PATIENTS: AN ELECTROMYOGRAPHY STUDY

ABSTRACT

Mastication procedure involves muscular activity by chewing, swallowing and digestion of food where the occlusal surfaces of the teeth are involved for crushing and grinding of solid foods. It is well established that malocclusion patient exhibits a decrease in masticatory performance when compared with normal occlusion. This study aimed to investigate and compare the effect of the facial (buccinator and orbicularis oris) and masticatory (masseter and temporalis) muscle activity via surface electromyography (sEMG) in orthodontic patients pre and at 6 months of the orthodontic treatment. Malay patients with different types of malocclusion (Class I, II div 1, II div 2 and III) were selected through screening from the Specialist Orthodontic Clinic, Hospital Universiti Sains Malaysia. After taking the informed consent, patients were randomized, and the treatment plan was done with the final diagnosis. According to the objectives and sample size, patients were subdivided into different groups such as laser and non-laser groups; extraction and non-extraction groups and three different brackets groups (conventional, self-ligating and ceramic brackets). sEMG of muscles were done by using a two-channel electromyography device, where pre-gelled and self-adhesive electrodes (bilateral) were used. sEMG activity of masseter, temporalis, buccinator and orbicularis oris muscle were recorded during different action (chewing, clenching, blowing and smiling) before and at six months of fixed orthodontic treatment. In the statistical analysis, Class II div 1 malocclusion presented with higher

muscle activity in comparison to Class I, Class II div 2 and Class III malocclusion. There was a significant difference found in the chewing activity of the right masseter muscle (P= 0.025) with different overjet. Furthermore, malocclusion patients with different overbite showed a significant difference in blowing activity of lower orbicularis oris during 1st blow (P=0.007), 2nd blow (P=0.005), the high peak of 1st blow (P=0.014) and the high peak of 2nd blow (P=0.011). The present study showed a significant difference in right buccinator muscle activity during 1st smile (P= 0.040) with different face profile. However, the smiling activity of upper orbicularis oris showed significant differences during rest (P= 0.048), 2nd smile (P= 0.038), the high peak of 1st smile (P= 0.041) and the high peak of 2nd smile (P= 0.032) with different lip competency. Analysis of repeated measured ANOVA showed a significant difference in muscle activity between extraction and non-extraction treatment procedure. The patient who received conventional bracket for orthodontic treatment showed higher EMG activity in compare with self-ligating and ceramic bracket groups. Class II div 1 malocclusion patients who were treated with conventional bracket system and received LLLT (low level laser therapy), presented higher muscle activity in comparison with the self-ligating bracket system.

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Surface electromyography (sEMG) is defined as the recording and study of the fundamental electrical properties of skeletal muscle by means of superficial electrodes, which basically determine if the muscle is contracting or not (Ferrario *et al.*, 2000). sEMG is harmless and beneficial for assessing the muscles activity in healthy and dysfunctional persons and has clinical applications for both adults and children (Cecilio *et al.*, 2010; Prasad *et al.*, 2019). sEMG is an extensively used process of monitoring masticatory and facial muscles action (Andrade *et al.*, 2009), as an effort to recognise the physiological and pathological circumstances of the stomatognathic system. Any dental management is considered complete only if there is harmony between aesthetics and function (Cecilio *et al.*, 2010; Klasser and Okeson, 2006). The ease of application of sEMG procedures clarifies their use in clinical and research areas. sEMG permits the recording of effective and reliable quantitative data on the functional condition of the facial and masticatory muscles in resting form, maximum muscle contraction, and bilateral symmetry of the contraction behaviour of the orofacial muscles (Castroflorio *et al.*, 2008; De Felício *et al.*, 2009; Hugger *et al.*, 2008; Svensson *et al.*, 2004). The masticatory muscle activity at its maximum exertion depends on occlusal factors such as the occlusal harmony, number of posterior occlusal contacts, proper horizontal and vertical overlapping of teeth etc (Moreno *et al.*, 2008). In clinics, EMG may be used to assess the influence of occlusal conditions on stomatognathic function. For instance, occlusal stability has been found to be related to muscular performance, i.e. subjects with higher occlusal stability showing shorter contraction times and larger EMG potentials during chewing than subjects with lower occlusal stability (Ferrario *et al.*, 2000).

A stable state of the musculoskeletal system is provided by a harmony of occlusion, the anatomy of temporomandibular joints, and the activity of the masticatory muscles under the control of the peripheral and central nervous system (Smaglyuk and Liakhovska, 2019). However, the changes in muscle activity (both masticatory and facial muscles) are more frequently considered as the result of diseases and are not related to their causes. It is supposed that an unnecessary increase of masticatory muscles activity is the consequences of functional disturbances in the stomatognathic system. In the same way, the EMG activity of the masticatory muscles varies according to facial type. Different craniofacial morphologies can cause alterations to neuromuscular activities, such as muscles' bioelectrical potentials (Custodio *et al.*, 2011; Farella *et al.*, 2003; Ginszt *et al.*, 2017; Sondang *et al.*, 2003). Furthermore, malocclusion and stomatognathic system are inter-related with each other, which may affect muscle activity. Moreover, the orthodontic treatment plan requires the knowledge and understanding of the surrounding muscles and their actions, which is related to malocclusion. The prime concern of most of the orthodontic patients is to improve their dentofacial aesthetics, and the secondary concern is to have oral health benefits (Samsonyanová and Broukal, 2014; Taibah and Al-Hummayani, 2017). Orthodontists are more frequently concerned about the vertical forces during treatment of malocclusions patient using Class II elastics or tip back bends (Sathyanarayana *et al.*, 2012). Malocclusion is associated with altered bite force (force produced by surrounding muscles, particularly in dental occlusion masticatory muscles). Bite strength is the result of the organisation between the components of the stomatognathic system that includes the teeth, muscles and bones (Alam, 2016; Sathyanarayana *et al.*, 2012; Sonnesen and Bakke, 2007).

A systematic review was done by Magelhaes *et al.* in 2010 to find out the relationship between malocclusion and masticatory performance. He also investigated the influence of malocclusion type and severity of masticatory performance. In the review, it was reported that malocclusions cause reduced masticatory performance which is also connected with decreased occlusal contact area or intercuspation (Magelhaes *et al.*, 2010). Masticatory performance is usually decreased due to malocclusion. Indeed, altered or reduced muscle activity is associated with fewer intermaxillary tooth contacts (Hatch *et al.*, 2001). So, it is necessary to find out the changes that occur in malocclusions patient after receiving orthodontic treatment. In addition, orthodontic treatment includes several types of orthodontic brackets, depending on the treatment needs and the patient's preference. These orthodontic brackets in the oral cavity are exposed to a variety of forces (such as chewing force, occlusal force, force created by the cheek muscles etc). Therefore, the orthodontic brackets need to deliver an optimal orthodontic force, which can tolerate the masticatory loads. The effects of orthodontic brackets and their force on muscle activity are still unknown (Scribante *et al.*, 2013).

The main problem of the orthodontic procedure is pain and longer duration of treatment following the application of forces. Several methods, such as laser therapy have been used to reduce the pain and the treatment duration. Many researchers have recommended the low-level laser therapy (LLLT), as it is easy to use, a localized, nonsurgical, non-invasive method with no adverse effect hence gaining importance in orthodontic tooth movement (Guram *et al.*, 2018). The application of LLLT in orthodontics has shown to be effective in reducing orthodontic pain and in the photo biomodulation that might accelerate orthodontic tooth movement (AlSayed Hasan *et al.*, 2016).

1.2 Problem statement

In malocclusion patient, the orthodontist needs to do protrusion and retraction of teeth for treatment purpose, which will also change the face profile from its previous shape. However, this change in facial profile causes a modification in orofacial muscle activity and may alter musculature strength. This study was therefore concerned with investigating muscle activity in the phase of muscle contraction, the relaxation phase, maximum activation level, the overall activity of the muscle spectrum using sEMG technique. In this study, the changes in muscle activity were evaluated in patients with malocclusions at 6 months of the fixed orthodontic treatment. The idea of changes in muscle activity with orthodontic treatment can be obtained from this study. In this study, the necessity of treatment of malocclusion and proper muscle function was reflected. Where the result of the current research showed some significant changes in the muscle activity, which is associated with tooth position, occlusal relationship and anatomy of the dental arches.

Now, many studies have reported that the prevalence of malocclusion and craniofacial deformities appear to be significantly increased (Peck, 2016). According to physical anthropologists, these changes in dental occlusion is related with individual's diet system (von Cramon-Taubadel, 2011), and recommended that masticatory behaviours might have a long-term effect on dentofacial growth and development. This issue has become an interesting topic for both orthodontists and physiologists, and some studies have been conducted to find out the association between masticatory performance, malocclusion and craniofacial morphology. Some of the researches compared the masticatory performance of different types of malocclusion based on Angle Classifications (Barrera *et al.*, 2011; Zhiyi *et al.*, 2018). According to Barrera *et al.* (2011), masticatory performance improves with age, and the changes appear to be influenced by the loss of the deciduous teeth during the late mixed dentition phase of dental development. Although there are limited sex differences in masticatory performance among subjects 6 to 17 years of age, mild forms of Class I and Class II malocclusions have little or no effect on masticatory performance (Barrera *et al.*, 2011).

Toro *et al.* (2006) demonstrated that children with normal occlusion had better masticatory performance than those with malocclusion in Class I, but there was no significant difference between those with Class II and Class III (Toro *et al.*, 2005). Another author English *et al.* (2002) and Heorikoon *et al.* (1998) found that children with normal occlusion had better mastication activity than those with Class II and III malocclusions (English *et al.*, 2002; Heorikoon *et al.*, 1998). The current study was, therefore, more focused on finding changes in muscle activity in adult patients with different malocclusions (Class I, II and III).

Orthodontic management of malocclusions and craniofacial abnormalities helps to achieve the goal of treatment, by ensuring appropriate teeth alignment, occlusal harmony and jaw relationship. This can improve mastication, speech and facial aesthetics that play a major role in improving the quality of life. However, one of the etiological factors for malocclusion is muscle pressure, which remains active after orthodontic treatment and relapse towards the original malocclusion can be accepted. Tooth relapse after orthodontic treatment is associated with lip-tongue factors related to the muscle balance (Proffit, 1975). Furthermore, there are some controversies remain regarding the treatment effects and relapse of malocclusion (Class I, II and III). Among the malocclusions, Class II div 1 malocclusion demonstrates more muscular pressure as masticatory muscles have some association with this. Most patients of Class II div 1 malocclusion present with hyperactive perioral muscle and altered tongue position (Lau and Hägg, 1999). Therefore, after orthodontic treatment, patients with Class II div 1 malocclusion can experience a major change in muscle activity. Their muscle activity may become more or less hyperactive than before (Sathyanarayana *et al.*, 2012). It is very important to know about the changes in muscle activity in different malocclusion patients after receiving orthodontic treatment.

EMG was used in orthodontic diagnosis, but also to verify the effects of therapy; in particular, muscular effects in Class II malocclusion treatment by functional appliances were investigated (Di Palma *et al.*, 2017). But the impact of different orthodontic brackets on muscle activity which used in orthodontic treatment is still unknown. Goldreich *et al.* in 1994 evaluated the effect of orthodontic archwire adjustment pain on masseter electromyographic activity. The electromyographic levels during function decreased significantly after treatment started. The results suggest that orthodontic pain on teeth tend to reduce muscle activity during function (Goldreich *et al.*, 1994). Masticatory muscles activity could affect the active treatment of malocclusions and jaw deformities, as well as the stability of such treatment. Therefore, it is an important issue to focus and find out the changes in muscle activity with different orthodontic brackets in fixed orthodontic treatment (Sumonsiri and Thongudomporn, 2017).

Low-level laser therapy (LLLT) has been introduced in orthodontic procedures with the initial purpose of reducing pain after appliance adjustment and improving the healing of the painful spot caused by impingement of appliances (Kim *et al.*, 2015). Clinical observation shows that discomfort and pain sensations usually appear a few hours after force application for orthodontic tooth movement (Bergius *et al.*, 2000) or during the 1st day or 1st couple of days of treatment and that pain intensity reduces to normal levels after 1 week (Fernandes *et al.,* 1998; Scheurer *et al.,* 1996). It has been emphasised that pain reduction is necessary for orthodontic treatment without analgesic drugs. Several studies revealed that effective pain reduction could be achieved through low-level laser therapy (LLLT) after undergoing various dental treatments (Youssef *et al.*, 2008). Till today the studies conducted on LLLT for orthodontic tooth movement did not assess its effect on soft tissue structure like surrounding musculature and its activity which is highly connected with malocclusion.

So the question arises, are there any changes occurring in the muscular activity in the patients treated with low level laser therapy (LLLT)? If any changes are happening, then it’s very important to concentrate on muscle activity during orthodontic treatment to minimize this change.

1.3 The Rationale of the study

It is very difficult to define the relationships between craniofacial morphology or structure and the function of the stomatognathic system (WoŸniak *et al.,* 2013). Patients with different malocclusions have different craniofacial structures, where the surrounding musculature also differ in actions. Because of this malocclusion, their occlusal relationship appears with different characteristics as well as altering muscle function accordingly. It's very important to know the changes in the muscle (both facial and masticatory) activity in different malocclusion patients for proper orthodontic management. Few studies were conducted previously to find out electromyographic activity, specially masseter and temporalis muscle, in patients of different ethnicity, malocclusion and temporomandibular joint disorder. In 2012, De Felício *et al.* conducted a research to evaluate the association between surface EMG of masticatory muscles, orofacial myofunctional status, and severity scores of TMD (De Felício *et al.*, 2012). Alam *et al.* (2013) conducted a study in Malaysia, to evaluate malfunction by sEMG of the face (masseter) and head (temporalis) muscles during brushing teeth Miswak, which may induce a dynamic role in the face and head muscles exercise (Alam *et al.*, 2013). Alam *et al.* (2015) conducted another study to assess the satisfaction of patients with posterior implants concerning the criteria for clinical success and the sEMG findings of the masseter and temporal muscles in Malaysia (Alam *et al.*, 2015). But the stomatognathic function of the orthodontic patients needs to evaluate which have not been conducted yet.

In sEMG recording, by placing EMG electrodes over particular muscles of the face, head, or neck, it is possible to monitor the amount of tension in these. The EMG electrodes pick up the activity and transmit it to a graphical recorded, and this gives an objective way of measuring how much tension a muscle is experiencing. When a malocclusion exists, muscles must torque to bring the jaw together. By identifying which muscles are working harder, it is possible to determine where adjustments need to be made to relieve muscle strain. A deep bite, a crossbite, and premature hitting on a rotated bicuspid can all result in tense torqued muscles. By tensing, measuring jaw movement, and measuring muscle activity, a definitive and reproducible position where the muscles are most relaxed can be established (Zhiyi *et al.*, 2018). However, some electromyographic study has also been conducted in recent years. But they mainly focused on masseter and temporalis muscle and their actions (especially maximum clenching) with different myofunctional appliances. In 2016, a study was conducted by Biondi *et al.* to evaluate the relationship between masseter size, maxillary intermolar width and craniofacial vertical skeletal pattern (Biondi *et al.*, 2016). Szyszka-Sommerfeld also established a study in 2017, to evaluate the electrical activity of the superior orbicularis oris muscle in children surgically treated for unilateral complete cleft lip and palate (UCCLP) (Szyszka-Sommerfeld *et al.*, 2017). Moreover, in 2018 another interesting study was conducted to determine the difference in electromyography (EMG) of the orbicularis oris muscles between subjects with lip incompetence and lip competence and to elucidate the effectiveness of hypoxic lip training with EMG (Yoshizawa *et al.*, 2018). According to Siqueira *et al.* (2011), electromyographic activity of the buccinator, mentalis, orbicularis oris, temporal, masseter and mandibular depressor muscles during the movements of deglutition, light contact of the teeth, forced occlusion, suction, rest and various mandibular movements did not differ among children with deciduous dentition and adults with normal occlusion (Siqueira *et al.*, 2011). So, it’s evident that malocclusion and muscle activity have a strong connection. For the clinicians, during treatment of the malocclusion patients without knowing the muscle strength and tonicity might cause recurrence of the condition. Therefore, a proper evaluation of muscle activity among different malocclusion patients before and after receiving their treatment is a topic to be focused.

Nowadays, LLLT is very popular in dental pain management, as well as in orthodontics. LLLT is helpful in orthodontic pain reduction and also accelerate the orthodontic tooth movement by increases osteoblastic activity, vascularization, and organization of collagen fibers (Ge *et al.*, 2015; Oliva *et al.*, 2009). The present study has been evaluated the effects of LLLT in muscle activity of the orthodontic patients. sEMG was assessed for chewing, clenching, blowing and smiling activity of the facial and masticatory muscle in malocclusion patients. All of this muscle activity is highly connected with our tooth relation and aesthetics. This will be helpful in diagnosing abnormal or altered muscle function of orthodontic patients before planning the treatment.

Up to our limitation of knowledge, this is the first study involving Malay population to investigate the facial (buccinator and orbicularis oris) and masticatory (masseter and temporalis) muscle activity in different malocclusions patient measured via sEMG and treated by different types of brackets (conventional, self-ligating and ceramic). Evidence from population studies has demonstrated that Class II malocclusion is closely related to the effect of masticatory muscle function (Lowe *et al.*, 1983; Pancherz *et al.*, 1997; Sood *et al.*, 2011; Usumez *et al.*, 2004). In Malaysia, no study has been done so far to investigate Electromyography activity in Class II div 1 malocclusion patients treated with conventional and self-ligating bracket system with low level laser therapy (LLLT).

1.4 Objectives

1.4.1 General objectives

To investigate and compare the effect of the facial (buccinator and orbicularis oris) muscle and masticatory (masseter and temporalis) muscles activity via surface electromyography (sEMG) in orthodontic patients.

1.4.2 Specific objectives

1. To determine the facial and masticatory muscles activity measured via sEMG in Class I, Class II (division 1 and division 2) and Class III malocclusion patients.
2. To determine the facial and masticatory muscles activity measured via sEMG in different malocclusion patients with different overjet, overbite, facial profile, facial morphology and lip competency.
3. To compare the effect of facial and masticatory muscles activity measured via sEMG in malocclusion patients treated by extraction and non-extraction in conventional bracket system pre and at six months of the orthodontic treatment.
4. To determine the effects of facial and masticatory muscles activity measured via sEMG between different bracket types (conventional, self-ligating and ceramic bracket) in orthodontic patients pre and at six months of the orthodontic treatment.
5. To investigate and compare the effect of facial and masticatory muscles activity measured via sEMG in Class II division 1 malocclusion treated by LLLT and without LLLT in conventional bracket system pre and at six months of the orthodontic treatment.

6. To investigate and compare the effect of facial and masticatory muscles activity measured via sEMG in Class II division 1 malocclusion treated by LLLT and without LLLT in self-ligating bracket system pre and at six months of the orthodontic treatment.
7. To investigate the effect of facial and masticatory muscles activity measured via sEMG in Class II division 1 malocclusion treated by LLLT between conventional and self-ligating bracket system pre and at six months of the orthodontic treatment.

1.5 Research questions

1. Is there any difference in the facial and masticatory muscles activity measured via sEMG in Class I, Class II (division 1 and division 2) and Class III malocclusion patients?
2. Is there any difference in the facial and masticatory muscles activity measured via sEMG in different malocclusion patients with different overjet, overbite, facial profile, facial morphology and lip competency?
3. Is there any difference in the facial and masticatory muscles activity measured via sEMG in malocclusion patients treated by extraction and non-extraction in conventional bracket system pre and at six months of the orthodontic treatment?
4. Is there any difference in the facial and masticatory muscles activity measured via sEMG between different bracket types (conventional, self-ligating and ceramic bracket) in orthodontic patients pre and at six months of the orthodontic treatment?

5. Is there any difference in the facial and masticatory muscles activity measured via sEMG in Class II division 1 malocclusion treated by LLLT and without LLLT in conventional bracket system pre and at six months of the orthodontic treatment?
6. Is there any difference in the facial and masticatory muscles activity measured via sEMG in Class II division 1 malocclusion treated by LLLT and without LLLT in self-ligating bracket system pre and at six months of the orthodontic treatment?
7. Is there any difference in the facial and masticatory muscles activity measured via sEMG in Class II division 1 malocclusion treated by LLLT between conventional and self-ligating bracket system pre and at six months of the orthodontic treatment?

1.6 Hypothesis

1.6.1 Alternative hypotheses

1. There is a significant difference in the facial and masticatory muscles activity measured via sEMG in Class I, Class II (division 1 and division 2) and Class III malocclusion patients.
2. There is a significant difference in the facial and masticatory muscles activity measured via sEMG in different malocclusion patients with different overjet, overbite, facial profile, facial morphology and lip competency.
3. There is a significant difference in the facial and masticatory muscles activity measured via sEMG in malocclusion patients treated by extraction and non-

extraction in conventional bracket system pre and at six months of the orthodontic treatment.

4. There is a significant difference in the facial and masticatory muscles activity measured via sEMG between different bracket types (conventional, self-ligating and ceramic bracket) in orthodontic patients pre and at six months of the orthodontic treatment.
5. There is a significant difference in the facial and masticatory muscles activity measured via sEMG in Class II division 1 malocclusion treated by LLLT and without LLLT in conventional bracket system pre and at six months of the orthodontic treatment.
6. There is a significant difference in the facial and masticatory muscles activity measured via sEMG in Class II division 1 malocclusion treated by LLLT and without LLLT in self-ligating bracket system pre and at six months of the orthodontic treatment.
7. There is a significant difference in the facial and masticatory muscles activity measured via sEMG in Class II division 1 malocclusion treated by LLLT between conventional and self-ligating bracket system pre and at six months of the orthodontic treatment.

CHAPTER 2

LITERATURE REVIEW

2.1 Definition of malocclusion

A malocclusion is a misalignment of teeth and/or inappropriate relation between the teeth of two dental arches when they contact each other as the jaws close. The term was recognized by Edward Angle, the "father of modern orthodontics" (Proffit *et al.*, 2006). It may be characterized by anomalies within the dental arches, malrelation of dental arches and skeletal facial discrepancies (Mtaya *et al.*, 2017). According to World Health Organization (WHO), malocclusion can be defined as “a dento-facial anomaly that refers to irregular occlusion and/or abnormal craniofacial relationships, which may interrupt aesthetic appearance, function, facial harmony, and psychosocial well-being” (Zou *et al.*, 2018).

2.2 Prevalence of malocclusion

Malocclusion is one of the most common dental problems, with a high prevalence ranging from 20% to 100% based on the evidence of different researchers (Zou *et al.*, 2018). The prevalence of malocclusion in different populations have been reported in many studies. The prevalence of malocclusion differs broadly from country to country and among races. Table 2.1 shows the reported prevalence of malocclusion in several countries.

Table 2.1: Reported prevalence of malocclusion in different countries.

Author and year	Study population	Sample size	Age of the samples	Prevalence of malocclusion (%)
(Al-Emran *et al.*, 1990)	Saudi Arabia	500	13.5-14.5	62.4
(Kang and Ryu, 1992)	Korea	2460	18-21	91.5
(Lew *et al.*, 1993)	Australian Chinese	1050	12-14	92.9
(Ansai *et al.*, 1993)	Japanese	409	15-18	40
(Ng'ang'a *et al.*, 1996)	Kenya	919	13-15	72
(Thilander *et al.*, 2001)	Colombia	4724	5-17	88
(Silva and Kang, 2001)	United states (Latino)	507	12-18	93
(Onyeaso, 2004)	Nigeria	636	12-17	76
(Alhaija *et al.*, 2005)	Jordan	1003	13-15	92
(Gábris *et al.*, 2006)	Hungary	483	16-18	70.4
(Rwakatema and Nganga, 2006)	Tanzania	289	12-15	97.6
(Dhar *et al.*, 2007)	India	1587	5-14	36.42
(Gelgör *et al.*, 2007)	Turkey	2329	12.5-17.4	89.9
(Atashi, 2007)	Iran	398	13-15	90
(Nobile *et al.*, 2007)	Italy	1000	11-15	59.5
(Ajayi, 2008)	Nigeria	441	11-18	84.1
(Grando, 2008)	Brazil	926	8-12	88.45
(Borzabadi-Farahani *et al.*, 2009)	Iran	502	11-14	77.1
(Martins and Lima, 2009)	Brazil	264	10-12	74.2

Table 2.1 continue

(Komazaki *et al.*, 2012)	Japan	821	12-15	46.5
(Shrestha *et al.*, 2012)	Nepal	937	14-16	73.3
(Bugaighis and Karanth, 2013)	Libya	900	12-17	95.8
(Kumar *et al.*, 2013)	India	1200	10-15	Male= 53.7 Female= 32.8
(Haralur *et al.*, 2014)	Saudi Arabia	250	15-35	42.8
(Dimberg *et al.*, 2015)	Sweden	277	3,7 and 11.5	3 years= 71 7 years=56 11.5 years=71
(Cabrita *et al.*, 2017)	Portugal	202	13-45	37.6
(Figueroa *et al.*, 2017)	Chile	130	14-18	63.8

From the beginning of the orthodontic practice, orthodontists have conducted several studies on the incidence and prevalence of malocclusion. The prevalence varies depending on the age range of the participants, gender, different population, ethnicity and malocclusion scoring criteria (Gelgör *et al.*, 2007). A study conducted by Rwakatema and Nganga (2006) showed the prevalence of malocclusion was 97.6% in a Tanzanian population among the 13-15 years age group (Rwakatema and Nganga, 2006). Similarly, another study by Bugaighis and Karanth (2013) found that the prevalence of malocclusion was 95.6% in a Libyan population among the 12-17 years old subjects (Bugaighis and Karanth, 2013). However, in the United States, the prevalence of malocclusion was 93% (Silva and Kang, 2001). Malocclusion prevalence in the Jordanian population was 92% (Alhaija *et al.*, 2005). The prevalence of malocclusion in Australian Chinese (92.9%) and Korean (91.5%) population was almost very close (Kang and Ryu, 1992; Lew *et al.*, 1993). According to Woon *et al.* (1989), the prevalence of Class III occlusion among the Chinese and Malays was significantly higher as compared to the Indians. (Woon *et al.*, 1989). A systematic review and meta-analysis for the prevalence of Class III malocclusion found that Chinese and Malaysian populations have a higher prevalence of Angle Class III malocclusion compared to other racial groups, while Indian populations have a lower prevalence than all other racial groups (Hardy *et al.*, 2012). Abdullah and Rock (2001) observed the prevalence of malocclusion was 47.9% in Malaysian population (Abdullah and Rock, 2001). On the other hand, Dhar *et al.* (2007) found 36.42% prevalence of malocclusion for the Indian population, which is the lowest compared to other populations (Dhar *et al.*, 2007). However, another study by Kumar *et al.* (2013) showed a prevalence of malocclusion in Indian population of 32.8% for females and 53.7% for males (Kumar *et al.*, 2013). Furthermore, the prevalence of malocclusion was found 37.6% in Portugal people with the age range between 13-45 years (Cabrita *et al.*, 2017).

2.3 Classification of malocclusion

According to Klages *et al.* (2004), an individual with malocclusion may refrain himself or herself from social interactions, may lose career opportunities and may feel embarrassed about their dental appearances (Klages *et al.*, 2004). The malocclusion has been found to affect oral-facial health, increased prevalence of tooth caries and may lead to temporomandibular joint disorders (TMJD). Although some of the patients seek orthodontic management to improve their oral musculature and functional ability.

However, most of the people request for orthodontic treatment because of their motivation towards attractive appearance and improvement of their self-confidence (Abu Alhaija *et al.*, 2005; Soh and Sandham, 2004). The benefits of receiving orthodontic management comprise prevention of surrounding tissue damage, improvement of aesthetics as well as the physical function (Shrestha *et al.*, 2012).

Malocclusion classification is a description of dentofacial deviations according to a common characteristic or standard (Singh, 2012). Different researchers have proposed a different classification of malocclusion based on their experiences and depending on what they found to be clinically relevant. In 1899, Edward Angle classified malocclusion based on the mesio distal relation of the teeth, dental arches and jaws. For this classification, he considered the maxillary first permanent molar as a fixed anatomical point in the jaws and the key to occlusion (Brin *et al.*, 2000; Singh, 2012).

Angle classified malocclusion into three major classes and represented by Roman numbers- I, II and III. (Figure 2.1)

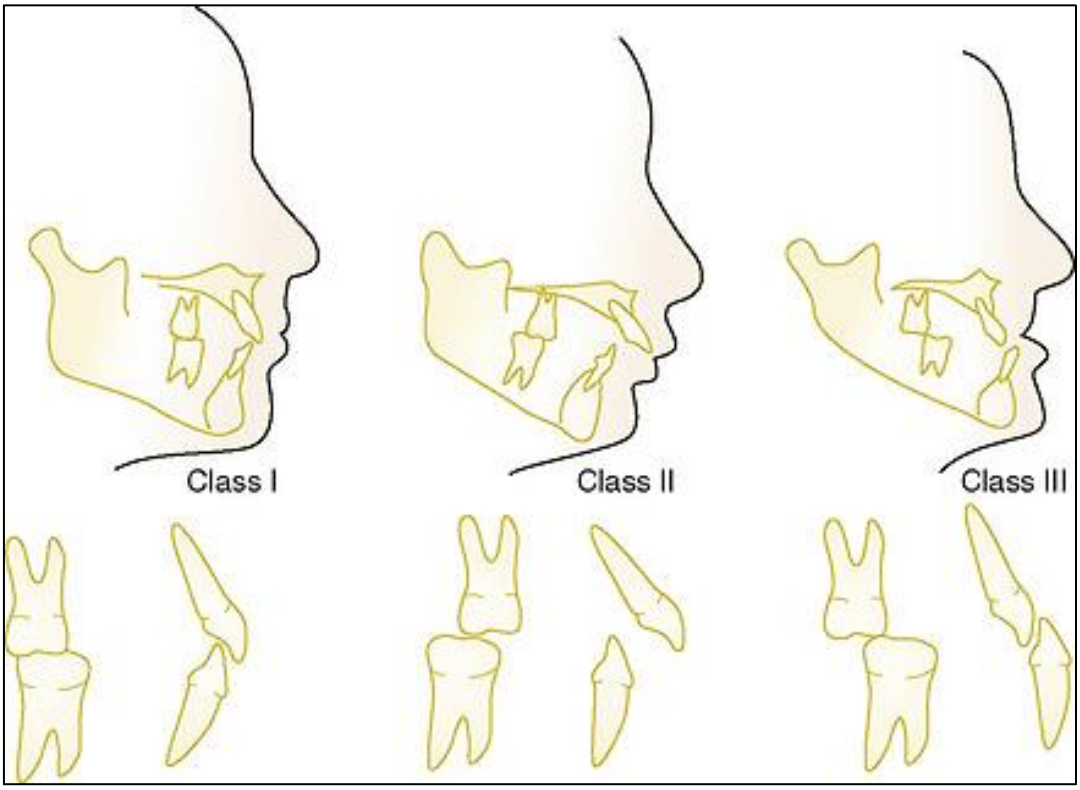

Figure 2.1: Angle's classification of malocclusion (Class I, II and III) {Retrieved from (Bondemark, 2018)}.

2.3.1 Class I malocclusion

Angle's Class I malocclusion present with normal inter-arch first permanent molar relation with the mesiobuccal cusp of the maxillary 1st molar occluding in the buccal groove of the mandibular 1st molar and mesiolingual cusp of the maxillary 1st molar occludes with the occlusal fossa of the mandibular 1st molar when the jaws are at rest, and the teeth approached in centric occlusion. Though Class I malocclusion appears with normal molar relationship but there may be found crowding, misalignment of teeth, spacing, crossbite etc. Patients with Class I malocclusion (Figure 2.2) exhibits normal skeletal relation with normal muscle function. The teeth are in a state of balance with environmental forces. However, actual measurements of tongue and lip forces show that they are not equal in any one area during the function. (Nishi *et al.*, 2017; Proffit *et al.*, 2014; Singh, 2012).

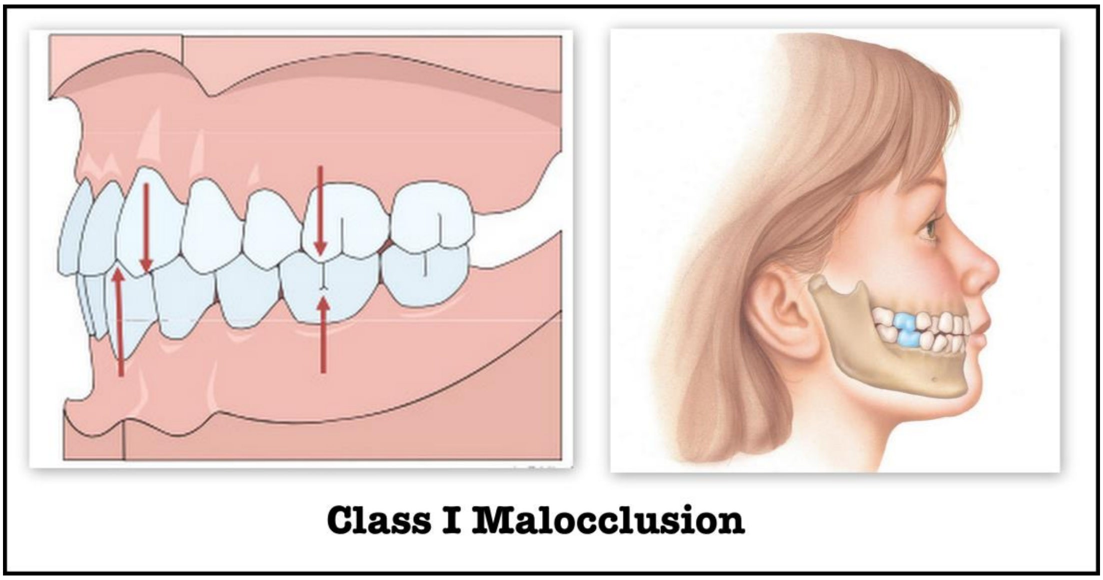

Figure 2.2: Angle's Class I malocclusion {Retrieved from (Bondemark, 2018)}.

According to Angle's observation, it is reported that almost every malocclusion has some soft tissue involvement. Muscle function and mainly tongue position and function have a major influence on the dentition and can lead to a deterioration of an orthodontic correction or even a relapse of the original problem sometimes noticed (Yagci *et al.*, 2010).

2.3.2 Class II malocclusion

Class II malocclusion is where the maxillary 1st molar is even with, or anterior to the mandibular 1st molar and the buccal groove of the mandibular 1st molar is distal to the mesiobuccal cusp of the maxillary 1st molar (Moyers *et al.*, 1980). It is characterized when the disto-buccal cusp of the upper first permanent molar occludes in the buccal groove of the lower first permanent molar (Nishi *et al.*, 2017). The distal surface of the mandibular canine is distal to the mesial surface of the maxillary canine by at least the width of a premolar. In this unusual relationship, the upper front teeth and jaw project more forward than the lower teeth and jaw (Moyers *et al.*, 1980). Class II malocclusions (Figure 2.3) are the most common problem faced in orthodontic practice. Angle has subclassified Class II malocclusions into two divisions: Class II division1 and Class II division 2. Class II division 1 malocclusion patient exhibits hyperactive buccinators and mentalis muscle function with altered tongue position. Class II division 2 patients exhibit normal perioral muscle activity (Bader *et al.*, 2008; Bishara, 2001b; MK, 2012; N *et al.*, 2001; Nishi *et al.*, 2017; Sanborn, 1955).

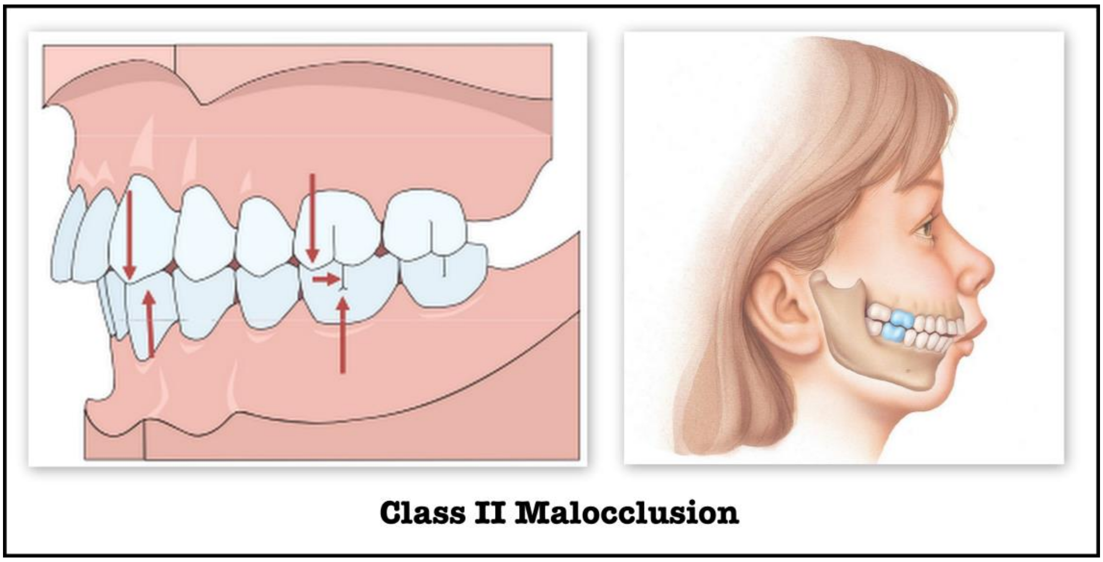

Figure 2.3: Angle's Class II malocclusion {Retrieved from (Bondemark, 2018)}.

According to Egermark-Eriksson *et al.* (1983), children with Class II malocclusion tended to experience more masticatory muscle tenderness (Egermark-Eriksson *et al.*, 1983). An association between muscle tenderness and Class II malocclusion has been verified in adults (Demir *et al.*, 2004). There was no relationship between muscle tenderness and Angle classification in one study. Another study, reported that there was no statistical association of Class II malocclusion with muscle tenderness, whereas a significant interaction was noticed between molar relationship, gender, and age and the probability of muscle tenderness (Riolo *et al.*, 1987). However, some controversies remain regarding the treatment effects and relapse of Class II malocclusion as masticatory muscles have some association with this (Lau and Hägg, 1999).

McNamara and James (1981) claimed that the most common skeletal problem in Class II malocclusions in preadolescents is mandibular retrognathia. Class II, division 1 malocclusions may be treated effectively in actively growing patients with any functional appliance (McNamara Jr, 1981). Author H. Pancherz conducted a study, in which he noticed a significant increase in EMG activity for masseter muscle in Class II div 1 malocclusion cases treated with the Herbst appliance (Pancherz and Anehus-Pancherz, 1980). Class II division 2 malocclusion, characterized by distocclusion of the buccal teeth and retroclination of some or all of the maxillary incisors, is primarily determined by hereditary factors. Many clinicians have hypothesized that the retroclination of the upper incisor results from non-physiologically high lip pressure against these teeth. This suggests that the lips act as a local genetic factor in Class II division 2 malocclusion . Lapatki *et al.* (2002) indicated that orthodontic treatment of

Class II division 2 cases should include intrusion of the maxillary incisors, to eliminate the non-physiologically high pressure exerted by the lower lip on these teeth and, consequently, to reduce the high risk of a post-orthodontic relapse (Lapatki *et al.*, 2002).

2.3.3 Class III malocclusion

An Angle Class III malocclusion means that the mandibular 1st molar is anteriorly placed in relation to the maxillary 1st molar. Class III malocclusion (Figure 2.4) characterized by a Class III molar relation with the mesio-buccal cusp of the maxillary first permanent molar occluding in the interdental space between the mandibular 1st and 2nd molars. It can be true Class III and Pseudo Class III. Class III malocclusion appears with altered muscle function (Nishi *et al.*, 2017; Park and Baik, 2001; Proffit *et al.*, 2014; Singh, 2012).

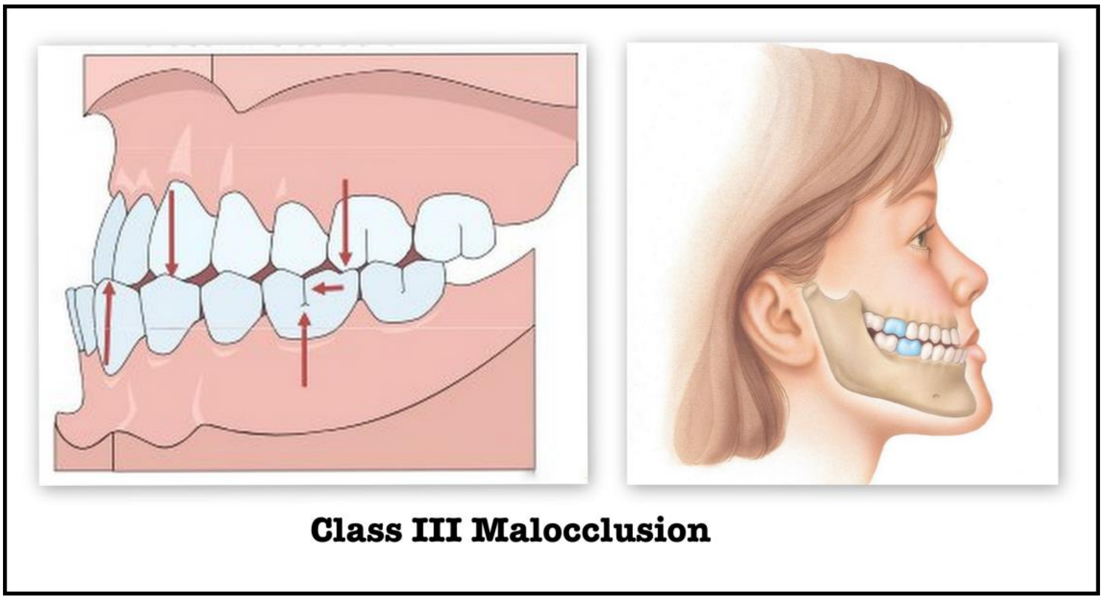

Figure 2.4: Angle's Class III malocclusion {Retrieved from (Bondemark, 2018)}.