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THE EFFECTS OF THE PLACEMENT OF PREFABRICATED METAL CROWNS UTILIZING THE HALL TECHNIQUE ON MASSETER MUSCLE ACTIVITY: A SURFACE ELECTROMYOGRAPHY STUDY IN CHILDREN

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ABSTRACT:

The effects of the placement of prefabricated metal crowns utilizing the Hall technique on masseter muscle activity: A surface electromyography study in children

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Background: Hall technique crowns, used to restore non-pulpal carious primary molars, change the occlusal apparatus temporarily, of which the masseters muscles are part of. Surface-electromyography (sEMG) is used to assess masseter muscle activity (MMA).

Aim: To assess the effect of Hall technique crowns on MMA in children by measuring sEMG.

Methods: Bilateral MMA was recorded (mean integrated sEMG expressed in μV.s) for ten cycles of *Rest Position* (RP) and *Maximum Voluntary Clenching* (MVC) over 20 seconds immediately-pre (P_1) and immediately-post (P_2) cementing a single HTC in 12 healthy children with caries. Further post op results at two weeks (P_3) and six weeks (P_4) results were obtained for 9 and 7 out of the 12 children respectively. T-test, ANOVA and *post hoc* statistical analyses were used. Significance was set at ($p<0.05$).

Results: Bilateral MMA was low at rest and increased during clenching in children. MMA increased significantly ($p<0.001$) between RP and MVC at P_1 from 1.85($\pm$0.96) to 5.49($\pm$2.30) μV.s; at P_2 from 1.77($\pm$1.15) to 3.75($\pm$1.81); at P_3 from 1.39($\pm$0.54) to 5.54($\pm$1.45) and finally

at P_4 from 1.46(±0.56) to 6.6(±2.56). While there were no significant differences between all RP-MMA readings at P_1, P_2, P_3 & P_4 (p=0.18), the MVC-MMA readings differed significantly (p<0.001) as MVC-MMA at P_1 (baseline) reduced by a third at P_2, returning to (p=0.822) and increasing above (p<0.001) MVC-MMA baseline levels at P_3 and P_4 respectively.

Conclusions: Children's masseter muscle clenching activity, as measured by sEMG, reduced immediately after cementing a single HTPMC. The activity returned to, and later exceeded, baseline levels at two and six weeks respectively. HTPMCs had minimal effect on masseter muscle rest activity.

DEDICATION

I would like to dedicate my research to:

My father Ismail. The person that gave me the greatest opportunities anyone could ever wish for. Thank You for believing in me. I'm the luckiest person ever to be your daughter. I wouldn't have made it without your support.

My mother Fadia. The person that has taken care of me from day one. She taught me how to fight and work hard pursuing my dreams and to never underestimated my capabilities.

My beloved siblings. Maram, Al-Haitham, Wasan, and Mohammed. Thank You for all the sacrifices you made for me. Without your encouragements, I would have made it to the person I am today. I love you today, tomorrow and forever.

My dearest husband, Ahmad. My second half. Thank You for all the love, care, attention and support.

Last but not least. My baby and my little angel. I can't wait to see you. I can't wait to be your mother.

DECLARATION

I declare that all the content of this thesis is my own work. There is no conflict of interest with any other entity or organization

Name:

Signature:

ACKNOWLEDGMENTS

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ABBREVIATIONS

(ART): Atraumatic Restorative Treatment

(BSPD): British Society of Paediatric Dentistry

(CNS): Central Nervous System

(DAQ): Data Acquisition

(DDH): Dubai Dental Hospital

(ECC): Early Childhood Caries

(EMG): Electromyography

(GIC): Glass Ionomer Cements

(HT): Hall Technique

(L): Left

(MMA): Masseter Muscle Activity

(MIP): Maximum Intercuspation Position

(MVC): Maximum Voluntary Clenching

(MBRU): Mohammed Bin Rashid University of Medicine and Health Sciences

(OBF): Occlusal Bite Force

(OVD): Occlusal Vertical Dimension

(PMC): Preformed Metal Crown

(P1, P2, P3, P4): Pre and post treatment points in the study

(RP): Rest Position

(R): Right

(SSC): Stainless Steel Crown

(STD): Standard Deviation

(sEMG): Surface-Electromyography

(TMD): Temporomandibular Joint Disorders

(TMJ): Temporomandibular Joints

(UK): United Kingdom

(USA): United States of America

(UAE): United Arab Emirates

(WHO): World Health Organization

LIST OF APPENDICES

1.00 INTRODUCTION

Tooth decay (dental caries) in children is very common.[1] Management of multi-surface dental caries in the primary molar tooth has historically followed the convention of removing dental caries surgically using a drill,[2] preparing the tooth with a high speed bur and placement of a preformed metal crown (PMC).[3,4] However, this convention has been challenged in the past decade by the use of the *Hall technique*[3,5] in addition to other alternative methods.[6]

The Hall technique (HT)[5,7] is a method of caries management in the primary molar using a PMC that does not require any caries removal, tooth preparation or local analgesia.[5,7,8] The HT is based on minimally invasive treatment in children and can be expected to cause less discomfort than conventional treatment approaches.[2,7,8] In the HT, the PMC, also called a stainless steel crown (SSC), is cemented over caries that does not extend radiographically beyond the middle third of dentine.[7,8] The PMC is cemented in place using glass ionomer cement and the carious tooth tissue is sealed, rather than removed, into the crown thus isolating it from the rest of the mouth and sugary substrates.[7,8] As a result of the HT technique, the bite rises but self corrects in two weeks to 30 days.[9] In a major study in children with high caries levels,[10] Hall PMCs were considered a successful method for managing caries in primary molars when compared to control restorations placed in this high caries risk group in primary dental caries.[11] In children with dental caries also, the HT may help reduce anxiety and fear from dentistry.[12] While many studies supported the HT[5,10,11,12] some authors were skeptical about it, [13] condemned it and raised multiple questions regarding the effect of HT on the child's occlusion, the temporomandibular joints (TMJ) and jaw muscles amongst other concerns.[13] van der Zee study[9] proved that the effects on the occlusion and the bite was self-corrected and returned back to the pre-treatment situation within six weeks.[9] Thus, the Hall PMC became so popular in the United Kingdom (UK) that it was labeled as the 'Gold Standard' for managing

the non-pulpally involved carious primary molar[14] but there were no studies that looked into the effect of the HT on the TMJ and jaw muscles. Therefore, there was a need to answer more questions about the short and the long-term effects of the HT and to try to understand the effects of this technique on the jaw muscles and in particular the masseter muscles. One method of assessing such muscles is surface electromyography.[15, 16, 17]

The jaw muscles (masseter, temporalis and pterygoid muscle) are involved in the complex function of oral behaviors, such as mastication, clenching, swallowing, talking, and functions which are under the control of speed, force and jaw movements.[15] Their activity, especially the masseter muscle, can be measured in many ways. Surface electromyography (sEMG) provides a non-invasive method to gather information on the muscular activity through electrodes located over the skin.[15] The simplicity of application of the sEMG technique determined its spread usage in dentistry, both in clinical and research fields.[15] Specifically, muscular activity, as recorded by sEMG has been shown to change when occlusion changed.[18] Occlusal disharmony, such as that introduced by a high restoration or crown, might induce local symptoms of temporomandibular joint pain or intramuscular pain the orofacial pain may be possibly attributed to the occlusal interference as malocclusion or poor/high restorations.[19] Changes in muscle activity in relation to occlusal changes have been assessed through studies in children.[19] sEMG as a quantitative assessment of patients in dentistry can be an objective and reliable diagnostic tool for assessing changes in the electrical activity of the masticatory muscles.[19] As it has been used before in dentistry to assess the effects of orthodontic appliances;[19] it could be a useful tool in assessing the effect of HT on the muscles of mastication.

To our knowledge, there are no studies assessing the effect of the HT on the muscles of mastication as represented by the masseter muscles using the sEMG method, hence this study.

2.00 LITERATURE REVIEW

2.1 Dental caries

Dental caries is a disease of the hard tissue of teeth. It is a patho-biological phenomenon with pathological consequences that affects both primary and permanent teeth.[20] In children, Early childhood caries (ECC) has been defined as ‘‘the presence of one or more decayed (non-cavitated or cavitated lesions), missing (due to caries), or filled tooth surfaces in any primary tooth in a child 71 months of age or younger’’.[21,22] It is a well-established fact that dental caries is a chronic disease which affects children and adults and can be transmitted by different routes.[22,23] Dental caries is known to be a progressive and if cavitated irreversible process that affects the enamel, dentine and the pulp tissue. The treatment of caries is considered to be expensive and painful.[22,23,24] The etiology of dental caries is the combination of different factors including sugar, carbohydrates and multiple host factors such as the salivary flow, mineral content and viscosity.[23,25] The importance of focusing on dental caries in children is due to the fact that it is considered to be the most common chronic childhood disease.[26] It affects the child’s lifestyle due to pain, and psychological problems that develop from poor esthetic appearance and the impairment of normal oral cavity functions such as eating.[26] In the United Arab Emirates (UAE) dental caries is still one of the most prevalent diseases among the population.[23] According to the World Health Organization (WHO) criteria, dental caries mean *dmft* in the UAE is 4.5.[27] It is important to recognize that dental caries effects multiple surfaces of primary molars and incisors, and the HT relates to the former only.

2.2 Primary molars

Healthy children have four primary first molars and four primary second molars in the oral cavity, which start to erupt shortly after the age of one year until three years of age. Primary

molars begin to exfoliate between the age of ten and twelve years old. As it is well-known, primary teeth enamel and dentine are much less in thickness when compared to the permanent teeth.[28] The pulps of the primary teeth in relation to the crown size ratio are larger than the permanent teeth.[28,29] Consequently; the pulp horns of the primary teeth are closer to the outer/enamel surface than the permanent ones. That is why proximal caries in primary teeth should have a wider field of concern.[30] Dental caries can be present from an early age as ECC or SECC. [25,30] The etiology and causes of ECC and SECC is a combination of many factors such as the frequency and the amount of consumption of fermentable carbohydrates and cariogenic bacteria (especially *mutans streptococci*)[20] that plays a major role in the demineralization of the tooth tissues leading to cavitated lesions.[31] According to Ivana *et al.* the strongest predictors of ECC is putting a child to sleep with the use of a bottle with milk formula, sugary drinks or combined frequently along with the high sugary diet consumption.[32]

2.3 Management of primary molar caries

In pediatric dentistry the challenge for the dentist and parents is to gain the children's cooperation with the different dental treatment approaches.[33] The behavior of the dentists and staff will influence the patient behavior and might have a positive impact. In addition, the different modalities of treatment might influence the patient behavior and the extent of accepting the treatment.[33] Different approaches of treatment have been reported in the literature[2,29], such as the conventional treatment. This is the traditional complete removal of carious dentin lesions using a drill usually with the use of oral anesthesia injection with the need to be restored by different dental materials. [2,34,35] In this procedure, a significant amount of the dental structure is removed and this might lead to a pulp tissue exposure.[2,34] In light of this, it is no longer mandatory to completely remove of all the decayed tooth structure.[2,34] This is supported by evidence,[28] but it is argued that carious lesions remaining in the cavity could

be sealed completely.[36] This will facilitate spending less time in lesion removal and giving more attention to adequate cavity restoration.[26] Methods for treating caries in molars vary in many different ways,[29] ranging from sealing in techniques with no caries removal by pit and fissure sealants or the HT. [29,36] to partial caries removal and restoration. Thus, aiming to remove a sufficient carious tissue to enable a proper marginal seal of the dental tissue and the bonded adhesive restoration which leads to the inhibition of further progression of residual caries.[29,37.] A third method is the complete caries removal and restoration which basically aims to remove all the carious tooth structure to restore its function.[29] This method was previously accepted as the best dental practice by the British Society of Paediatric Dentistry (BSPD).[38] Patient cooperation is highly required in this method.[29,2] The procedure steps are local analgesia , the use of high speed handpieces for the complete removal of soft carious tissue which might progress to a pulp exposure and pulp therapy.[29,36]

2.4 Sealing carious lesions

Sealing in techniques with no caries removal for example, sealing the pits and fissures of the occlusal surfaces susceptible to carious lesions with resin based sealants aim to prevent the accumulation of food debris and bacteria's biofilm in these surfaces and hence prevent the development of carious lesions. [29,39] Other methods of sealing carious lesions without intervention with the cavity is by cementing a stainless steel crown with a glass ionomer cement.[40]

2.5 Atraumatic restorative treatment (ART)

ART is an approach used for the treatment of asymptomatic teeth, which is based on controlling the etiological factors of development and progression of carious teeth. It mainly works on small cavities that tooth brush bristles cannot easily penetrate and clean.[27] The cavity is

manually excavated with standard excavators to remove some of the caries and render the cavity retentive. ART is completed by using glass ionomer cements (GIC) to restore the lesion. This had been shown to be as effective as the conventional treatment using amalgam and composite resin restorations.[30,41]

2.6 Resin based composites

Resin-based composite is an esthetic restorative material used for anterior and posterior teeth.[35,42] Resin-based composites have the benefits of allowing the practitioner to be conservative during tooth preparation by avoiding the complete traditional removal of the carious lesion and this will decreases the chances of removal of the sound tooth structure.[35,43,42] The resin based composites restorations are technique sensitive procedures, thus the need for rubber dam is essential and they require a longer time of placement compared to amalgams. [37] Therefore, in cases where isolation is compromised resin composites are not the restorative material of choice.[35]

2.7 Preformed metal crown (PMC)

They are preformed metal crowns,[44,45] commonly called stainless steel crowns (PMCs or SSCs) and were introduced for the first time in 1950. PMCs are recommended for the treatment of primary and young permanent teeth especially after pulp therapy and also for multi surface caries in the primary molars even without pulpal involvement. [4,31,46,] PMCs are also recommended for the treatment of multi surfaces caries and developmental defects of the teeth.[42,47] PMCs have advanced favorable outcomes in primary molars treatment compared to amalgam restorations.[47,45] In addition, it was reported that PMCs performed successfully in restoration of large carious teeth with a 97% success rate.[48] Marginal seal is one of the important factors in the successful survival of the PMCs.[49,50] However, achieving this optimal

result of marginal adaption is difficult due to the limited ability to adjust the prefabricated dimensions and shapes.[50] The conventional restorative approach requires patient's cooperation to some degree, which might be difficult to find in some children. According to Page *et al*.[51], the 'failure of restorations in primary teeth is more common in younger age groups, perhaps because, in children, the anatomy of primary teeth, small mouths, and age-appropriate limited cooperation can make the placement of restorations challenging'. Therefore for purposes of longevity, and to reduce failure, the guidelines recommend PMCs for multi surface caries in primary molars in high risk individuals, but this often requires tooth preparation using high speed rotary instruments.[35,46]

2.8 The Hall technique

The Hall technique (HT) was first introduced in 2000[52] and later to the public by the BBC news article in 2001.[53] The Hall technique as reported by Innes *et al.* [5] in 2006 was a method of treatment of dental caries without the use of drill or local anesthesia. [8,54,55,56] Treatment with performed metal crowns PMCs isolates caries from oral environment and for a result of the that the bacterial biofilm in the caries will change resulting in less cariogenic potential and caries lesion will not progress furthermore.[57,58,59] The HT works by leaving the caries without fuel that sustains it.[5,58] The aim of arresting caries lesion is to prevent inflammation of the dental pulp.[58] Clinical trial shown the effectiveness and acceptance by the majority of children, parents and clinicians.[57]

2.8.1: The indications and the contra-indications of the HT

The indications and the contra indications of the HT have been summarized in Innes *et al.* 2009:[40]

- Indications include:

- Class I lesion, non-cavitated, if patient unable to accept fissure sealant, or conventional restoration.
- Class I lesion, cavitated, if patient unable to accept partial caries removal technique, or conventional restoration.
- Class II lesions, cavitated or non-cavitated.

- Contra-indications include:
  - Teeth with signs or symptoms of irreversible pulpitis, or dental sepsis.
  - Teeth with clinical or radiographic signs of pulpal exposure, or periradicular pathology.
  - Teeth with crowns so broken down with caries, they would normally be considered as unrestorable with conventional techniques.
  - Patients at risk of infective endocarditis.

2.8.2 The HT procedure:

The HT usually requires two appointments[5,8,7] after the assessment of the child, tooth shape and contact points if tight or broad. The initial appointment to place elastomeric orthodontic separators if the contacts points are tight, the second appointment usually follows the initial one by three to five days to remove the separators [7,57] and place the PMC . In the second appointment, the PMC appropriate size is selected which should cover all the cusps, feels tight with a spring tuck back feeling.[8,55,57] After the crown selection, PMC will be cemented with glass ionomer luting cement.[8,60] The child has to be seated in an upright position and the airway has to be protected using a gauze swab.[8,55,57] When the crown is fully seated the child should bite firmly with on a cotton roll after applying pressure by the thumb and four fingers supporting the maxilla\mandible to prevent displacement.[40] As stated by Hyde *et al.* (2015) 'PMCs should not be fitted at the same appointment to opposing teeth, but can be cemented on

contralateral teeth in the same or an opposing arch'.[55] The HT was recommended for carious primary molars with no signs or symptoms of pulpitis or sepsis clinically or radiographically.[40] A clear band of dentine must be seen between the carious lesion and the pulp tissue on a bitewing radiograph,[40] after fulfilling certain selection criteria by Innes *et al.* (2009)[40], the following must be applied: 1) A careful case selection , 2) high level of clinical skills , 3) excellent patient management and 4) a long term monitoring for its success. The HT was used to increase the patient's co-operation and since local anesthesia and drilling are not used. The technique was considered an easy-to-perform operation by many [61,62,63] and according to Welbury (2017)[59] it contained the following properties:

- Overall easier for the child (and parent) to cope with
- Quicker to complete
- Not requiring local anesthetic
- Proven efficacy by randomized controlled trials.[11,60]
- Easy to teach to students and general practitioners.

2.8.3 Hall technique effect on the occlusion:

Occlusal vertical dimension (OVD) can increase after cementation of a HT, because the HT does not involve any preparation or tooth tissue removal prior to its placement, and this may lead to a minimal increase in the patient's bite. The occlusion will return back to normal, due to dental-alveolar compensation, within few weeks with no TMJ pain as stated by Innes *et al.* (2006, 2007 and 2009)[5,11,40] and this was later confirmed by van der Zee and van Amerongen (2010), who said bite recovers fully.[9, 64,65] The latter suggested that occlusion returns back to normal within 15 to 30 days.[9] According to van der Zee and van Amerongen (2010)[9] study, they reached to this conclusion after measuring the most prominent incisal point of maxillary and mandibular canine before the placement of the HT crown and after the cementation within

2-4 weeks.[9] They concluded that the overbite reduction seems to be caused by intrusion of the treated tooth (HT treated tooth) and the antagonist tooth.[9] In a 10-patient study, that used 3-D laser scanning of pre and post HT treatment models, the exact cause of the bite to return to normal was found to be the intrusion of the treated tooth.[65] This issue has been of concern to some authors[13] as it is important to recall that that changes in dental occlusion is generally known to affect the TMJ and muscles of mastication such as the masseter muscle.[66]

2.9 Mastication:

Mastication is an important function of the stomatognatic system.[67,17] When we talk, eat, drink or simply laugh we trigger the muscles of the jaw which involve simple and complex patterns, but when we sleep or rest most of the behaviors of the oro-motor complex such as mastication disappear and the activities of the jaw muscles remain low.[68] Chewing is the most important function of stomatognatic system and is simply defined as the breakdown of food into smaller particles to be prepared for swallowing and digestion.[68,69] The chewing function depends on the forces and integrated complex of muscles, bone, ligaments and teeth structures and its controlled by the central nervous system (CNS).[69] Complexity and pattern of the chewing process is mainly voluntary controlled by the muscles of mastication.[69] The *Masseter*, *Temporalis* and *Medial Pterygoid* muscles that belong to the jaw-opening muscles which mainly have the role to produce an adequate masticatory forces between the teeth and jaws to crush food.[68,70] In humans the maximum biting forces ranges between 400-1110 N when they clench their teeth together.[71]

2.10 The masseter muscle:

The masseter muscle in specific is one of the major jaw elevators muscles of the masticatory system and is considered to be a skeletal muscle that responds to cortical control[72]. The main

difference between the skeletal and masticatory muscles is the embryological origin difference[72] Masticatory muscles arise from the neural crest cells whereas skeletal muscles are derived from mesoderm.[72, 73] The masseter muscle is a complex jaw opening muscle with a multi pennate structure,[72] and is controlled by fifth cranial nerve (trigeminal) which is a mixed sensory and motor nerve. It carries the main motor supply for the muscles of mastication which includes the masseter muscle via the mandibular division.[74] The masseter muscle has a major role in the masticatory muscles as its provides force for chewing, moreover, it is involved in facial expression and speech.[72, 75, 76, 77, 78] The masseter muscle has been analyzed by many recent studies with electromyography (EMG).[15, 18, 79, 68, 80, 81, 82, 83]

2.11 Surface electromyography (sEMG)

Surface Electromyography is the study of bioelectric phenomena that occurs in the muscle fibers during sleep, rest, stress and maximum contraction. [84] sEMG is considered the most reliable technique for evaluating the function and efficiency of the muscles by detecting its electrical potentials.[85, 86] sEMG helps in the assessment of the extent and duration of muscleactivity[85] and it is a tool that is used extensively to analyze and explore the neural circuitry[72] by registering the signals of muscle contractility through the action potentials that is delivered by the motoneurons.[72] sEMG study is characterized by being safe, noninvasive and easy to perform[69] and has increased our understanding of the neurophysiology of the muscles of mastication through the past 60 years as it was introduced in the 1950's.[87] The earliest sEMG studies reported on muscles of mastication were in the mid-fifties of last century. [88] These studies improved the basic and fundamental understating of the complexity of mastication muscles' system. [72] Other studies considered to have a historical interest is from Perry and Harris (1954)[89] and Ahlgren (1967).[90]

sEMG electrodes are placed on the skin overlying the muscle to be evaluated to facilitate the capture of electrical activity of the active muscle fibers.[69] The sEMG registers the muscle contractility through the action potentials from the motor neurons, and the sEMG electrodes are considered highly refined bipolar which are sensitive to the electrical signals and once amplified it will be visible on the sEMG recordings. [72] The electromyography registration records will allow us to observe the electrophysiology behavior of several muscles in different physiological conditions.[69]

2.12 sEMG studies in dentistry:

sEMG is a very useful tool in the field of dentistry as it was used in many studies to assess the activity of the muscles. sEMG has been widely used in orthodontic studies.[19, 79, 85, 91, 92, 93,94] For instance the Saccucci *et al.* (2011)[19] study highlighted the important benefits of the use of sEMG to assess the effects of interceptive orthodontics on orbicular muscle activity. This showed that a significant increase of the sEMG activity of the lower orbicular oris muscle at rest and of the upper orbicular oris muscle occurred during mandibular protrusion.[19] sEMG has been used widely in children as is considered safe and noninvasive way,[16,19,79,95,93] in addition to the field of restorative and prosthodontic studies.[18, 67, 68, 69, 96, 97, 98]

2.13 The process of sEMG and data capture

Electromyography is the technique for the detection and analysis of sEMG.[99] With electrodes placed on the surface of the skin to detected muscle tissue. [100,101] The skin should be wiped clean and be free from hair and foreign bodies such as plasters. Detection of sEMG signals is achieved with appropriate hardware (See Figure 2.1). The sEMG signals are generated by the muscle fibers which are captured by the electrodes on the skin then amplified and filtered by the sensor before being converted to digital signals by the encoder which is a device that circuit

and convert the information from one format to another. It is then sent to the computer's software to be processed, displayed and recorded.[102] Reference points can be used as standardized ends of a spectrum, such as maximum voluntary clenching, or rest positions, intertwined with functional dynamic points such as the process of chewing.

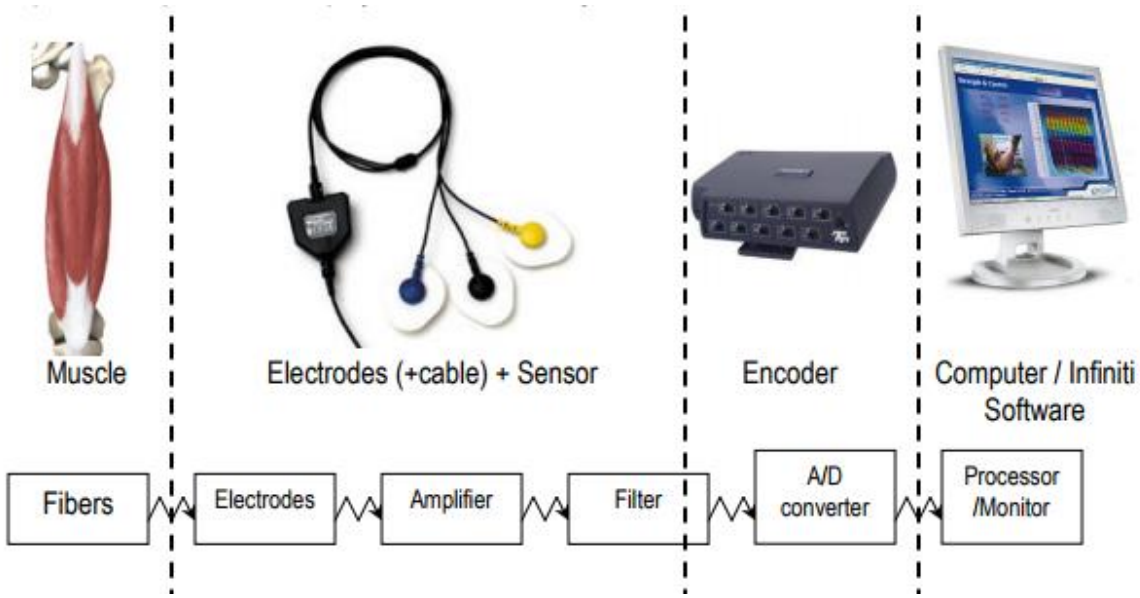


Figure 2.1: The outline of the sEMG principle (adapted from Thought Technology Ltd, Canada, 2008) [102]

2.14 Normalization of the sEMG data

Normalization refers to the conversion of the signal to a scale relative to a known and repeatable value. [103] It was first presented by Eberhart, Inman and Bresler in 1954.[104] Why is it important to normalize ? It has been recognized that intrinsic and extrinsic factors can cause fluctuations in the raw EMG signal, reducing longitudinal reliability and increasing inter and intra subject variability when used to analyze the muscle activity using (sEMG) is frequently.[105] Extrinsic factors are those which can be influenced by the experimenter for example electrode configuration (distance between electrodes), electrode placement and orientation to the muscle

fibers and skin preparation.[106, 107] Intrinsic factors includes physiological, anatomical and biochemical characteristics of the muscles as the fiber type of the muscles , blood flow to the muscle , diameter of the muscles fiber , the distance between the active fibers within the muscle with respect to the electrode , and the amount of tissue between the surface of the muscle and the electrode. [103]

2.15 The effect of the Hall Technique on the muscles of mastication

The effect of the HT on the occlusion has been assessed, but to the authors knowledge, there are no studies that investigate any effect of the HT on the muscles of mastication. This was the main drive behind conducting this sEMG study

2.16 The aim of the study

The aim of the study is to assess the effect of PMCs placed using the Hall technique on the muscular activity of the masseter muscles in children based on sEMG readings.

Specific objectives:

1. To measure the change in masseter muscle activity immediately before and immediately after the placement of a Hall technique PMC and two and six weeks after using sEMG using maximum voluntary clenching and rest as reference points.
2. To assess if the masseter muscle activity at rest remains the same pre and post treatment
3. To assess if the masseter muscle activity returns to normal at two and six weeks after placement of a Hall technique PMC.

2.17 The null hypothesis

No difference exists in the masseter muscle activity during resting and clenching before and after the placement of a Hall technique PMC as measured by sEMG.

3.00 AIM

The aim of the study is to assess the effect of PMCs placed using the Hall technique on the muscular activity of the masseter muscles in children based on sEMG readings.

Specific objectives:

1. To measure the change in masseter muscle activity immediately before and immediately after the placement of a Hall technique PMC and two and six weeks after using sEMG using maximum voluntary clenching and rest as reference points.
2. To assess if the masseter muscle activity at rest remains the same pre and post treatment
3. To assess if the masseter muscle activity returns to normal at two and six weeks after placement of a Hall technique PMC.

4.00 MATERIALS AND METHODS

In this chapter, the study's logistics will be presented, including the study's ethics (Appendix 1), design, criteria , statistical analysis and consent process (Appendix 2).

4.1 Study Design / location/ candidates:

The design of this study was a prospective cohort study that involved measuring the changes in muscular activity before and after the placement of the HT PMC. The study sample was taken from children of four-to-nine years of age who were presenting with a parent to the pediatric department of Mohammed Bin Rashid University (MBRU) clinical partner, Dubai Dental Hospital (DDH) and who would receive a Hall technique PMC for treating a carious primary molar tooth. The HT is routinely used clinically in MBRU following the standard Hall manual and guidelines.[7] Based on similar conducted studies related to the Hall technique,[65] we anticipated that 10 subjects will be required.

4.2 Inclusion and exclusion criteria

All patients and parents attended the Dubai Dental Hospital in the period between January 12th, 2018 and March 12th, 2018 who meet the inclusion criteria and accepted to participate were included in the study.

4.21 Inclusion criteria

- A cooperative child.
- Children 4-9 -year-old attending the MBRU/DDH with their legal guardian/parent.
- A primary molar with a carious lesion indicated for a Hall PMC as per the Hall technique manual

4.22 Exclusion criteria

- Pre -cooperative patients or patients with learning difficulties or language problems.
- Patients with contraindications to use the HT such as patients at risk of infective endocarditis.
- Patients who their parents/guardians refuse to consent.
- Placement of more than one HT crown at the start of the study.
- Children in need of urgent treatment for other primary teeth.
- Special needs and medically compromised children.
- Patients with neuromuscular disorders.
- Patients with teeth near exfoliation
- Patients with Temporomandibular Joint Disorders (TMD)
- Patients with malocclusions.
- Patients with cleft lip and palate.

4.3: The sEMG device

The sEMG device has two components, hardware and software; The hardware device to be used is called *Power Lab.* Power lab is a data acquisition (DAQ) device engineered for precise, consistent, reliable data acquisition. Power Labs are capable of recording at speeds of up to 400,000 samples per second continuously to disk (aggregate) see Figure (4.1)

Figure (4.1) : Hardware Power lab 2\26 T AD instruments.

The software component is the *Lab Chart Reader* data analysis software creates a platform for all recording devices to work together, allowing to acquire biological signals from multiple sources simultaneously and apply advanced calculations and plots (figure 4.2).

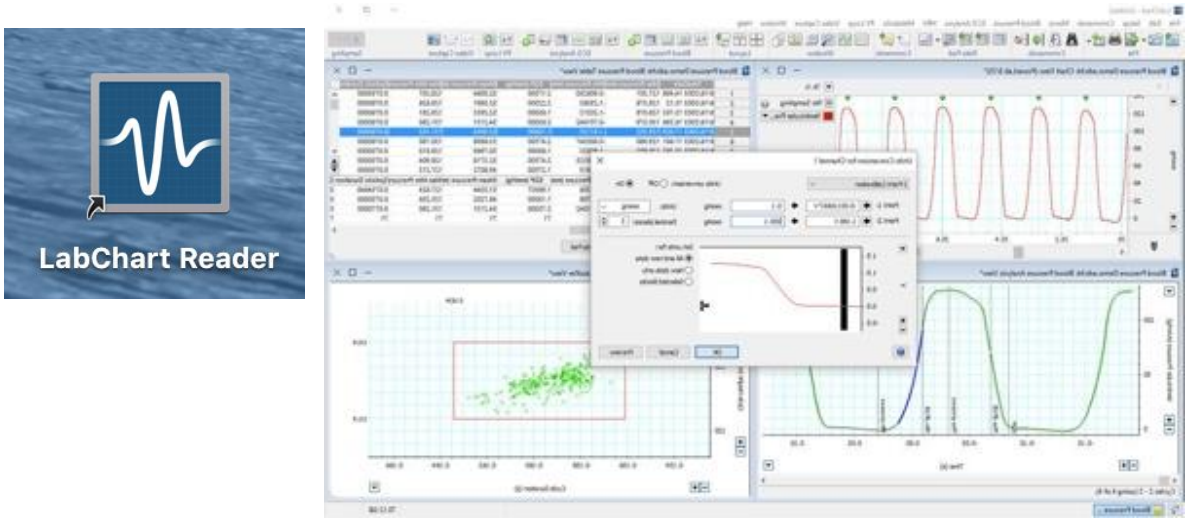


Figure (4.2) : LabChart Reader software platform

4.4 Study procedure

sEMG measurements are non- invasive and were conducted in the pediatric dentistry clinic in a dedicated surgery. Parents and their children who qualified to participate in the study were given a written and oral explanation about the study and were invited to participate. Parents who accepted to allow their children to participate were asked to sign the informed consent form and Consent Statement (Appendices 2 and 3). The parents were also asked to complete the demographic data (Appendix 4) form which included; age of the child, gender. Each participating child was informed about the procedures using a child-friendly information sheet (Appendix 5) designed for this purpose.

Upon selection of a child patient, the patient was asked to clench to accurately locate the masseter muscle. He/she was fitted with five adhesive electrode stickers (two pairs and one earth) placed on his/her face (see below). The first pair of the adhesive electrodes (black or brown: positive see Figure (4.3) was placed on both sides of the face superficial to the masseter muscles on the middle anterior aspect of the zygomatic arch. The second pair of electrodes; the negative pair (white and red) was placed on both angles of the mandible. The white electrode was placed on the same side as the black one, while the brown one was placed on the same side as the red one. The fifth (the earth; green) was placed on the subject's forehead. The distance between the earlobe tragus and the middle part of the positive electrode was measured by taking a photo and by a ruler and recorded. This was done to serve as a reference point for the placement of the positive electrodes during the follow up visits to ensure accuracy. Extra oral photographs, after consent, were taken of the electrodes in place (Figure 4.3). Subjects' privacy and anonymity was be assured by covering the eyes of all subjects if they were to be used for any future research or educational purpose.

Each child had sEMG measurements carried out (in μV.s) immediately pre, immediately post, 2 weeks post and 6 weeks post placement of a HT crown. The first measurement of sEMG was

taken as follows during the same visit intended to fit and cement the HT crown: The patient was asked to practice clenching (maximum voluntary clenching/intercuspation or MVC) and relax the lower jaw and alternate between them every second over a period of 20 seconds (timed). The sEMG analytical software (Lab chart program V 8.1.8, 1994-2016 AD Instruments- see figure 4.4) was used. This captured 10 cycles of clench and 10 cycles of rest, from both left and right masseter muscles.

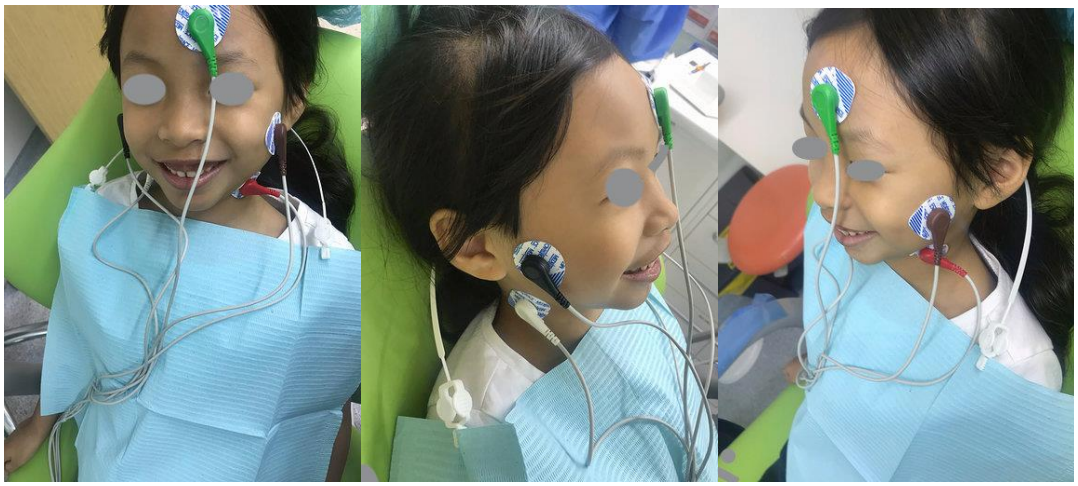


Figure (4.3) Extra oral photographs with electrodes in place

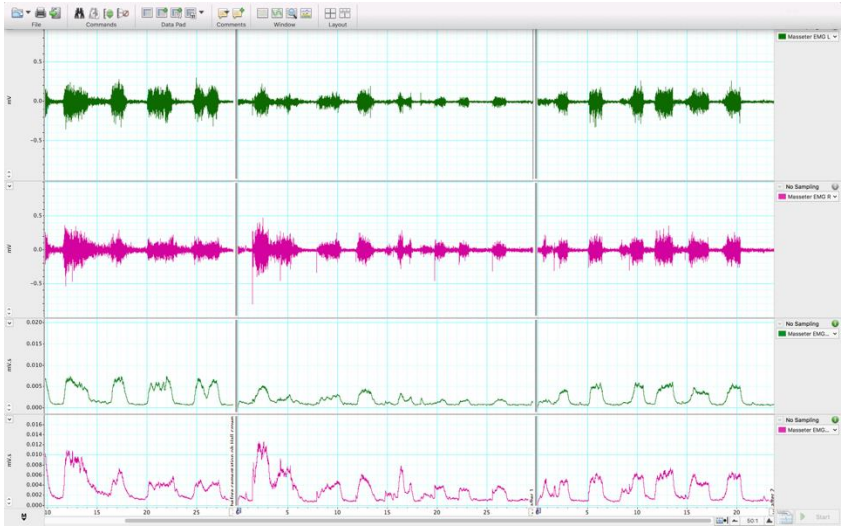


Figure (4.4): The sEMG analytical software (Labchart program reader V 8.1.8, 1994-2016 AD Instruments

Automatically generated simulation graphs were displayed on the computer monitor in front of the child (Figure 4.4) for both left and right masseter muscles. The child subject was asked to

monitor and follow the simulation graphs on the computer screen and clench at the start of a moving visual wave. The cycle lasted for 20 seconds which translated into approximately 10 cycles of clenching in the sEMG graph. The electrodes were left in place and we proceeded with the fitting and cementation of the HT PMC on one primary molar tooth. Following that, the patient was asked to repeat the same procedure explained above for measurement of sEMG. The measurement of the sEMG was repeated after two weeks and after six weeks from the first reading. At the conclusion of the study, any other non-urgent treatment required for the rest of the dentition was performed. No other treatment unless urgent was performed during the six-week study period or in the period of 6 weeks preceding the study period to eliminate any confounding factors. If treatment was carried out, the patient was excluded from the study. The flow chart of the study is presented in Figure (4.5).

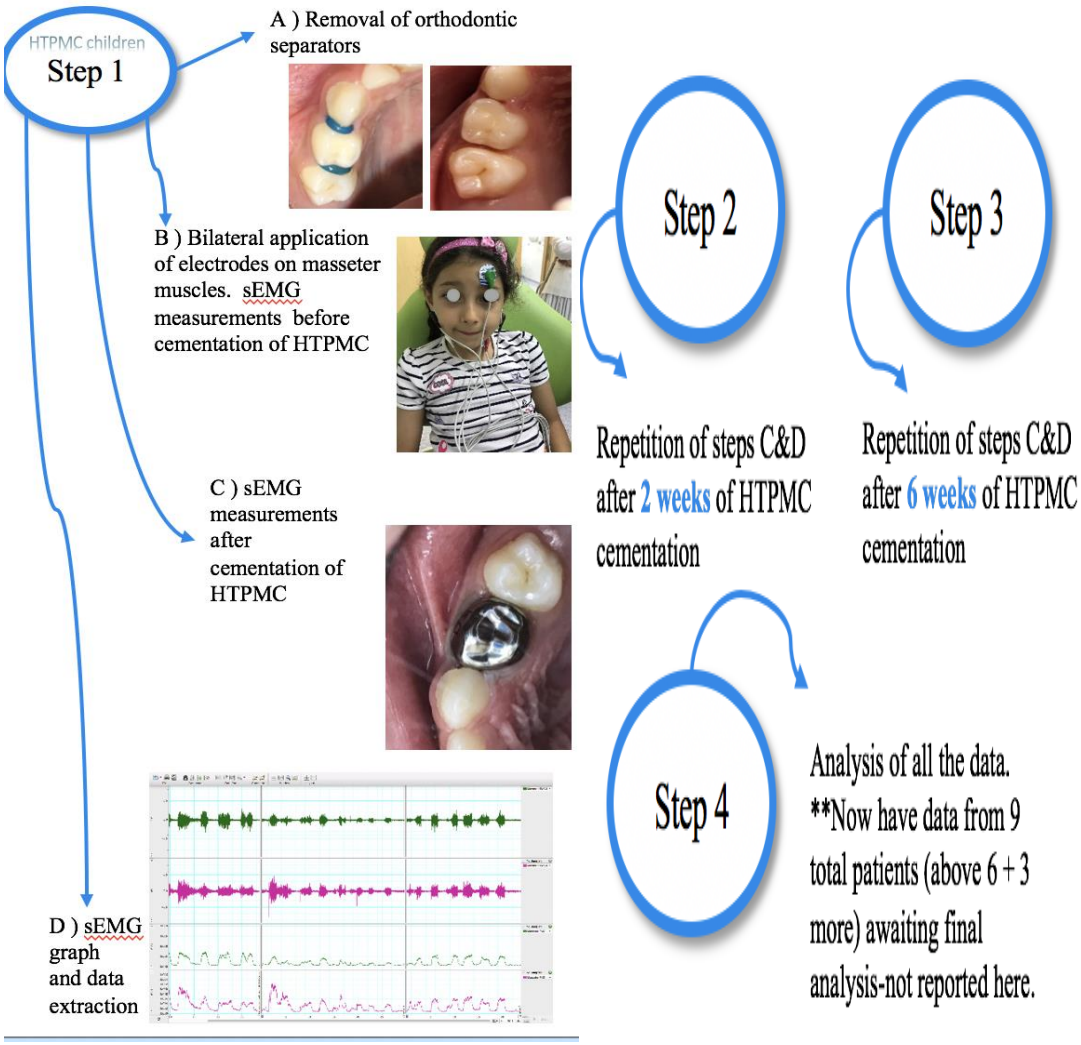


Figure (4.5): flow chart of the study design. For abbreviations see text.

4.4 Training:

The principle investigator, and the primary supervisor were trained in using the sEMG device by an expert co-supervisor from the Physiology department at MBRU (Professor Vaughan Macefield-Professor of Physiology). This included:

- Installation of the equipment, the different switches, buttons actions cables and wires.
- The use of the electrodes and their distribution.
- The software program for the analysis of the graphs and how to transfer them to numerical data to be exported into an excel sheet.

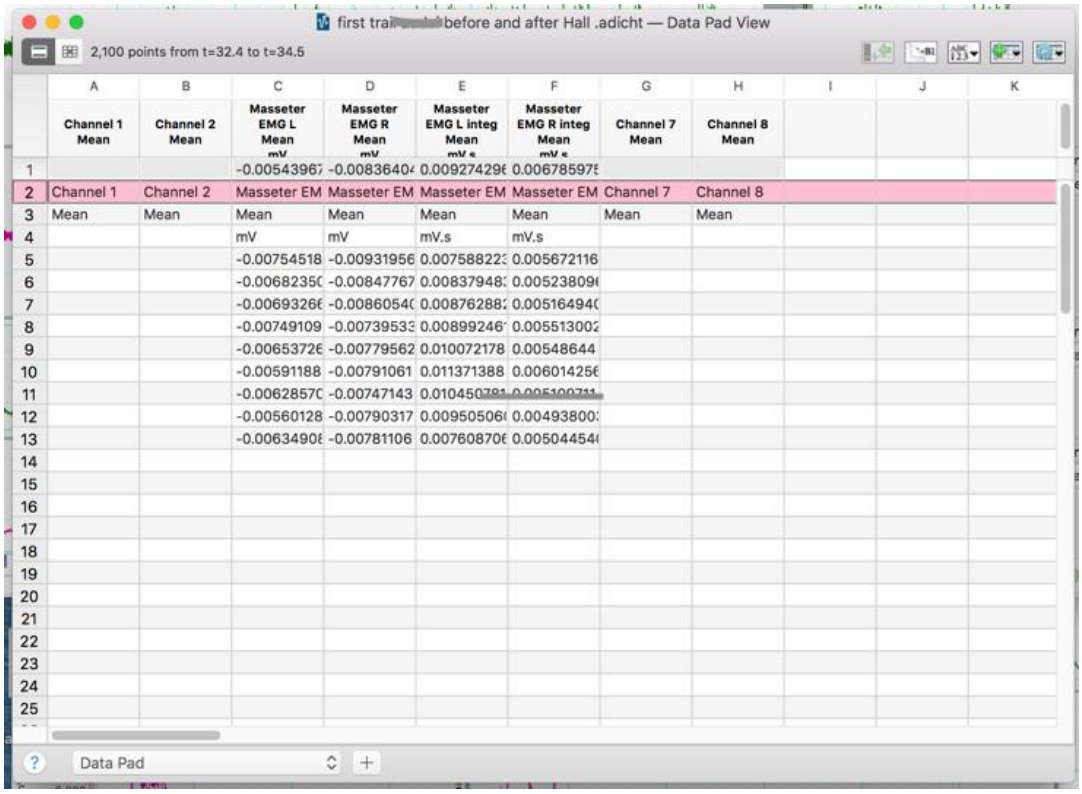
- The correct anatomical placement of the electrodes on the patient's face.

4.5 Piloting

To assess the feasibility of the hardware, software and process of sEMG recording in the clinic, a pilot trial was conducted on an on a volunteer child (with parental consent). The child did not require any treatment. After fitting the electrodes, sEMG records was obtained after a series of clench/relax cycles. Then a sterile orthodontic metal ruler of a 1mm thickness was used by asking the volunteer to bite on it, mimicking the HT bite rise. The cycles of clench /rest were recorded. The feasibility of the sEMG was assessed as a result. The pilot results are presented in the next chapter

4.6 The outcome and outcome measures

The outcome was considered to be masseter muscular activity while the outcome measures were sEMG readings in mV.s. The outcome measures results were shown on the "Lab chart" software reader as graphs of each patients (See figure 4.4), which represented the masseter muscle EMG left (Green color), masseter muscle EMG right (Pink color) both in two units the mV(millimeter voltage) and mV.s (millimeter voltage. Seconds). Data Pad chart was used to transfer the data from graph/liner data to numerical data (see figure 4.6) and then to a Microsoft Excel^{tm} sheet.



first trai[redacted]before and after Hall .adicht — Data Pad View

2,100 points from t=32.4 to t=34.5

	A	B	C	D	E	F	G	H	I	J	K
	Channel 1 Mean	Channel 2 Mean	Masseter EMG L Mean mV	Masseter EMG R Mean mV	Masseter EMG L integ Mean mV.s	Masseter EMG R integ Mean mV.s	Channel 7 Mean	Channel 8 Mean			
1			-0.00543967	-0.00836404	0.00927429	0.00678597					
2	Channel 1	Channel 2	Masseter EM	Masseter EM	Masseter EM	Masseter EM	Channel 7	Channel 8			
3	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean			
4			mV	mV	mV.s	mV.s					
5			-0.00754518	-0.00931956	0.00758822	0.005672116					
6			-0.00682350	-0.00847767	0.00837948	0.00523809					
7			-0.00693266	-0.00860540	0.00876288	0.00516494					
8			-0.00749109	-0.00739533	0.00899246	0.005513002					
9			-0.00653726	-0.00779562	0.010072178	0.00548644					
10			-0.00591188	-0.00791061	0.011371388	0.00601425					
11			-0.00628570	-0.00747143	0.010450781	0.005100711					
12			-0.00560128	-0.00790317	0.00950506	0.00493800					
13			-0.00634908	-0.00781106	0.00760870	0.00504454					
14											
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Data Pad

Figure (4.6) Data Pad chart was used to transfer the data from graph/liner data to numerical data and then to a Microsoft Excel^{tm} sheet

4.7 Statistical analysis

Data were entered in computer using SPSS for windows version 21.0 (SPSS Inc., Chicago, IL). Results were cross-tabulated to examine the independency between variables. Statistical analysis was performed using Chi-square ($\chi^{2)}$ for test of association and Fisher's exact test as appropriate. Where two or more continuous independent variables were examined, t-test and analysis of variance was used as adequate. An ANOVA with repeated measures, with *post hoc* analysis where applicable was used to compare the repeated means where the multiple measures for the same subjects were used. Frequency tables' bar and lines graphs were performed as descriptive statistics. A P-value of less than 0.05 was considered significant in all statistical analysis.

4.8 Ethical considerations

This study was conducted in full conformance with principles of the "Declaration of Helsinki", Good Clinical Practice (GCP), and within the laws and regulations of the UAE/DHCC. The ethical approval (Appendix 1) was obtained from the Research Ethics Review Committee in Hamdan Bin Mohammed College of Dental Medicine under the number of Ref EC1017-005.

5.00 RESULTS

5.1 Pilot results

We piloted the sEMG system on an Eight-year-old girl with parental consent to measure *Masseter Muscular Activity* (MMA) in order to test feasibility. She was fit and healthy and did not required treatment. After fitting the electrodes (Figure 5.1(a)), a baseline (Test 1: T1) sEMG left and right MMA were recorded at *Rest Position* (RP) and *Maximum Voluntary Clenching* (MVC). Then a sterile orthodontic metal ruler of a 1mm thickness was used on the left side (chosen randomly) by asking the child pilot subject to rest then bite (clench) on it, mimicking the HT bite rise (see Figure 5.1 (b)). This was (Test 2: T2). Ten cycles of RP/MVC were recorded over 20 seconds, pre (T1) and post (T2) biting on a ruler. Therefore, T1 represented the position before the ruler was introduced (Figure 5.1(a)), while T2 represented the position after the ruler was introduced (Figure 5.1(b)). A graphical diagram of the RP/MVC cycles at T1 and T2 was generated (See Figure 5.2).

The following results show the T1 (pre-ruler position) and T2 (post-ruler position), left and right MMA, at RP (rest) and MVC (clench) readings (Table 5.1):

Pilot Rest MMA: *Pre ruler-position (T1)*, the mean Left (L)-MMA at RP $\pm$ standard deviation (STD) was 1.99 $\pm$ 0.64 µV.s, while the mean Right (R)-MMA at RP was 1.47 $\pm$ 0.31 µV.s. *Post ruler position (T2)* the mean L-MMA at RP was 2.10 $\pm$ 0.64 µV.s, while the mean R-MMA at RP was 2.22 $\pm$ 0.91µV.s.

Pilot Clench MMA*: Pre ruler-position (T1)*, the mean L-MMA at MVC was 10.23$\pm$ 1.67 µV.s, while the mean R-MMA at MVC was 8.87 $\pm$1.53 µV.s. Post-ruler position (T2) the mean L-MMA at clench was 7.04 $\pm$ 1.14 µV.s, while the mean R-MMA at clench was 6.02 $\pm$ 0.88 µV.s.

Figure 5.1 (a & b) Showing the pilot subject being tested by the sEMG system.

a) b)

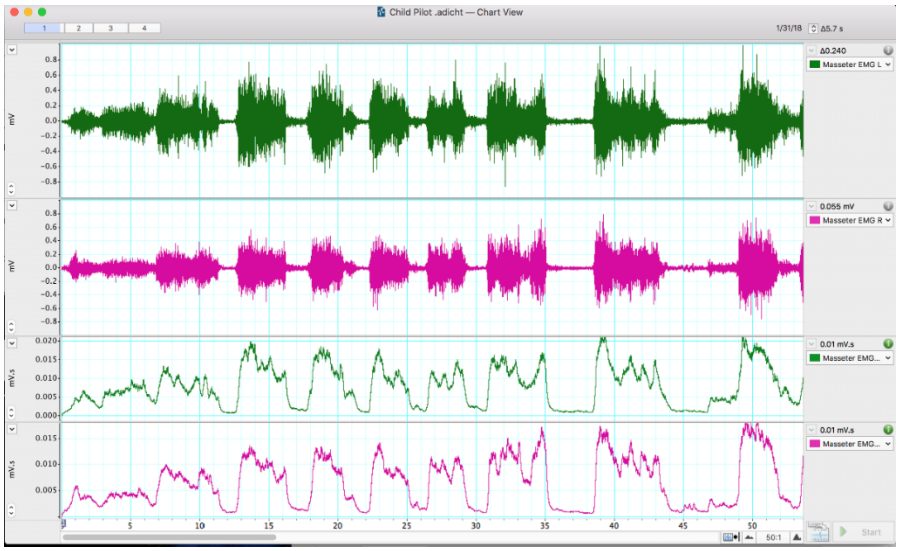


Figure (5.2). Shows a standard sEMG graph generated showing ten cycles of rest and ten cycles of clenching activity.

Table 5.1. Child pilot sEMG Masseter Muscular Activity (MMA) raw results. This is an example of the raw data collected from a sEMG session.

T1	Child Pilot **Rest** Position (RP) Pre-Ruler (T1)		Child Pilot Maximum Voluntary **Clenching** (MCV) Pre- Ruler (T1)	
	Masseter sEMG L integ	Masseter sEMG R integ	Masseter sEMG L integ	Masseter sEMG R integ
	Mean	Mean	Mean	Mean
	µV.s	µV.s	µV.s	µV.s
Reading No.				
1	1.593804804	1.418575024	8.017289494	6.850864029
2	1.873711198	1.500402391	12.03275497	8.6976331
3	1.768997246	1.223559188	10.75260731	7.763297175
4	1.991969874	1.805297248	8.674156847	7.281505746
5	2.256354507	1.309197245	8.429101362	7.680033027
6	1.265291185	0.987278486	11.14084773	10.37813814
7	1.669473585	1.590671124	11.56734149	10.28848501
8	3.737995273	2.165159505	13.28894454	11.80903798
9	2.236156576	1.463590148	9.092460484	9.839453282
10	1.604975251	1.27999108	9.318044006	8.171967606
Mean	1.99987295	1.474372144	10.23135482	8.87604151
STD	0.646650944	0.311346321	1.678806855	1.536944874
T2	Child Pilot **Rest** Position (RP) Post Ruler (T2)		Child Pilot Maximum Voluntary **Clenching** (MCV) Post-Ruler (T2)	
Reading No.				
1	1.426951762	2.017063189	6.709120512	5.128048633
2	1.903288097	2.37444572	7.822809462	6.69924123
3	3.901049311	4.769306615	9.453511137	7.522191787
4	1.869076774	1.458853131	8.472339585	7.337368915
5	2.209943336	1.46038216	5.841665531	5.590204775
6	2.109847539	1.944840828	5.899162321	5.139768719
7	1.823778093	2.17910741	7.010453126	5.038873152
8	2.168358022	1.841860988	6.176737193	6.416306159
9	2.032366429	2.476778168	7.065646714	6.115739956
10	1.593621412	1.68585969	5.983753012	5.276735907
Mean	2.103828078	2.22084979	7.043519859	6.026447923
STD	0.643645599	0.910602681	1.148856298	0.888221724

For each side (L/R), the pilot reliably detected an increase in MMA from RP to MVC in both T1 and T2. Reduction of MVC-MMA from T1 to T2 and bilateral correlation of MMA ($p<0.05$). There was no significant difference between rest readings at T1 and at T2 (t-test; left

side: p=0.731; right side: p=0.06). There was a significant difference between rest and clench readings for each of T1 and T2 (each side; t-test, p<0.001) and between clench at T1 and at T2 (t-test; left side: p = 0.001: right side: p=0.002). The MVC reading at T2 was less than that at T1.

When we combined the left and right MMA readings, a similar pattern was found. There was no significant difference between rest readings at T1 and T2 (t-test; p=0.84). There was a significant difference between rest and clench readings for each of T1 and T2 (t-test, p<0.001), and there was a significant difference between clench at T1 and T2 (t-test, p<0.001).

In summary of the pilot results. The rest MMA sEMG was the same before and after biting on the ruler. When the subject clenched without a ruler, the MMA on both sides increased. When the subject clenched with a ruler, the MMA was higher than rest MMA but did not reach the levels of clench MMA without a ruler. In other words, the clench MMA when biting on a ruler was less than the clench MMA without a ruler. The results of one individual had the ability to demonstrate that the sEMG MMA was significant between rest and clench. This suggested that the sEMG system was feasible, simple effective and sensitive. Therefore, we went on to the study subjects as below.

5.2 Demographic characteristics of the study participants:

Our patients for this study were recruited from a pool of patients who had attended with their carers /parents to our postgraduate dental hospital, and whom were deemed suitable for the HT. We recruited, after obtaining parental consent, 12 children with an average age of 7.6 years ± STD 1.3. Out of the 12 children that were treated by means of HTPMC, seven children attended all three visits and were followed up for 6 weeks, two others attended two appointments and were followed up for two weeks, and three participants attended the baseline appointment only. Six HTPMCS were placed on the right, and six were placed on the left side. The study visits

are designated by the points of recording the sEMG. The first visit had two points of data measuring: P1 (immediate pre HT), P2 (immediate post HT); the second visit had one point: P3 (two weeks post HT) and the third visit had one point; P4 (6 weeks post HT).

Table 5.2: The characteristics and attendance of the patients in this study.

Patient Number	Patient Age in years	Tooth number treated with HT	Side	P1: IMMEDIATE PRE-HT	P2: IMMEDIATE POST- HT	P3: 2WEEKS POST-HT	P4: 6WEEKS POST- HT
1	9	85	R	√	√	√	√
2	8	65	L	√	√	√	√
3	7	75	L	√	√	√	√
4	9	64	L	√	√	√	√
5	8	65	L	√	√	√	√
6	7	55	R	√	√	√	√
7	9	55	R	√	√	√	√
8	7	55	R	√	√	√	x
9	6	74	L	√	√	√	x
10	9	75	L	√	√	x	x
11	5	75	L	√	√	x	x
12	8	64	L	√	√	x	x

5.3 The MMA results for the 12 patients

We measured the immediate pre and post HT MMA results (P1 and P2) in the first visit for 12 patients using the sEMG system, P3 (for nine patients) and P4 (for seven patients). All the patients were fit and healthy. After fitting the electrodes, a baseline (P1) sEMG L/R MMA records at RP and MVC were obtained. Then a HT PMC was cemented, and the subjects were asked to rest then clench (P2). The patient returned two- and six-weeks post HT. The electrodes were positioned in the same positions using standardized photos. The 10 cycles of RP/MVC rest were recorded over 20 seconds at P1, P2, P3 and P4. Therefore, P1 represented the position immediately before the PMC was cemented, P2 represented the position immediately after the PMC was cemented, with P3 and P4 two- and six-weeks post HT respectively. We obtained 1600 sEMG (RP and MVC) MMA readings (800 for each of the left and right MMA readings). See Table 5.3 and See raw data in Appendix 6

Number of MMA readings obtained

Category		Definition	N
Patient		1	160
		2	160
		3	160
		4	160
		5	160
		6	160
		7	160
		8	120
		9	120
		10	80
		11	80
		12	80
HT PMC position		Crown in right side	440
		Crown in left side	1160
Activity	1	Rest	800
	2	Clench	800
Time	P1	Pre-Hall	480
	P2	Immediate Post Hall	480
	P3	2 weeks	360
	P4	6 weeks	360

Table 5.3: The distribution of the 1600 MMA readings taken in this study

5.4 The left and right MMA results for each individual patient

The following results show the P1, P2, P3 and P4 results for all 12 patients. Figure 5.3 and Table 5.4 shows the mean (±STD) results for each of the 12 patients (P1, P2 P3 and P4) while all the raw data of all individual subjects are presented in detail in Appendix 1

Patient 1

Patient 1 Rest MMA:

- *P1:* the mean L-MMA at RP ± STD was 0.99± 0.10µV.s, while the mean R-MMA at RP was 1.02 ± 0.16 µV.s.
- *P2:* the mean L-MMA at RP was 1.33 ± 0.18 µV.s, while the mean R-MMA at RP was 1.19± 0.21µV.s.
- P3: the mean L-MMA at RP was 1.00± 0.17µV.s, while the mean R-MMA at RP was 1.06 ± 0.14 µV.s.
- P4: the mean L-MMA at RP was 1.13± 0.17 µV.s, while the mean R-MMA at RP was 1.77± 0.30µV.s.

Patient 1 Clench MMA*:*

- *P1:* the mean L-MMA at MVC was 2.49± 0.95 µV.s, while the mean R-MMA at MVC was 3.05 ±1.07 µV.s.
- *P2:* the mean L-MMA at clench was 3.35± 0.82 µV.s, while the mean R-MMA at clench was 2.43 ±0.83 µV.s.
- P3: the mean L-MMA at MVC was 5.10± 0.46 µV.s, while the mean R-MMA at MVC was 6.56±1.47 µV.s.
- P4: the mean L-MMA at clench was 5.11± 0.53 µV.s, while the mean R-MMA at clench was 7.25±0.79µV.s.

Patient 2

Patient 2 Rest MMA:

- *P1:* the mean L-MMA at RP was 1.47± 0.81 µV.s, while the mean R-MMA at RP was 2.29 ±0.64 µV.s.

- *P2 :* the mean L-MMA at RP was 0.99 ± 0.09 µV.s, while the mean R-MMA at RP was 1.32± 0.282µV.s.
- *P3:* the mean L-MMA at RP was 1.13± 0.17µV.s, while the mean R-MMA at RP was 1.77 ± 0.30 µV.s.
- *P4:* the mean L-MMA at RP was 1.02± 0.07 µV.s, while the mean R-MMA at RP was 1.33± 0.20µV.s.

Patient 2 Clench MMA*:*

- *P1:* the mean L- MMA at MVC was 5.77± 0.87 µV.s, while the mean R-MMA at MVC was 7.88 ±3.33 µV.s.
- P2: the mean L-MMA at clench was 2.25± 0.82 µV.s, while the mean R-MMA at clench was 3.68±0.97 µV.s.
- *P3:* the mean L-MMA at MVC was 4.23± 030 µV.s, while the mean R-MMA at MVC was 7.68 ±1.03 µV.s.
- *P4:* the mean L-MMA at clench was 4.23± 0.30 µV.s, while the mean R-MMA at clench was 7.68±1.03µV.s

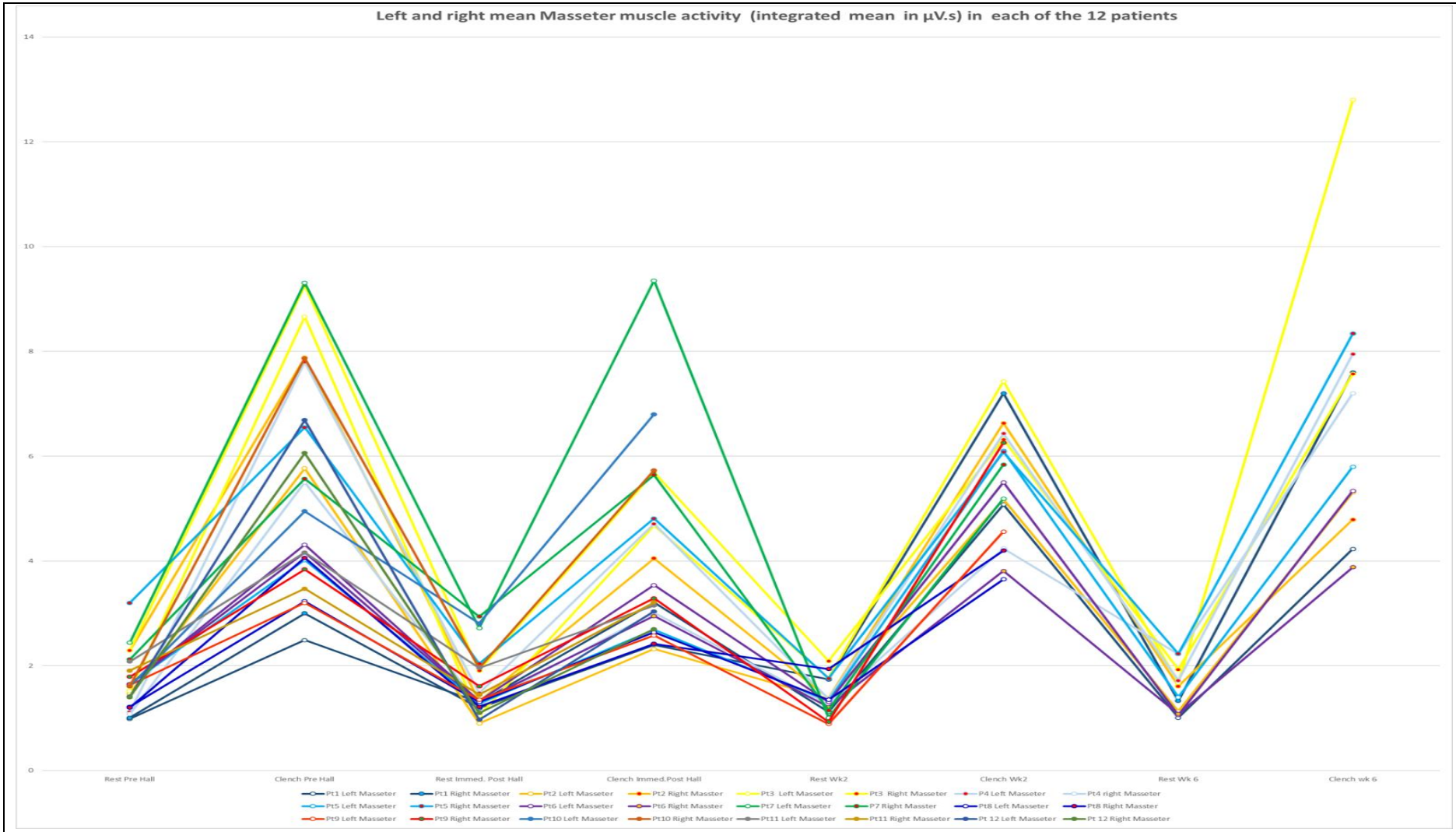


Figure 5.3: The L and R mean MMA for all the 12 patients(seven patients completed P1,P2,P3,P4 visits, two patients completed P1,P2,P3 visits and three patients completed P1,P2). Note that a zig zag pattern is a common feature of all patients, with troughs at rest and peaks at clench MMA

Patient 3

Patient 3 Rest MMA:

- *P1:* the mean L-MMA at RP was 1.52± 0.21µV.s, while the mean R-MMA at RP was 2.29 ± 0.79 µV.s.
- *P2 :* the mean L-MMA at RP was 1.05 ± 0.14 µV.s, while the mean R-MMA at RP was 1.91± 0.66µV.s.
- P3: the mean L-MMA at RP ± standard deviation (STD) was 1.66± 0.38µV.s, while the mean R-MMA at RP was 2.04 ± 0.54 µV.s.
- *P4:* the mean L-MMA at RP was 1.75 ± 0.74 µV.s, while the mean R-MMA at RP was 1.99± 0.32µV.s.

Patient 3 Clench MMA*:*

- *P1:* the mean L-MMA at MVC was 8.63± 0.71 µV.s, while the mean R-MMA at MVC was 9.26 ±0.62 µV.s.
- P2: the mean L-MMA at clench was 4.86± 0.98 µV.s, while the mean R-MMA at clench was 6.07±1.39 µV.s.
- *P3:* the mean L-MMA at MVC was 7.58± 0.86 µV.s, while the mean R-MMA at MVC was 6.41 ±1.59 µV.s.
- *P4: the* mean L-MMA at clench was 12.8± 3.45 µV.s, while the mean R-MMA at clench was 7.59±1.72µV.s.

Patient 4

Patient 4 Rest MMA:

- *P1: the* mean L-MMA at RP ± standard deviation (STD) was 1.12± 0.24µV.s, while the mean R-MMA at RP was 1.08 ± 0.16µV.s.

- *P2:* the mean L-MMA at RP was 1.48 ± 0.43 µV.s, while the mean R-MMA at RP was 1.25± 0.35µV.s.
- *P3: the* mean L-MMA at RP was 1.38± 0. 43µV.s, while the mean R-MMA at RP was 1.30 ± 0.31µV.s.
- *P4:* the mean L-MMA at RP was 1.66 ± 0.38 µV. s, while the mean R-MMA at RP was 2.41± 0.95µV.s.

Patient 4 Clench MMA*:*

- *P1:* the mean L-MMA at MVC was 7.80± 0.92 µV.s, while the mean R-MMA at MVC was 5.50 ±0.50 µV.s.
- P2: the mean L-MMA at clench was 4.77± 0.52 µV.s, while the mean R-MMA at clench was 3.04 ± 0.31µV.s.
- *P3:* the mean L-MMA at MVC was 6.48± 2.01 µV.s, while the mean R-MMA at MVC was 4.23 ±1.13µV.s.
- *P4:* the mean L-MMA at clench was 7.60± 1.49 µV.s, while the mean R-MMA at clench was 7.12±1.00µV.s.

Patient 5

Patient 5 Rest MMA:

- *P1:* the mean L-MMA at RP was 1.65± 0.36 µV.s, while the mean R-MMA at RP was 3.27 ± 0.92 µV.s.
- *P2 :* the mean L-MMA at RP was 1.28± 0.21 µV.s, while the mean R-MMA at RP was 2.04± 0.62µV.s.
- *P3:* the mean L-MMA at RP was 1.37± 0.38µV.s, while the mean R-MMA at RP was 1.85 ± 0.46µV.s.

- *P4:* the mean L-MMA at RP was 1.45 ± 0.16 µV.s, while the mean R-MMA at RP was 2.38± 0.43µV.s.

Patient 5 Clench MMA*:*

- *P1:* the mean L-MMA at MVC was 4.02± 0.80 µV.s, while the mean R-MMA at MVC was 6.55 ±1.11 µV.s.
- P2: the mean L-MMA at clench was 2.65± 0.42 µV.s, while the mean R-MMA at clench was 4.79±1.24 µV.s.
- *P3:* the mean L-MMA at MVC was 6.00± 0.96µV.s, while the mean R-MMA at MVC was 5.99 ±0.80µV.s.
- *P4:* the mean L-MMA at clench was 5.50± 0.72µV.s, while the mean R-MMA at clench was 7.62±1.12µV.s.

Patient 6

Patient 6 Rest MMA:

- *P1:* the mean L-MMA at RP was 1.64± 0.28 µV.s, while the mean R-MMA at RP was 1.65 ± 0.40 µV.s.
- *P2:* the mean L-MMA at RP was 1.33± 0.24 µV.s, while the mean R-MMA at RP was 1.31± 0.30µV.s.
- *P3:* the mean L-MMA at RP was 1.30± 0.11µV.s, while the mean R-MMA at RP was 1.22 ± 0.16µV.s.
- *P4:* the mean L-MMA at RP was 1.07 ± 0.19 µV.s, while the mean R-MMA at RP was 1.07± 0.15µV.s.

Patient 6 Clench MMA*:*

- *P1:* the mean L-MMA at MVC was 4.31± 0.44 µV.s, while the mean R-MMA at MVC was 4.16 ±0.97 µV.s.

- P2: the mean L-MMA at clench was 3.56± 0.53 µV.s, while the mean R-MMA at clench was 2.92±0.35 µV.s.
- *P3:* the mean L-MMA at MVC was 5.47± 0.66µV.s, while the mean R-MMA at MVC was 3.79 ±0.39µV.s.
- *P4: the* mean L-MMA at clench was 5.32± 0.78 µV.s, while the mean R-MMA at clench was 3.83 ±0.66µV.s.

Patient 7

Patient 7 Rest MMA:

- *P1:* the mean L-MMA at RP was 2.44 ± 0.42 µV.s, while the mean R-MMA at RP was 2.12 ±0.28 µV.s.
- *P2:* the mean L-MMA at RP was 2.72± 0.47 µV.s, while the mean R-MMA at RP was 2.94± 0.58 µV.s.
- *P3:* the mean L-MMA at RP ± was 1.00± 0.22 µV.s, while the mean R-MMA at RP was 1.14 ±0.18 µV.s.
- *P4:* the mean L-MMA at RP was 0.95 ± 0.09µV.s, while the mean R-MMA at RP was 1.13± 0.19µV.s.

Patient 7 Clench MMA*:*

- *P1:* the mean L-MMA at MVC was 9.31± 1.42 µV.s, while the mean R-MMA at MVC was 5.57±0.83 µV.s.
- P2: the mean L-MMA at clench was 9.48 ± 1.16 µV.s, while the mean R-MMA at clench was 5.59±0.38 µV.s.
- *P3:* the mean L-MMA at MVC was 5.11± 0.43µV.s, while the mean R-MMA at MVC was 5.77 ±0.26µV.s.

- *P4:* the mean L-MMA at clench was 4.17± 0.37 µV.s, while the mean R-MMA at clench was 7.22 ±0.90µV.s.

Patient 8

Patient 8 Rest MMA:

- *P1:* the mean L-MMA at RP was 1.22 ± 0.12 µV.s, while the mean R-MMA at RP was 1.20 ±0.12 µV.s.
- *P2 :* the mean L-MMA at RP was 1.31± 0.34 µV.s, while the mean R-MMA at RP was 1.22± 0.20 µV.s.
- *P3:* the mean L-MMA at RP was 1.38± 0.21 µV.s, while the mean R-MMA at RP was 1.95 ± 0.62 µV.s.

Patient 8 Clench MMA*:*

- *P1:* the mean L-MMA at MVC was 3.23± 0.67 µV.s, while the mean R-MMA at MVC was 4.06 ±1.27 µV.s.
- *P2*: the mean L-MMA at clench was 2.64 ± 0.45 µV.s, while the mean R-MMA at clench was 2.49±0.43 µV.s.
- *P3:* the mean L-MMA at MVC was 3.68± 0.53µV.s, while the mean R-MMA at MVC was 4.21 ±0.49 µV.s.

Patient 9

Patient 9 Rest MMA

- *P1:* the mean L-MMA at RP was 1.63 ± 0.36 µV.s, while the mean R-MMA at RP was 1.79 ±0.33 µV.s.
- *P2:* he mean L-MMA at RP was 1.35±0.17 µV.s, while the mean R-MMA at RP was 1.61± 0.35 µV.s.

- *P3: the* mean L-MMA at RP was 0.85± 0.07 µV.s, while the mean R-MMA at RP was 0.95 ± 0.13 µV.s.

Patient 9 Clench MMA*:*

- *P1:* the mean L-MMA at MVC was 3.20± 0.43 µV.s, while the mean R-MMA at MVC was 3.84± 0.49 µV.s.
- *P2*: the mean L-MMA at clench was 2.51± 0.28µV.s, while the mean R-MMA at clench was 3.17±0.58 µV.s.
- *P3:* the mean L-MMA at MVC was 4.37± 1.16µV.s, while the mean R-MMA at MVC was 6.09 ±1.64µV.s.

Patient 10

Patient 10 Rest MMA

- *P1:* the mean L-MMA at RP was 1.61 ± 0.002 µV.s, while the mean R-MMA at RP was 1.61 ±0.25 µV.s.
- *P2:* the mean L-MMA at RP was 2.81± 0.54 µV.s, while the mean R-MMA at RP was 1.96± 0.27 µV.s.

Patient 10 Clench MMA*:*

- *P1:* the mean L-MMA at MVC was 4.95 ± 0.67 µV.s, while the mean R-MMA at MVC was 7.87± 0.72 µV.s.
- P2: the mean L-MMA at clench was 6.80± 1.20µV.s, while the mean R-MMA at clench was 5.37±0.61µV.s.

Patient 11

Patient 11 Rest MMA:

- *P1:* the mean L-MMA at RP was 2.08 ± 0.002 µV.s, while the mean R-MMA at RP was 1.91 ±0.66 µV.s.
- *P2:* the mean L-MMA at RP was 1.96 ± 0.27 µV.s, while the mean R-MMA at RP was 1.45 ± 0.38 µV.s.

Patient 11 Clench MMA*:*

- *P1:* the mean L-MMA at MVC was 4.16 ± 0.64 µV.s, while the mean R-MMA at MVC was 3.47± 0.57 µV.s.
- P2: the mean L-MMA at clench was 3.15± 0.46 µV.s, while the mean R-MMA at clench was 3.21± 0.86 µV.s.

Patient 12

Patient 12 Rest MMA:

- *P1:* the mean L-MMA at RP ± standard deviation (STD) was 1.14 ± 0.002 µV.s, while the mean R-MMA at RP was 1.40 ± 0.40 µV.s.
- *P2:* the mean L-MMA at RP was 0.97 ± 0.12 µV.s, while the mean R-MMA at RP was 1.10 ± 0.36 µV.s.

Patient 12 Clench MMA*:*

- *P1:* the mean L-MMA at MVC was 6.69 ± 1.05 µV.s, while the mean R-MMA at MVC was 6.06 ± 0.82 µV.s.
- P2: the mean L-MMA at clench was 3.04±1.59 µV.s, while the mean R-MMA at clench was 2.70± 1.23 µV.s.

Table 5.4: The mean left and right MMA in each of the 12 patients ± standard deviation

Patient number	TIME	LEFT MMA	RIGHT MMA	Patient number	TIME	LEFT MMA	RIGHT MMA	Patient number	TIME	LEFT MMA	RIGHT MMA
1	P1 Rest	0.99 ± 0.10	1.02 ± 0.16	**5**	P1 Rest	1.65 ± 0.36	3.27 ± 0.92	**9**	P1 Rest	1.63 ± 0.36	1.79 ±0.33
	P1 Clench	2.49 ±0.95	3.00 ± 1.07		P1 Clench	4.02 ± 0.80	6.55 ± 1.11		P1 Clench	3.20 ±0.43	3.84 ±0.49
	P2 Rest	1.33 ± 0.18	1.19 ± 0.21		P2 Rest	1.28 ± 0.21	2.04 ± 0.62		P2 Rest	1.35 ± 0.17	1.61 ± 0.35
	P2 Clench	3.35± 0.82	2.43±0.8		P2 Clench	2.65 ± 0.42	4.79 ± 1.24		P2 Clench	2.51 ± 0.28	3.17 ± 0.58
	P3 Rest	1.00 ±0.17	1.06 ±0.14		P3 Rest	1.37 ± 0.38	1.85 ± 0.46		P3 Rest	0.85± 0.07	0.95± 0.13
	P3 Clench	5.1 ±0.46	6.56 ±0.79		P3 Clench	6.00 ± 0.96	5.99 ± 0.80		P3 Clench	4.37± 1.16	6.09 ±1.64
	P4 Rest	1.13 ±0.17	1.77 ±0.3		P4 Rest	1.45 ± 0.16	2.38 ± 0.43				
	P4 Clench	5.11±0.53	7.25 ±0.79		P4 Clench	5.50 ± 0.72	7.62 ± 1.12				
2	P1 Rest	1.47 ± 0.81	2.29 ± 0.64	**6**	P1 Rest	1.64 ± 0.28	1.65 ± 0.40	**10**	P1 Rest	1.61 ±0.02	1.61 ± 0.25
	P1 Clench	5.77 ± 0.87	7.88 ± 3.33		P1 Clench	4.31 ± 0.44	4.16 ± 0.97		P1 Clench	4.95 ± 0.67	7.87 ± 0.72
	P2 Rest	0.90 ± 0.09	1.32 ± 0.28		P2 Rest	1.33 ± 0.24	1.31 ± 0.30		P2 Rest	2.81 ± 0.54	1.96 ± 0.27
	P2 Clench	2.25 ± 0.82	3.68 ± 0.97		P2 Clench	3.56 ± 0.53	2.92 ± 0.35		P2 Clench	6.80 ± 1.20	5.37 ± 0.61
	P3 Rest	1.00 ± 0.17	1.06 ± 0.14		P3 Rest	1.30 ± 0.11	1.22 ± 0.16	**11**	P1 Rest	2.08 ± 0.02	1.92 ± 0.66
	P3 Clench	5.10 ± 0.46	6.56 ± 1.47		P3 Clench	5.47 ± 0.66	3.79 ± 0.39		P1 Clench	4.16 ± 0.66	3.47 ± 0.57
	P4 Rest	1.06 ± 0.16	1.57 ± 0.46		P4 Rest	1.07 ± 0.19	1.07 ± 0.15		P2 Rest	1.96 ± 0.27	1.45 ± 0.38
	P4 Clench	5.20 ± 0.46	4.74 ± 0.67		P4 Clench	5.32 ± 0.78	3.83 ± 0.66		P2 Clench	3.15 ± 0.46	3.21 ± 0.86
3	P1 Rest	1.52 ± 0.21	2.29 ± 0.79	**7**	P1 Rest	2.44 ± 0.42	2.12 ± 0.28	**12**	P1 Rest	1.14 ± 0.02	1.40 ± 0.40
	P1 Clench	8.63 ± 0.71	9.26 ± 0.62		P1 Clench	9.31 ± 1.42	5.57 ± 0.83		P1 Clench	6.69 ± 1.05	6.06 ± 0.82
	P2 Rest	1.05 ± 0.14	1.91 ± 0.66		P2 Rest	2.72 ± 0.47	2.94 ± 0.58		P2 Rest	0.97 ± 0.12	1.10 ± 0.36
	P2 Clench	4.86 ± 0.98	6.07 ± 1.39		P2 Clench	9.48 ± 1.16	5.59 ± 0.38		P2 Clench	3.04 ± 1.59	2.70 ± 1.23
	P3 Rest	1.66 ± 0.38	2.04 ± 0.54		P3 Rest	1.00 ± 0.22	1.14 ± 0.18				
	P3 Clench	7.58 ± 0.86	6.41 ± 0.59		P3 Clench	5.11 ± 0.43	5.77 ± 0.26				

	P4 Rest	1.75 ± 0.74	1.99 ± 0.32		P4 Rest	0.95 ± 0.09	1.13 ± 0.19				
	P4 Clench	12.87 ± 3.45	7.59 ± 1.72		P4 Clench	4.17 ± 0.37	7.22 ± 0.90				
4	P1 Rest	1.12 ± 0.24	1.08 ± 0.16	**8**	P1 Rest	1.22 ± 0.12	1.20 ± 0.11				
	P1 Clench	7.80 ± 0.92	5.50 ± 0.50		P1 Clench	3.23 ± 0.67	4.06 ± 1.27				
	P2 Rest	1.48 ± 0.43	1.25 ± 0.35		P2 Rest	1.31± 0.34	1.22 ± 0.20				
	P2 Clench	4.77 ± 0.52	3.04 ± 0.31		P2 Clench	2.64 ± 0.45	2.49 ± 0.43				
	P3 Rest	1.38 ± 0.43	1.30 ± 0.31		P3 Rest	1.36± 0.21	1.95± 0.62				
	P3 Clench	6.48 ± 2.01	4.23 ± 1.13		P3 Clench	3.68± 0.53	4.21 ±0.49				
	P4 Rest	1.66 ± 0.38	2.41 ± 0.95		P4 Rest						
	P4 Clench	7.60 ± 1.49	7.12 ± 1.00		P4 Clench						

5.4: Average Left and Right mean MMA of all 12 patients where applicable (Figure 5.4)

When the means of the 12 patients MMA results were averaged, the following were the results. Figure 5.4 shows the diagrammatic representation of these means.

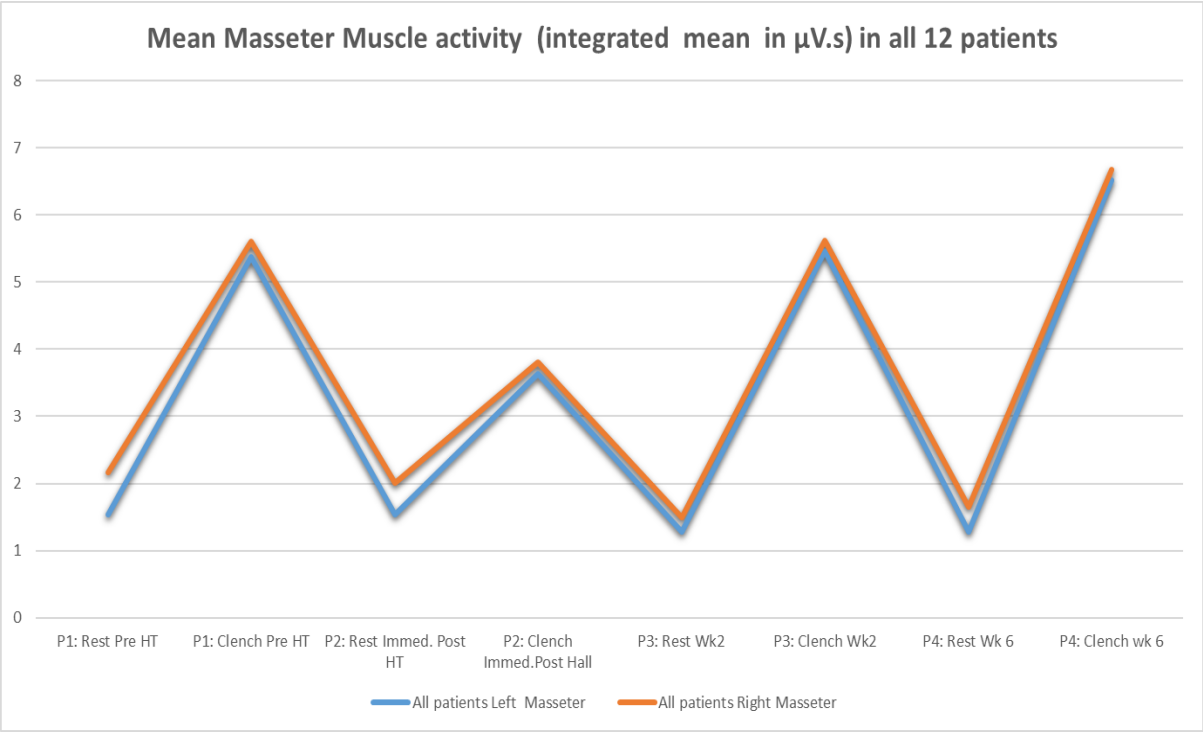


Figure 5.4. The mean left and right MMA in all 12 patients combined. Note the zig zag pattern.

5.4.1 All Patients Rest MMA (see figure 5.5)

- *P1:* the mean L-MMA at RP ± standard deviation (STD) was 1.54 ± 0.531 µV.s, while the mean R-MMA at RP was 2.16 ±1.39 µV.s.
- *P2:* the mean L-MMA at RP was 1.54± 0.68 µV.s, while the mean R-MMA at RP was 2.01 ± 1.62 µV.s.
- *P3:* the mean L-MMA at RP was 1.28± 0.532 µV.s, while the mean R-MMA at RP was 1.50 ± 0.62 µV.s.

- *P4*: the mean L-MMA at RP was 1.28± 0.479 µV.s, while the mean R-MMA at RP was 1.65 ± 0.66 µV.s.
- *The overall mean RP of all patients overall the 6 week period was 1.522*±0.31 (95% CI: 1.461-1.584) (see figure 4.5).

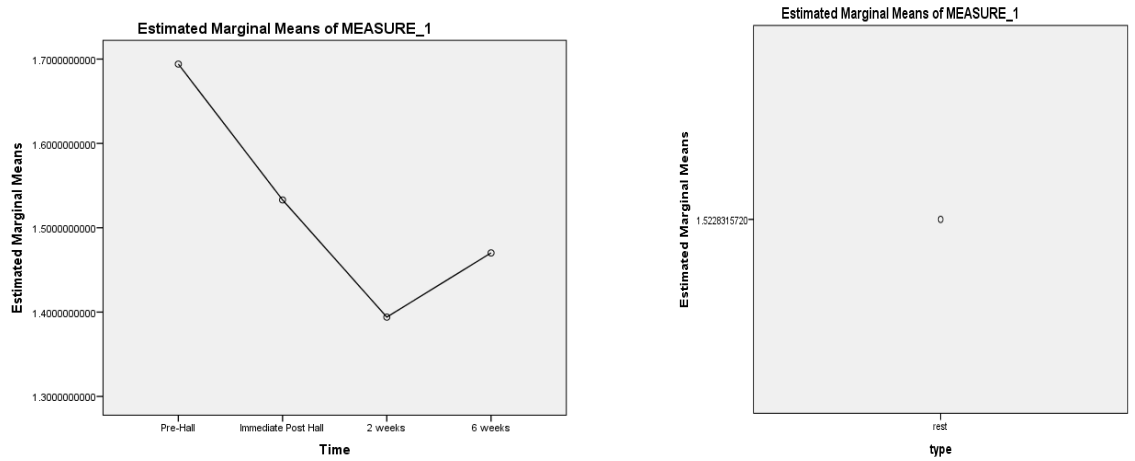


Figure 4.5. Shows the relative fluctuation of the rest RP MMA (in µV.s) over time. Although there were variations, this was not significant (See below).The mean rest RP MMA is shown on the right (*1.522*±0.31 µV.s).

Table 5.4. Rest RP MMA means

Rest MMA Mean

Measure: Overall Rest MMA

Mean	Std. Error	95% Confidence Interval	
		Lower Bound	Upper Bound
1.523	.031	1.461	1.584

Measure: Left and right Rest MMA

factor1	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Left MMA	1.378	.029	1.321	1.436
Right MMA	1.667	.039	1.590	1.744

5.4.2 All patients Clench MMA (see figure 5.6)

- *P1:* the mean L-MMA at MVC was 5.38± 2.33 µV.s, while the mean R-MMA at MVC was 5.60 ± 2.29 µV.s.
- P2: the mean L-MMA at clench was 3.63±2.09 µV.s, while the mean R-MMA at clench was 3.8± 1.54 µV.s. See Figure 4.3.
- P3*:* the mean L-MMA at MVC was 5.46± 1.42 µV.s, while the mean R-MMA at MVC was 5.62 ± 1.49 µV.s.
- P4*:* the mean L-MMA at MVC was 6.52± 3.21 µV.s, while the mean R-MMA at MVC was 6.68± 1.93 µV.s.
- *The overall mean MVC of all patients overall the 6 week period was 5.38* ± 0.1µV.s (see figure 4.6)

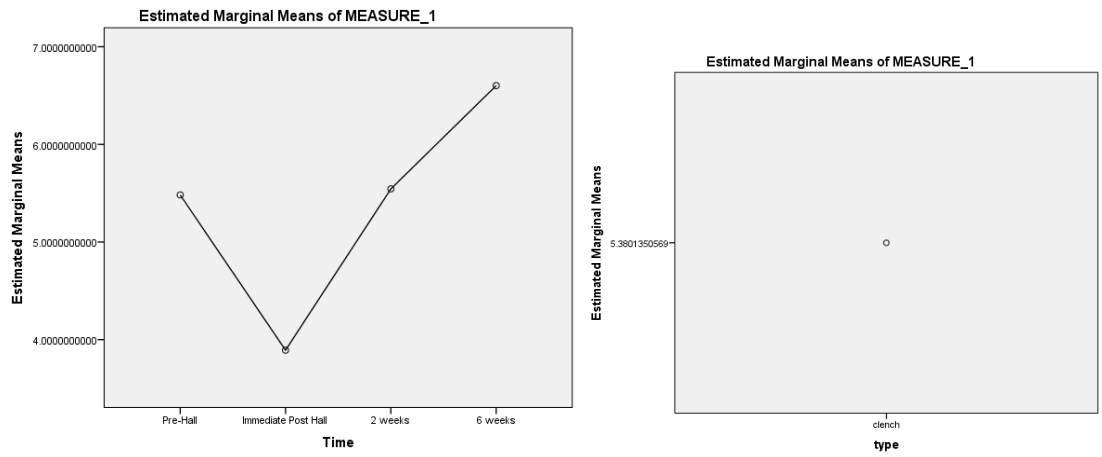


Figure 5.6. Shows the relative fluctuation of the clench MVC MMA (in µV.s) over time. The changes were significant (see below). The mean clench MVC MMA is shown on the right (5.38 ± 0.1 µV.s).

Table 5.5: Clench MMA means.

Clench MMA Mean

Measure Overall Clench MMA

Mean	Std. Error	95% Confidence Interval	
		Lower Bound	Upper Bound
5.380	.101	5.182	5.579

Measure: Left and right Clench MMA

factor1	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Left MMA	5.346	.131	5.089	5.603
Right MMA	5.414	.103	5.212	5.616

5.5 Statistical analysis of MMA results for the 12 patients

The raw data of the above results (See Appendix 6) were analyzed using multivariant ANOVA test and *post hoc* comparisons where applicable (significance was set at $p<0.05$). We analyzed the 12 patients (P1 and P2), the nine patients (P1, P2 and P3) and the seven patients (P1, P2, P3 and P4) MMA readings separately. The following factors were considered:

1) The activity (rest or clench).
2) The time (P1: Pre HT and P2: Post HT, P3: 2 weeks post HT and P4: 6 weeks post HT).
3) The patient
4) The side of the crowned tooth (left or right),
5) The side of the masseter muscle (left or right)

5.6 The multivariate ANOVA results

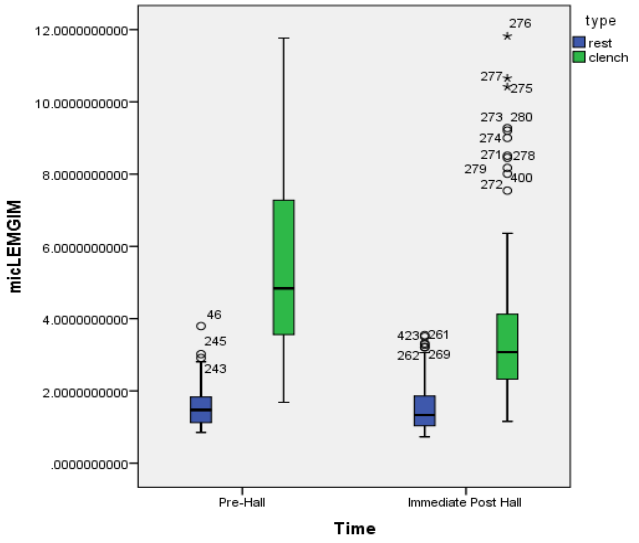
The following results were found from the multivariate ANOVA: There was a very significant difference between the RP activity and the MVC activity within each of P1, P2 (for the12 patients for both left and right sides- figure 5.7), P3 and P4 (for 9 and 7 patients respectively-see figure 5.8) (all $p<0.0001$). Thus, the sEMG system was able to differentiate in all patients a clear shift between RP MMA activity and MVC MMA activity at all the four stages ($p<0.0001$). It was also noticed that the MMA readings (whether at rest or clench) differed between patients ($p<0.001$), as older patients tended to have higher MMA clench readings.

There were no significant differences between the left and right-side rest RP MMA within each individual stage and over the six weeks' time period ($p=0.180$). Similarly, there was no significant difference between the left and right-side clenching MVC MMA within each individual stage ($p=0.731$). This is apparent graphically in figures 5.4, 4.7 and 5.8 as the reader can notice a similar pattern between the left and right sides. This allowed us to compile a box plot chart combining the

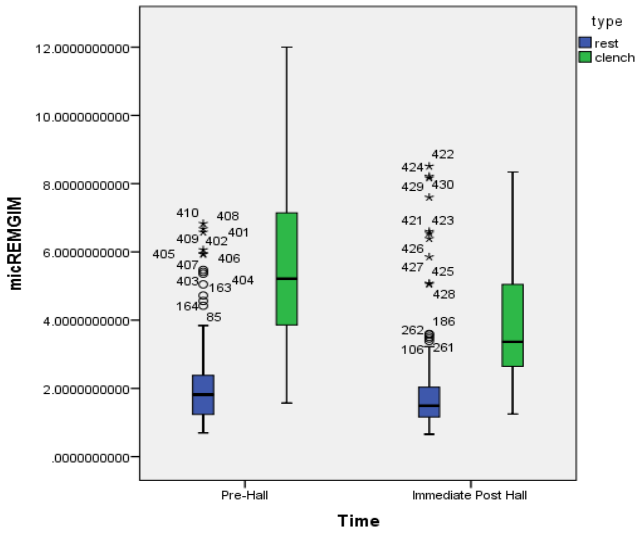
left and right MMA into one activity (see figure 5.9) and this showed the same pattern overall and corresponded to figure 5.4. This also suggested that the position of the HT crown within the subjects (whether left or right) had no differential effect on the MMA (whether left or right). Indeed, when we further analyzed the position of the crown, the ANOVA showed that the position of the HT PMC had no bearing on the left or right MMA activity (p=0.790). See Table 5.6.

Table 5.6. The MMA according to the HT crown position

HT PMC position	MMA Activity	Mean	Std. Error	95% Confidence Interval		P Value
				Lower Bound	Upper Bound	
Crown in right side	Rest	1.479	.147	1.335	1.624	p=0.790
	clench	4.906	.247	4.761	5.505	
Crown in left side	rest	1.732	.071	1.64	3.641	
	clench	5.225	.091	5.176	5.35	



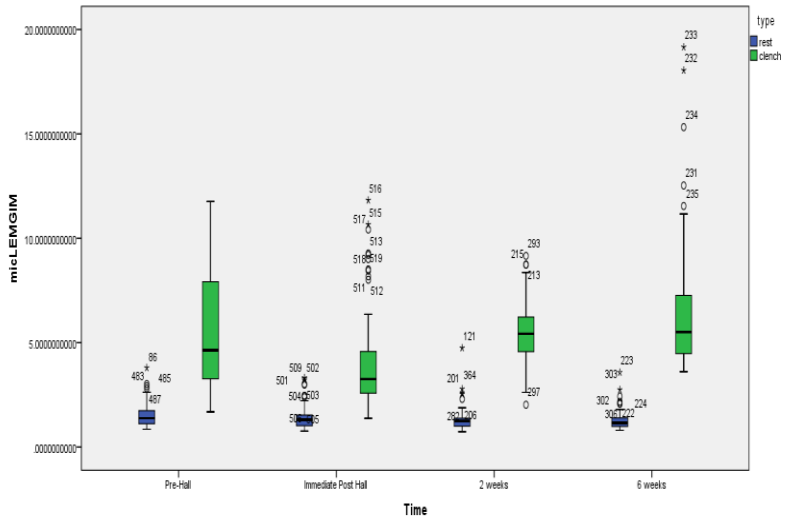
a)



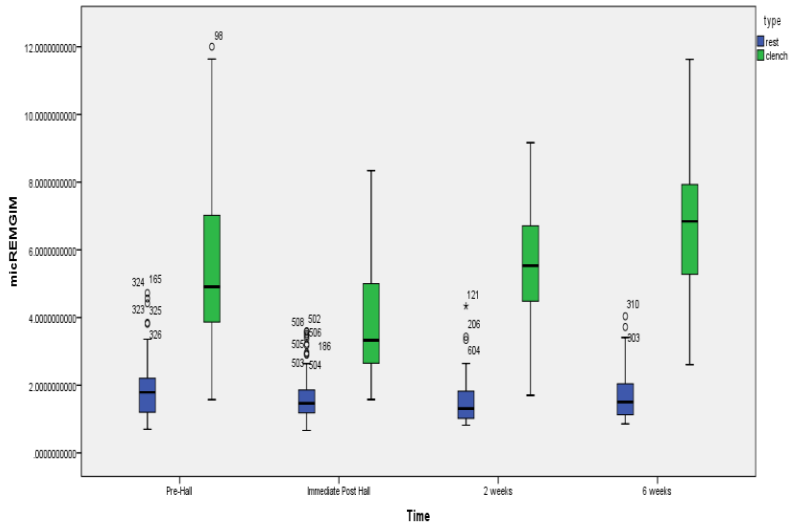
b)

Figure 5.7: Box plots of the 12 patients MMA readings at P1 and P2.

a) Left MMA (Rest-Blue and Clench-Green) for all 12 patients at P1(Immediate Pre-Hall) and P2 (Immediate Post Hall). b) Right MMA (Rest-Blue and Clench-Green) for all 12 patients at P1 (Immediate Pre-Hall) and P2 (Immediate Post Hall). **micLEMGIM:** Left Electromyography Integrated Mean in microvolts. **micREMGIM**: Right Electromyography Integrated Mean in microvolts. Note the similarity between the left and right-side MMA readings. The black line represents the mean, while the boxes represent the standard deviation, and the range represents the confidence intervals.



a)



b)

Figure 5.8: Box plots of the 9 patients MMA readings at P1, P2, P3 and P4 (7 patients)

a) Left MMA (Rest-Blue and Clench-Green) b) Right MMA (Rest-Blue and Clench-Green). **micLEMGIM:** Left Electromyography Integrated Mean in microvolts. **micREMGIM**: Right Electromyography Integrated Mean in microvolts. Note the similarity between the left and right side MMA readings. The black line represents the mean, while the boxes represent the standard deviation, and the range represents the confidence intervals.

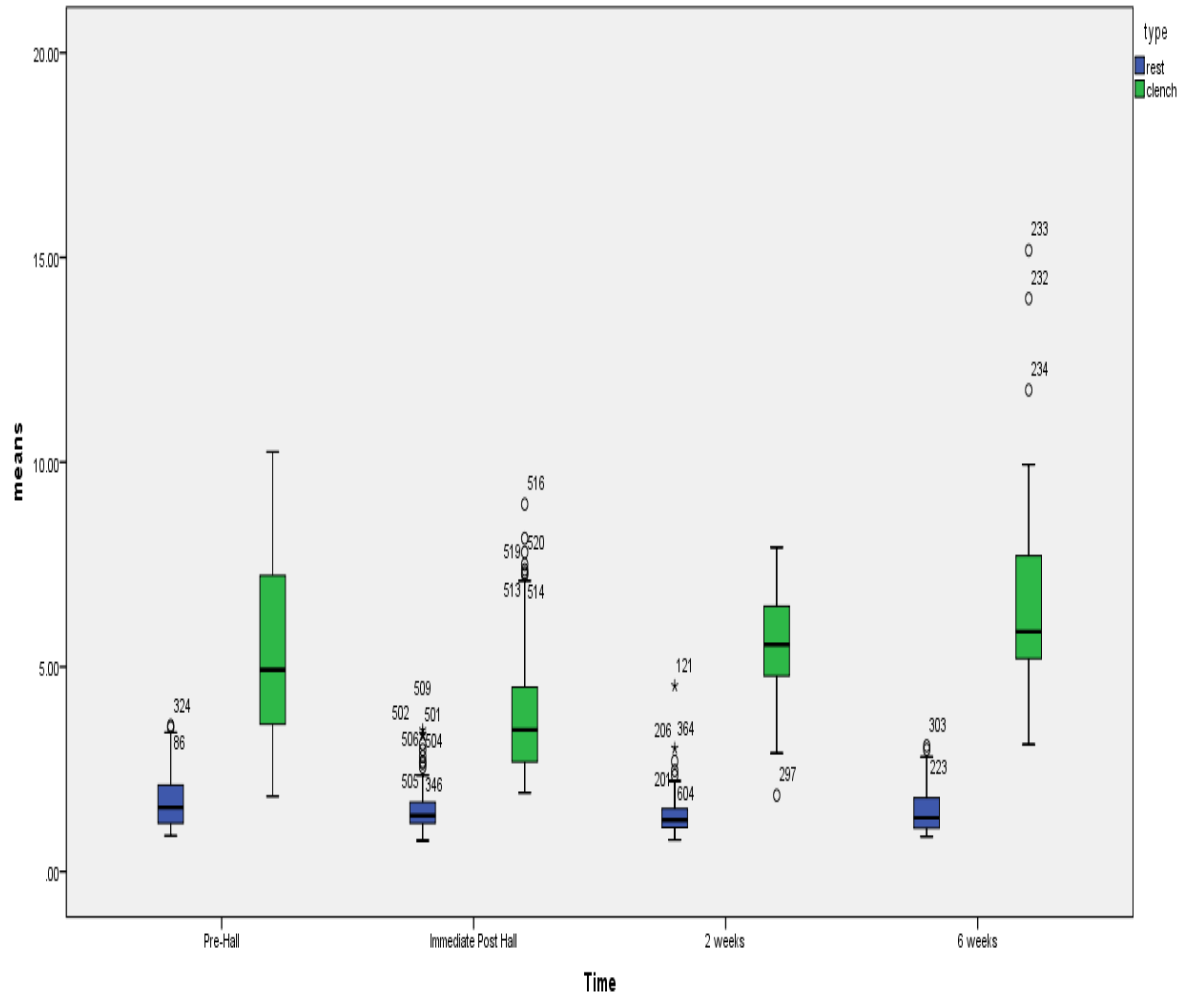


Figure 5.9 Shows the overall combined L/R MMA for all patients at P1, P2, P3 and P4.

5.7.1: The analysis of the rest MMA

When the L/R rest RP MMA was assessed over the six weeks (see figure 5.4 and 5.9), it was found that, although slight variations were present (see figure 5.5), there was no significant difference between rest RP MMA at P1, P2, P3 or P4 (p=0.180). Further *post hoc* analysis confirmed this as there was no significant difference between RP MMA at P1 and that of P2 (p=0.61), and P2 and

that of P3 (p=0.105), and P3 and that of P4 (p=0.406). Thus, the sEMG constantly recorded rest RP at a constant and this averaged to 1.522±0.31 (see figure 5.5).

5.7.2 The analysis of the clench MMA

The clench MMA pattern was clearly different from the rest MMA pattern. When the L/R clench MVC MMA was assessed over the six weeks (see figures 5.4, 5.6 and 5.9), it was found that there were significant differences between clench RP MMA at P1, P2, P3 or P4 (p<0.000). This was confirmed when further *post hoc* analysis was carried. For example, the MVC MMA reduced from P1 (5.49± 0. 22µV.s) to P2 (3.71 ± 0. 22µV.s) (by one third), and this was significant (p<0.001) (See Figure 4.6). The MVC MMA rose to 5.52± 0. 23µV.s at P3 and this rise was significantly different from P2 (p<0.001) but was not significantly different from P1 MVC MMA reading (p=0.822). The MVC MMA further rose at P4 to 6.70± 0. 25µV.s and the difference between this and P3 was statistically significant (p<0.001). When we compared the MVC MMA at P4, to that of the MVC MMA at P1, the P4 reading was higher and this difference was significant (p<0.001). Therefore, the clenching MVC MMA dropped immediately post HT by a third, returned to pretreatment levels at two weeks, and rose to higher than pre-treatment levels at six weeks. A further detailed look at the drop in clenching MMA for both masseter sides, between P1 and P2 (i.e. the differences in MVC MMA between P1 and P1- as shown in figure 5.10) demonstrated that the difference between them was significant (p<0.001).

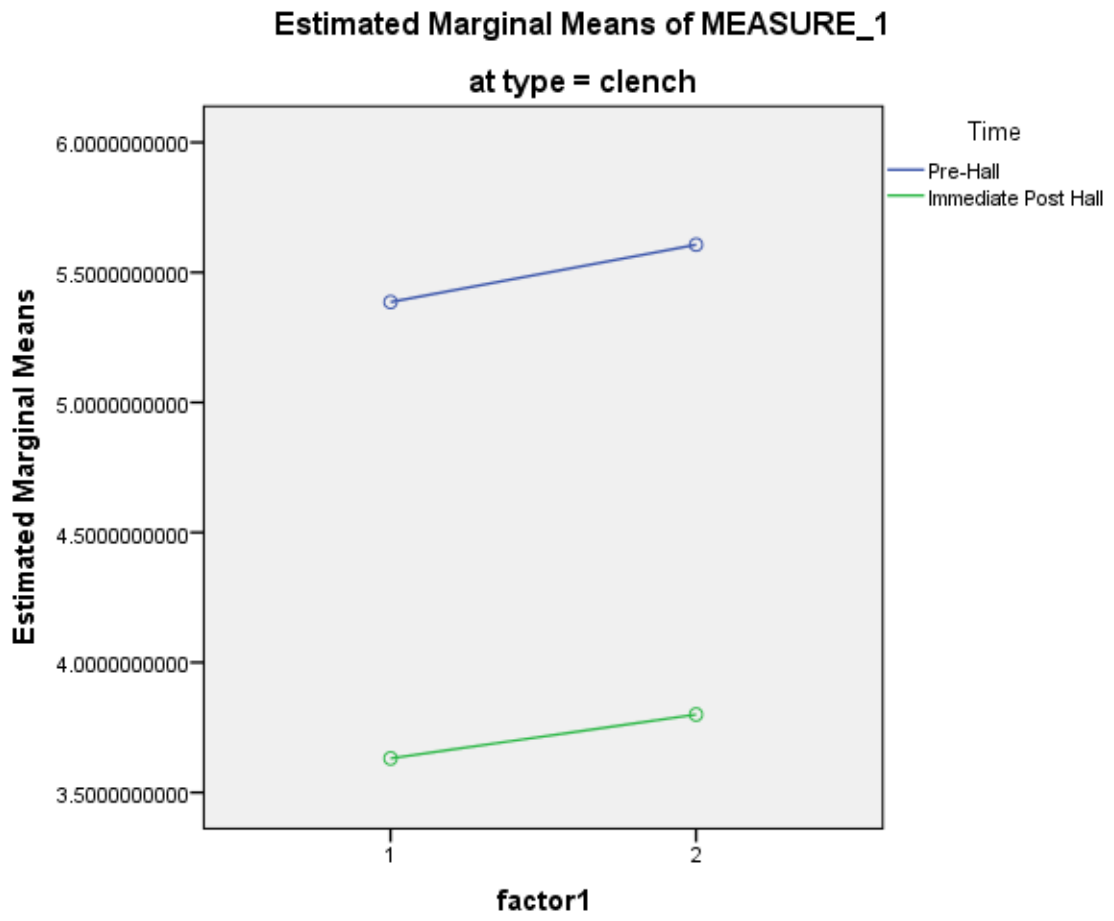


Figure 5.10 This shows the mean MVC readings for both left (1) and right (2) MMA at P1 (Blue line-pre HT) and at P2 (Green line-immediate post HT) for the 12 patients. Notice the clear reduction in the mean MVC value from the blue line (~ 5.49µV.s) to the green line (~3.71 µV.s). This was statistically significant ($p<0.001$) however there were no significant differences between the left and right-side clench MVC MMA

5.8 Summary of the results

In summary of the results; the findings showed that while the rest MMA for the 12 patients - as recorded by the sEMG- was constant throughout the six-week period, the clench MMA was affected by the placement of the HT PMC (See figure 5.11- which separates the rest from the

clench MMA readings). The clench MMA underwent a reduction immediately after the HT PMC cementation, returned to and finally surpassed pre-HT levels at two- and six-weeks post HT respectively.

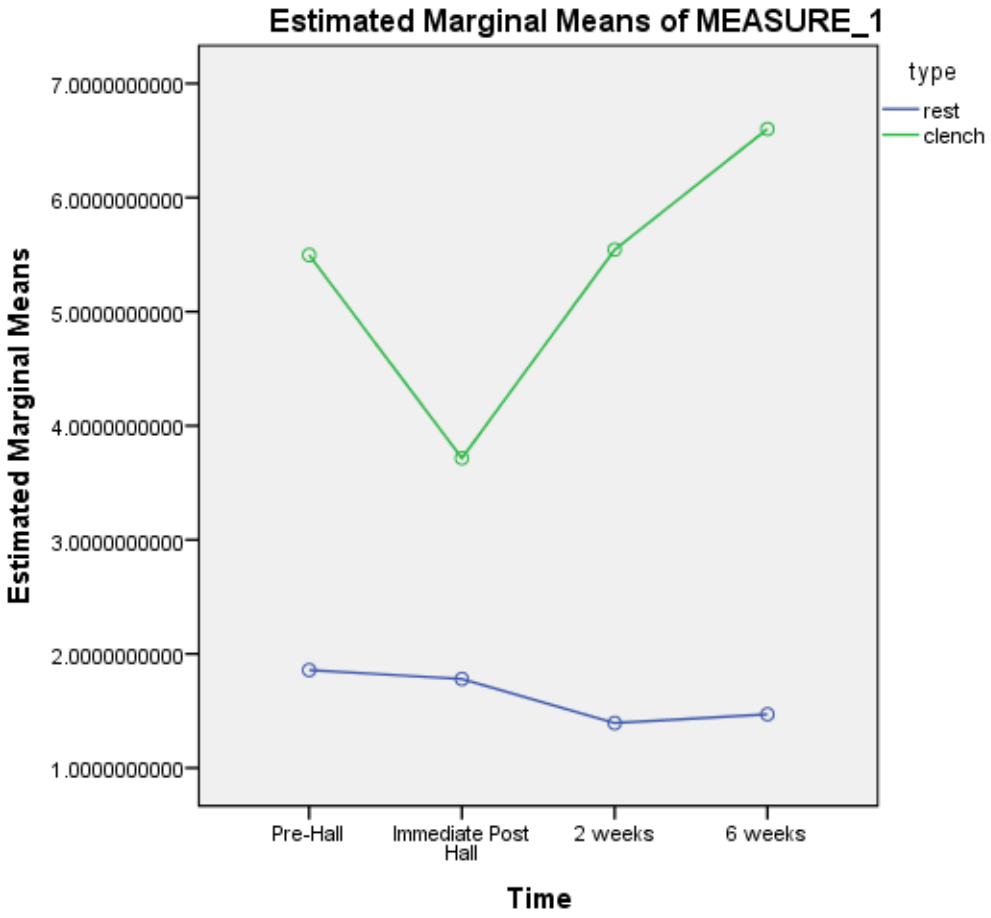


Figure 5.11. The pattern of average rest (blue) and clench (green) MMA separated from each other over time in comparison to one another. Note that while the rest MMA remains static almost over time, the clench MMA undergoes significant fluctuations after HT PMC cementation and showing a “cooking pot” pattern.

6.00 DISCUSSION

This study is part of the continuum of studies that cover the HT in children.[8,11, 51,65, 108,110] Ever since the HT was first publicized in the year 2000,[52] it was considered a controversial method [61] that divided the world of pediatric dentistry into those who supported it[58,59] and those who did not.[13,111] While many aspects of the HT have been assessed, like microleakage,[110] occlusion,[9] and patient/parent/dentist perception,[11] our study examined a facet of research related to the HT that, to our knowledge, had not been assessed.

6.1 Why is this study important?

This study is important because it was the first study to analyze and measure the use of sEMG in the context of the HT, in particular, the effect the HTPMC may have on children's masseter muscles before and after cementation. The HT has been criticized because of the alleged "harmful effects" it was deemed to have on many elements of the child's dental status including the occlusion[13,111]. It is known that the occlusal apparatus consists of the dentition (teeth), muscles of mastication and the temporomandibular joint. Any imbalance in one component leads to the disturbance of the occlusal equilibrium.[17,67] Our study focused on the assessment of the muscular facet of this triad. While HT PMCs are known to affect the occlusion and have been blamed for premature contact related discomfort in the first few days after their placement,[4,13] this premature contact of PMC restored teeth will return to pretreatment levels in 15–30 days.[9] This suggested that the premature contact was of a temporary nature and this was confirmed further by Gallagher *et al.* (2014) who studied the placement of a PMC changes to the maximum intercuspation position (MIP) in children.[112] They reported that MIP was disturbed by the placement of a PMC in seven of 20 cases. When MIP was disturbed, in most cases, it returned to preoperative status

within four weeks of crown placement.[112] While the transient nature of such disturbances has been highlighted,[9,11] no studies assessed the muscular changes in such cases, attributing the changes reversal as "dentoalveolar compensation".[4,11] Moreover, it had been previously reported that excessive occlusal interference should be avoided with conventional PMCS (greater than 1.0–1.5 mm), but slightly premature or high occlusal contacts up to about 1.0 mm were normally well tolerated in children, who were reported to have considerable capacity for dentoalveolar compensation, with the occlusion adapting to any prematurity within a few weeks[4]. On the other hand, the interference caused by HT PMCs has been shown to specifically due to crowned tooth intrusion.[9] Therefore, while these aforementioned studies confirmed the transient nature of the disturbance in the PMCs, no study had assessed muscular activity in this context. Thus, our study was designed to complement the research in this area, investigating this disturbance in the occlusal equilibrium from a muscular point of view. Our study assessed the particular activity of the masseter muscles by means of assessing the electrical muscular activity as recorded by surface electromyography.

6.2 Why was MMA and sEMG used in our study

There are many methods to assess masseter muscles that are non-invasive[72]. This study used sEMG recorded MMA because it was considered to be a safe,[113] non-invasive,[81] reproducible,[114] accurate[113], methodical and simple to analyze method that has been previously used in children in numerous medical [115,116,117] and dental studies.[16,19,93,90] PMCs had been subject to occlusal studies that employed models, clinical photos[65], clinical measurements,[9,64] electronic occlusal sensor devices, [112] and occlusal bite force devices.[116] For example, Owais *et al.* (2018)[118] studied PMCs and bite forces by using a hydraulic pressure gauge that children bit on. They detected the existence of a relationship between maximum occlusal bite force (MOBF) and PMCs placement. While this

study, and others[110] were pivotal in assessing PMC and the occlusion, their study did not use sEMG. Nevertheless, sEMG has been widely used for orthodontics regarding the dynamics of the occlusion,[18] cleft lip and palate,[93] TMD,[85,119] sleep bruxism,[68,90] and internal stress in children receiving dental treatment.[120] In addition, our sEMG device had already been utilized in the department of Physiology at our university (MBRU) for the purpose of undergraduate medical training and was available for use by the dental college for purposes of research. Therefore, our study utilized a tried and tested approach, but in the new context of occlusion and the HT.

6.3 Discussion of the study sample

We had 12 participants in this study. This sample was considered a convenient sample of patients who attended between January and March 2018 and who agreed to participate. As mentioned previously, no sEMG study was conducted under the umbrella of the HT prior to this research. Therefore, we had no direct studies to compare with. However, when we looked at studies using sEMG of masseter muscles for other purposes we found a range of study sample populations. Our study was similar in number to the study of Negoro *et al.* (1998),[91] where 12 children were recruited to study bruxism using sEMG, as was the case in Testa *et al.* in 2017 who studied sEMG and clenching in 12 patients with neck pain.[121] Many other similar studies included a fewer number of participants. For example there were six subjects in Li *et al*. (2008),[15] nine subjects in Castroflorio *et al*. (2011),[79] 10 subjects in So *et al*. (2015) [65] and 10 subjects per study group in Nuño-Licona *et al.(*1993).[122] However there were other studies that had a higher number of participants; 18 in Cecco Oncins *et al.* (2014),[98] 28 subjects in Saccucci *et al.(*2011),[19] 30 subjects in Alarcón *et al.(*2009),[92] 47 subjects in Wang *et al.* (2009),[18] and finally 82 subjects in Szyszka-sommerfeld *et al.* (2018). [93] It is important to recall that sEMG studies capture a high number of sEMG readings bilaterally over multiple time points, thus increasing the sensitivity of the data

collected in a small number of subjects. In this study, we captured 1600 sEMG readings from our 12 patients. It is worth highlighting that all of the 12 patients completed phase P2 (pre and post HT), nine patients completed phase P3 (2 weeks post HT) and seven patients completed phase P4 (six weeks post HT) of the study. While this is a limitation of the study, the wealth of data allowed robust analysis of the MMA sEMG readings at various levels.

6.4 Discussion of the MMA pattern over the study periods (P1, P2, P3 and P4)

In this study we examined the extent and duration of HT PMC effect on masseter muscles within four time periods using *clench* and *rest* activities. Measuring rest and clench MMA is a standard method and has been reported in numerous studies [69,97,122] despite the fact that some other studies focused on measuring other activities of the masseter muscles (and other muscles such as the temporalis muscles) such as during chewing[66,90,123] or the during the retruded contact position[118]. The present study showed a clear universal pattern of behavior of those masseter muscles in terms of MMA during rest and clenching in the six-week period of our study.

This study period for each patient was designed to last for six weeks. The main reason behind the choice of six weeks, was the known effect of the HT on the occlusion[9]. Although we did not objectively measure the occlusion/occlusal changes in our patients alongside with the MMA readings, as the former had been assessed in numerous studies published previously, [8,9,65] transient clinical occlusal changes and improvements were anecdotally observed as expected in all our HT patients. As the reported period in which changes in the occlusion following the HT was reported to be between two to four weeks,[9,11, 64] our study exceeded that time period and used the cutoff point of six weeks to assess MMA.

6.4.1 Discussion of the rest MMA in the study.

This present study found that the rest position MMA was constant throughout the study period, was within a normal range and was significantly lower than the MMA clenching activities. This was similar to other reports.[90,93,97,122] Thus, a considerable reduction in sEMG activity in the masticatory muscles with the mandible at rest and positioned at a few millimetres of inter-occlusal distance was an expected finding and our study confirmed this.

The determination of sEMG activity in the masseter muscles with the mandible at *rest* is of fundamental importance as muscle activity in the resting position is dependent on the lengthening reflex and is effectively maintained by the tonicity of the muscles that counterbalance the action of gravity and negative intra-oral pressure.[97,124] It also acts as a control to compare other measured activity against[90,93] (such as chewing whistling, MVC etc) although some authors also use maximum voluntary muscular contraction as a reference point for comparison and normalisation[93,124]. Rest is usually constant in the absence of pathology such as temporomandibular disorders (TMD)[97] especially when TMD affects the temporalis muscle. This is not the same for muscles such as the masseter muscle as MMA at rest appears to be unaffected by occlusal changes,[93] however, premature contact with incisors may produce registrable MMA activity[123] . However, it is important to highlight that the physiological basis of the mandibular resting position is one of the most controversial areas in oral physiology.[97] In the resting position, the muscles may be slightly contracted and sEMG activity can be slightly greater than in the absolute physiological resting position, where minimum action potentials are being generated, which would be in theory difficult to measure. We used the clinical rest position as described Szyszka-Sommerfeld *et al*. (2017)[93]. They noted that no significant differences were observed between in children in terms of the rest EMG activity of the masseter muscles, suggesting that the

occlusal alterations investigated in this study, as long as no early contact occurred at rest, had no predictable effect on the rest activity pattern of this muscle. This finding was similar to our study in this regard. It also highlighted the reproducibility of the method we chose in recording the sEMG MMA. As ‘rest” remained “rest” throughout the phases of the study, and almost had a flat-line graphical pattern indicting minimal change.

6.4.2 Discussion of the clench MMA in the study.

Our study showed that unlike the rest MMA, the clench sEMG MMA was clearly affected by the HT albeit temporarily. As reported above, the HT PMC was known to change the occlusion temporarily by opening the bite by 1-2 mm[11,65]. This would invariably influence the activity of the muscles of mastication as represented in this study by the masseter muscle. Occlusal changes following the placement of PMCs have been shown to occur whether the PMC was placed by conventional means[4,52,116] or the HT.[5,8,9,11,64] In addition, multiple studies have shown that clenching activity of muscles of mastication activity are affected by changes in occlusion in general[93,125,126,127] .

While occlusal changes caused by orthodontic treatment have been known to influence sEMG readings and permanently change them (as long as the occlusion had been altered),[125,126, 127] our sEMG clench readings were temporarily affected. The clench MMA profile developed a “cooking pot” pattern where the MMA slid down one side of the pot to the base, then slid upwards along the slightly upwards bent handle. This was in stark difference to the almost flat line rest pattern highlighted above. The clench MMA pre the HT dropped immediately after the HT PMC placement by almost a third (in all 12 patients), to recover to preoperative levels by two weeks (in 9 patients) and even exceeded preoperative levels by six weeks (in seven patients). Anecdotally,

this temporary pattern of muscular activity appears to correlate with the time frame of the recovery of the occlusion recovery seen in PMCs (whether conventional [4,109, 115] or by the HT, [9,11,65] however more studies are needed to confirm this correlation.

While all the HT studies had confirmed that the occlusion returned to normal within 30 days, those studies that assessed non-HT PMCs showed interesting findings that are in line with this present study. We single out the studies of Owais *et al.* in 2018[118] and Gallagher *et al.* 2014[112]. The former assessed changes in occlusal bite force (OBF) following placement of conventional PMCs on primary molars in 22 children 4–6 years old children over six months and found that OBF was reduced the first week after placement of PMCs, restored to and reached its original value at three months. At the six-month recall visit OBF was 148% and 136% of pre-treatment. While the clench MMA measured in this present study, is not the same as the OBF in Owais *et al.*, our study showed that the clench MMA recovered by two weeks as opposed to three months reported in the Owais *et al.* study.[116] In addition, the clench MMA in our study reached 120% of the pretreatment values at six weeks-from 5.49($\pm$2.30) to 6.6(+2.56) μV.s. Thus this present study's findings are in line with Owais *et al*[118] who concluded that the OBF decreased one week after placement of PMC restoration and started to increase after one month reaching 136–140% of its original value after six months. The reduction of sEMG clench reading by a third of the normal value in our present study may be explained by the temporary discomfort experienced by the child due to sub-gingival pressure of the crown margins (that underwent blanching as normally described by the HT manual[8]), changes in height and occlusal morphology that resulted from the HT PMCs cementation, which may have changed the original contact points on the occlusal surfaces (on one side) and the interproximal area. The drop may also be affected by the fact that child might be afraid to bite strongly on the new hard crown as they are unsure of the new change of the occlusion.

The recovery of the sEMG MMA in this present study (and the OBF as explained by Owais *et al*.[118]) can be explained by the tolerance of patients to PMCs and the restoration of the original occlusal contact points and the *intrusion* of the treated tooth as shown by So *et al*. 2015.[65] It may also be explained by the evidence presented by van der Zee and van Amerongen (2010)[9] who showed that premature contacting PMCs restored teeth will equilibrate within a month after treatment due to dento-alveaolar compensation. However, it took three months for occlusion to be restored in Owais *et al*. compared to one month in van der Zee and van Amerongen 2010[9] which may be due to the extensive number of posterior crowns placed in the former study. Our study subjects had one crown each thus the recovery of the sEMG MMA to normal levels appeared to follow a more rapid recovery pathway. As for the increase in MMA at six weeks compared to pretreatment recordings; this increase may be due to the increase in number and extent of tooth contact and increase in vertical dimension of jaw elevator muscles during mastication. Owais *et al.*[118] reported that increasing of number and size of occlusal contacts provided the basis for bite force increase. Also another factor that may explain this the increase by *repeated testing effect* suggested by Roldán *et al.* (2016)[128]. They reported that with repeated tests subjects reduce their anxiety (psychological accommodation to the testing procedures) over time and learn how to more effectively produce a stronger bite force, thus affecting MMA activity[119]. Gallagher *et al.* in 2014 [112] showed the same effect using a T-Scan occlusal device and showed that in 20 patients receiving PMCs , the maximum intercuspation position (MIP) in children recovered fully in four weeks [112]. Many studies have addressed the OBF in primary dentition,[118 ,129,130, 131] its influencing factors[132]. The OBF is a relatively reproducible outcome to measure[116], although to our knowledge, it has not been directly compared against sEMG[111,112]. However, it is postulated that an increase or decrease

in OBF would lead to corresponding increases and decreases in sEMG readings. This could be a basis for a future wider study in the HT context.

It is important to point out that measuring MMA using sEMG reliability may be difficult[112,130] due to a number of factors, including the accuracy of the measuring device itself. In our study we standardized the way of measuring RP and MVC MMA by the correct placement of electrodes, taking pre and post photos, and measuring their position to reproduce the same position in the later appointments.

In our study bilateral MMA measurements was conducted at the same time, which is the norm. While there were no differences between left and right-side MMA measurements, this has not been the case when pathology such as cleft lip [93] or TMD [94] existed. Also, measuring the OBF is usually unilateral or central. The hydraulic pressure gauge with a biting element made of a vinyl material encased in a polyethylene tube[118,133] measures OBF anteriorly unilaterally, which is more reproducible than bilateral measurements[134].

The children in this study had no malocclusions. It has been shown that malocclusion is associated with a reduced occlusal bite force. [130,135,136 ,137.] Roldán *et al.* (2016) reported that normal occlusions have a greater OBF than with Class I or Class II malocclusions[128]. Also, children with a unilateral posterior crossbite have reduced OBF and a reduced number of occlusal contacts compared with children with normal occlusions[135], which may affect master muscle activity. The only occlusal change in our study was the placement of the crown. However, whether left or right, the effects on the MMA was the same.

Due to the lack of published literature of similar studies and the fact that this is the first prospective cohort study studying the effect of HT PMCs on MMA in children, it was hard to compare the results of this study directly to previous studies. The results above suggest that the *Null Hypothesis*

outlined in 2.50 was partially rejected. There were no differences in the masseter muscle activity during resting before and after the placement of a HT PMC as measured by sEMG, however there were clear differences in the masseter muscle activity during clenching before and after the placement of a Hall technique PMC as measured by sEMG. This difference resolved by two weeks.

6.5 Limitations of this study:

This study had several limitations:

- No other outcome measures (such as occlusion or occlusal bite force) besides MMA were obtained
- The study contained a small sample size due to time restraints, and it was a convenience sample.
- Loss of some participants owing to inadequate follow-up.
- The use of PMCs on different teeth may have affected the results. This was not analyzed in our study. It would have been ideal to have the same tooth/arch/quadrant in all the HT patients.

7.00 CONCLUSIONS

In the sample of children undergoing a single Hall technique preformed metal crown treatment:

1- A surface electromyography device measuring masseter muscular activity differentiated rest from clenching activity.

2- Children's bilateral masseter muscle rest activity was constant and unchanged throughout treatment. Thus, the Hall technique had minimal effect on masseter rest activity

3- Children's bilateral masseter muscle clenching activity underwent a reduction immediately after cementing a single crown. The activity returned to, and later exceeded, baseline levels at two and six weeks respectively.

4- The clenching masseter muscle activity was the same whether the preformed metal crown was on the left or right side of the mouth.

Recommendations

1. The need of future research using a larger sample size involving studying the child's age/gender, the effect of HT on different teeth, side of treatment, other mastication muscle groups and studying the occlusion using other means such as bite force, 3D scanned models, intra-oral scans.
2. Increase the follow up timing up to six months.

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9.00 APPENDICES

Appendix 1

Ethical approval

Ref EC1017-005

Date: 15/10/2017

Dear Dr Salsabeel Abu Serdaneh

Re: Your research protocol

Titled: The effects of the placement of prefabricated metal crowns utilizing the Hall technique on masseter muscle activity: A surface electromyography study in children

Thank you for submitting your research protocol to the Research and Ethics committee of the Hamdan Bin Mohammed College of Dental Medicine, MBRU.

I give approval for the above named study.

The committee would like to remind you that it is a requirement of the programme that you complete a research dissertation, which comprises 15% of credits within the 3-year MSc programme.

Good luck with your project.

With best wishes

Yours sincerely,

Prof A Milosevic

Chair, Research and Ethics Committee, HBMCDM

Appendix 2

Parent Information and Informed Consent Form

Title of Study:

Effects of the placement of prefabricated metal crowns utilizing the Hall technique on masseter muscle activity: A surface electromyography study in children

Principal Investigator: Dr. Salsabeel Ismail Abu Serdaneh Department of Paediatric Dentistry, Hamdan Bin Mohammed College of Dental Medicine, Building 34, Dubai Healthcare City, Dubai, UAE. Telephone: (056) 7163613

Please take your time to review this information form, and feel free to consult with or discuss this study with your dentist, colleagues, family, friends, and/or physician before deciding whether or not to participate. If you have any questions regarding the study or any related issues we encourage you to ask the principal investigator, as listed above. This consent form may contain words that you do not understand. Please ask the research staff to explain any words or information you do not clearly understand.

Purpose of the study

This study is being conducted at the Hamdan Bin Mohammed College of Dental Medicine, Department of Pediatric Dentistry, to assess the effect of silver crowns on the activity of jaw muscles.

Study procedures

If you choose to take part in this study, the following procedures will be employed: the researcher will explain to you and to your child how the procedure will be done by showing you a simple informational sheets with pictures , then we will place 6 electrodes (skin stickers) on the child's cheeks and forehead , then will ask him/her to bite hard (clench)on his/her teeth intermittently for 20 seconds , after that we will choose and cement the silver tooth (Hall crown) and ask the child to clench again for 20 seconds. We will need to repeat this same procedure again after 2 weeks and 6 weeks. We will measure the jaw muscles activity.

Hall crown treatment will be provided as required in the treatment plan of the patient; you may stop participating in this study at any time.

Risks and discomforts

There are no additional risks or discomforts that may be caused to your child by participation in this

study.

Benefits

There may or may not be a direct benefit to your child from participating in this study. We hope the information we collect will help the profession in providing the best possible oral health care for their patients.

Cost / Payment

There is no cost to you for participating in the study and you will receive no payment or reimbursement for any expenses related to taking part in this study.

Alternatives: You should feel no obligation to participate in the study.

Confidentiality

All information obtained from this study including photographs is confidential and will remain so. Information gathered in this study may be published or presented in public forums; however, your and your child's name and other identifying information will not be used or revealed. In any published data, your identity (and your child's) will be protected and treated as confidential according to the Personal Health Information Act of UAE. To protect your identity, every participant will be given a Study Number instead of their name in all documents related to the study. All information obtained from this study will be used strictly for research purposes only. And confidentiality will be maintained unless the information is requested by law, if the study information is to be used in any subsequent investigation, your consent will be taken.

Hamdan Bin Mohammed College of Dental Medicine Research Ethics Committee may review study records for purposes of quality assurance only. Despite efforts to keep your personal information confidential, absolute confidentiality cannot be guaranteed. Your personal information may be disclosed if required by law.

All records relating to this study will be kept in a secure, locked area and only those persons identified will have access to these records. If any of your child's medical/research records need to be copied to any of the above, his/her name and all identifying information will be removed. No information revealing any personal information such as your/your child name, address or telephone number will leave the HBMCDM.

Voluntary participation / Withdrawal from the study

Your decision to participate and to allow your child to participate in the study is voluntary. You may refuse to give consent for child to participate in the study or withdraw from it at any point in time. If the research staff feels that it is in your child best interest to withdraw her/him from the study, they will remove you without your consent.

We will tell you about any new information that may affect your child health, welfare, or willingness

to stay in this study.

Questions

Please feel free to ask questions regarding the study or anything related to it that requires further clarification. To contact the research staff regarding a question, please call:

Dr. Salsabeel Abu Serdaneh (056) 7163613 or Dr. Iyad Hussein at +971 43838907

Do not sign this consent form unless you have had a chance to ask questions and have received satisfactory answers to all of your questions.

Appendix 3

STATEMENT OF CONSENT

I have read this consent form. I have had the opportunity to discuss this study with **Dr Salsabeel Abu Serdaneh** and/or her research staff. I have had my questions answered in a language I understand. All risks, benefits, costs, and alternatives regarding this study have been thoroughly explained to me. I believe that I have not been unduly influenced by any research team member to participate in the study by any statements or implied statements. Any relationship I or my child may have with the research team has not affected my decision to participate. I understand I will be given a copy of this consent form after signing it. I understand my and my child's participation in the study is voluntary and I may choose to withdraw my child from it at any point in time. I freely agree to participate in this research study and I give consent for my child to participate in the research study as well.

I understand that any information regarding my child's identity will be kept confidential, and confidentiality will be maintained unless the information is requested by law. I authorize the inspection of any of my records related to this study by the Hamdan Bin Mohammed College of Dental Medicine Research Ethics Board for quality assurance purposes.

By signing this consent form, I have not waived any of the legal rights that I or my child have as a participant in a research study.

Parent/legal guardian's signature: _____

Date: _____ (day/month/year)

Parent/legal guardian's printed name: _____

I, the undersigned, attest that the information in the participant Information and Consent Form was accurately explained to, and apparently understood by, the participant or the participant's legally acceptable representative and that the consent to participate in this study was freely given by the participant or the participant's legally acceptable representative.

Witness signature: _____

Date: _____ (day/month/year)

Witness printed name: _____

Appendix 4

DEMOGRAPHIC DATA COLLECTION SHEET

Child's ID No. : ……

Child Medical file No.: ☐☐☐☐☐☐☐☐☐☐☐☐

Gender: ☐ Male ☐ Female

Child Date of birth: D/d☐☐ M/m☐☐ Y/y☐☐☐☐

Appendix 5

Child information sheet

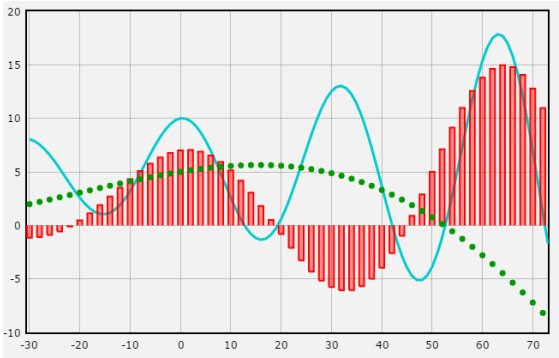
Are your Happy Face Muscles Strong Enough?

Today with the help of Mr. Super Tooth we will measure your muscles strength by our special equipment that only heroes can try!

1) First we will put the stickers on both sides of your cheeks.

2) We will place a strong diamond silver crown on your tooth.

3) We will ask you to bite hard on your teeth, press the computer button and watch the lines moves on the laptop screen.
4) Then we will measure how strong your happy face jaw muscles are.
   SIMPLE :-)



Are you ready?!

Let’s start!

Appendix 6

Raw Data

Pilot Results and analysis

- **Pilot Left side**
- **Left MMA**
- **Paired Samples Statistics**

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Masseter EMG REST Pre Ruler	1.999872949900	10	.6816299443588	.2155503145548
	Masseter EMG Rest with Ruler	2.103828077500	10	.6784620324421	.2145485328465
Pair 2	Child Pilot Clench Pre Ruler	10.231354823300	10	1.7696178044265	.5596022849975
	Child Pilot Clench with Ruler	7.043519859300	10	1.2110008691250	.3829520994879

Paired Samples Test

		Paired Differences	t	df	Sig. (2-tailed)
		95% Confidence Interval of the Difference			
		Upper			
Pair 1	Masseter EMG REST Pre Ruler - Masseter EMG Rest with Ruler	.5588417589576	-.355	9	.731
Pair 2	Child Pilot Clench Pre Ruler - Child Pilot Clench with Ruler	4.7012971209654	4.765	9	.001

- **Pilot Right side**
- **Right MMA**
- **Paired Samples Statistics**

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Masseter EMG REST Pre Ruler	1.474372143900	10	.3281878383189	.1037821069456
	Masseter EMG Rest with Ruler	2.220849789900	10	.9598595052954	.3035342270497
Pair 2	Child Pilot Clench Pre Ruler	8.876041509500	10	1.6200821468807	.5123149580719
	Child Pilot Clench with Ruler	6.026447923300	10	.9362679052580	.2960739080731

Paired Samples Test

		Paired Differences	t	df	Sig. (2-tailed)
		95% Confidence Interval of the Difference			
		Upper			
Pair 1	Masseter EMG REST Pre Ruler - Masseter EMG Rest with Ruler	.0380282680908	-2.153	9	.060
Pair 2	Child Pilot Clench Pre Ruler - Child Pilot Clench with Ruler	4.2905512857846	4.474	9	.002

- **Combination left and right**
- **Left and right**
- **Paired Samples Statistics**

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Masseter EMG REST Pre Ruler	1.737122546900	20	.5863219534987	.1311055744724
	Masseter EMG Rest with Ruler	2.162338933700	20	.8112121988665	.1813925620843
Pair 2	Child Pilot Clench Pre Ruler	9.553698166400	20	1.7916515597609	.4006254679620
	Child Pilot Clench with Ruler	6.534983891300	20	1.1756356147328	.2628801151313

Paired Samples Test

		Sig. (2-tailed)
Pair 1	Masseter EMG REST Pre Ruler - Masseter EMG Rest with Ruler	.084
Pair 2	Child Pilot Clench Pre Ruler - Child Pilot Clench with Ruler	.000

CONTINUE APPENDIX 6

Raw results of the 12 patients

	Patient 1 Rest Position (RP) P1			Patient 1 Maximum Voluntary Clenching (MCV) P1	
		Masseter sEMG L integ	Masseter sEMG R integ	Masseter sEMG L integ	Masseter sEMG R integ
		Mean	Mean	Mean	Mean
		µV.s	µV.s	µV.s	µV.s
P1					
1		0.90789521	1.02541257	2.10866846	1.57227198
2		0.99215062	1.23785954	1.68219097	2.21920411
3		0.88809196	1.00337387	1.93616077	2.57889486
4		1.04335445	1.19844957	2.05552182	2.76212521
5		0.85008582	0.96451343	1.77335302	2.92525711
6		0.90475245	1.07825315	1.95825276	2.20035654
7		1.01372731	1.23405429	1.74595647	2.24255163
8		1.11564537	0.87370004	3.39498034	3.93435458
9		1.15147806	0.69691688	4.40709401	4.82072336
10		1.11142986	0.96674668	3.90022015	4.80424357
Mean		0.99786111	1.027928	2.49623988	3.00599829
STD		0.10167253	0.16121351	0.95530035	1.07441588
	Patient 1 Rest Position (RP) P2			Patient 1 Maximum Voluntary Clenching (MCV) P2	
P2					
1		1.30520056	1.39293209	1.9445043	2.07874267
2		1.50656159	1.45020586	1.9445043	2.07874267
3		1.38059393	1.10294758	3.35095042	2.10731784
4		1.46081176	1.43002701	4.08259649	3.62913871
5		1.01865378	0.98563808	4.20984983	2.29775512
6		1.06805519	0.91387809	4.88589107	4.23217347
7		1.24429125	1.28410857	2.89185292	1.91588633
8		1.24605939	1.07335466	2.26691589	1.57764045
9		1.27173023	0.91793551	3.31070312	2.25271365
10		1.56169171	1.40917183	2.6331897	2.01058141
Mean		1.56169171	1.40917183	2.58324967	1.90658459
STD		1.33201405	1.1976439	3.35724435	2.43664351

	Patient 1 Rest Position (RP) P3			Patient 1 Maximum Voluntary Clenching (MCV) P3	
		Masseter sEMG L integ	Masseter sEMG R integ	Masseter sEMG L integ	Masseter sEMG R integ
		Mean	Mean	Mean	Mean
		µV.s	µV.s	µV.s	µV.s
P3					
1		1.000061175	1.502160582	4.76507049	6.76342649
2		0.990343113	1.443624483	4.28793648	5.61273966
3		1.221609365	1.707670287	5.78250706	7.55704588
4		1.353307469	2.380337865	5.97963664	7.716478
5		1.509933956	1.923890586	4.6020389	5.98279348
6		1.061806993	1.673339052	4.46611571	7.4707722
7		0.994609536	1.876166948	5.27132767	7.77599025
8		1.028513525	1.387057324	5.15757438	7.80655022
9		1.05745255	2.080892298	5.256288	7.48041559
10		1.000061175	1.502160582	5.23299148	7.93304334
Mean		1.135293076	1.775015492	5.11515737	7.25953651
STD		0.175527082	0.305873253	0.53970271	0.79946426
	Patient 1 Rest Position (RP) P4			Patient 1 Maximum Voluntary Clenching (MCV) P4	
P4					
1		0.926364594	1.299824249	4.18165209	6.9410019
2		1.040923949	1.40141972	3.92584618	7.95550814
3		1.010421237	1.470284803	4.65361514	9.32232198
4		0.930978491	1.157097061	4.72007977	9.17449114
5		1.126372853	1.426190825	4.34408265	7.5699242
6		1.073095275	1.642914294	3.85719647	7.33084155
7		1.002891777	1.276275773	4.18828945	7.98905135
8		1.150465696	1.560245183	4.47994925	7.35653603
9		0.983464626	1.036064946	4.00599011	6.31479759
10		0.930102754	1.03218325	3.96527232	6.12559094
Mean		1.027635184	1.333630651	4.23781348	7.6821181
STD		0.073631484	0.208890507	0.30696742	1.03390977

	Patient 2 Rest Position (RP) P1			Patient 2 Maximum Voluntary Clenching (MCV) P1	
		Masseter sEMG L integ	Masseter sEMG R integ	Masseter sEMG L integ	Masseter sEMG R integ
		Mean	Mean	Mean	Mean
		µV.s	µV.s	µV.s	µV.s
P1					
1		1.655556347	3.09053391	7.054863034	11.63602915
2		1.05942593	1.87572206	6.415888855	11.29351453
3		1.332092434	2.38157628	4.922823129	7.649797126
4		0.911586399	1.51666367	4.855103264	4.51347019
5		0.999709811	1.88341377	4.94184003	3.913782559
6		3.793892817	3.34186373	5.149690009	3.992987323
7		1.655556347	3.09053391	5.281091053	4.133387098
8		1.05942593	1.87572206	7.26151305	12.00224637
9		1.332092434	2.38157628	6.358320383	11.31978888
10		0.911586399	1.51666367	5.48305003	8.426166549
Mean		1.471092485	2.29542693	5.772418284	7.888116978
STD		0.817883347	0.64103566	0.870946	3.333855291
	Patient 2 Rest Position (RP) P2			Patient 2 Maximum Voluntary Clenching (MCV) P2	
P2					
1		0.927518169	1.06830883	2.983802324	7.428494754
2		0.934956497	1.00106486	2.000205649	5.904673274
3		0.974260137	1.5909819	2.198101986	3.294510239
4		1.021133887	1.53990116	3.056892351	3.907643868
5		0.891252714	1.65510838	2.03444226	3.861304286
6		0.797590633	1.14113983	1.375950607	2.914793936
7		0.760874827	1.06339637	1.491948813	2.755179528
8		0.824252965	0.94557942	1.378481528	2.567348942
9		0.908690531	1.56996062	2.756146769	3.495964319
10		1.058550409	1.63445779	3.984501895	4.446658134
Mean		0.909908077	1.32098991	2.25296354	3.683119614
STD		0.090585248	0.28258358	0.824983619	0.970843754

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	Patient 2 Rest Position (RP) P3			Patient 2 Maximum Voluntary Clenching (MCV) P3	
		Masseter sEMG L integ	Masseter sEMG R integ	Masseter sEMG L integ	Masseter sEMG R integ
		Mean	Mean	Mean	Mean
		µV.s	µV.s	µV.s	µV.s
P3					
1		4.742830697	4.33593914	5.863730542	7.248143872
2		1.007361143	1.12960987	5.597013868	5.402592106
3		1.350719614	1.25500551	5.036276485	5.013807494
4		1.108430009	1.23444048	5.41136604	9.039436355
5		1.127391232	1.10233692	5.586690192	7.681394009
6		0.873966592	0.97308615	4.839573569	4.913712237
7		0.81983485	0.90284119	4.566140299	6.581713353
8		0.860206147	0.9015581	5.074027841	7.608567016
9		1.069627267	1.20288819	5.633781585	7.977281491
10		0.791565982	0.8477784	4.227835098	4.911322049
Mean		1.001011426	1.06106054	5.108078331	6.569980679
STD		0.17230907	0.1482851	0.469445222	1.478422222
	Patient 2 Rest Position (RP) P4			Patient 2 Maximum Voluntary Clenching (MCV) P4	
P4					
1		1.80004804	1.96228166	6.323769889	5.18243174
2		0.889016431	1.18879016	5.6918096	5.461974765
3		1.230552121	1.56928094	5.562192984	4.666802586
4		1.298625048	1.65921953	5.454927752	5.323883151
5		1.140831723	2.04591605	5.102210093	5.92897427
6		1.160359381	2.00254127	4.908538827	4.444990086
7		1.201653364	1.83675915	4.667822924	3.833622479
8		0.891185795	1.54787409	4.39657894	3.809354697
9		0.803481027	1.0758801	5.181768966	4.53735088
10		0.98150258	1.21761618	5.876006705	4.710761451
Mean		1.066356385	1.57154194	5.204650755	4.746412707
STD		0.167343692	0.33446924	0.461685522	0.674733525

	Patient 3 Rest Position (RP) P1			Patient 3 Maximum Voluntary Clenching (MCV) P1	
		Masseter sEMG L integ	Masseter sEMG R integ	Masseter sEMG L integ	Masseter sEMG R integ
		Mean	Mean	Mean	Mean
		µV.s	µV.s	µV.s	µV.s
P1					
1		1.1359412	1.54126111	8.02457368	9.00311582
2		1.6543441	1.95638297	9.64353352	9.185671
3		1.24621266	1.88676711	8.48986532	9.81031033
4		1.42747683	2.05052953	8.5336848	9.34337194
5		1.90731843	4.42078973	8.24497711	8.86117413
6		1.65577335	2.56232078	9.65247224	10.8485357
7		1.50232088	2.05433167	8.44734128	9.10138059
8		1.70418751	2.86271972	8.95609671	9.14907809
9		1.51650819	1.81825345	7.21083103	8.47266702
10		1.51650819	1.81825345	9.19617389	8.86453584
Mean		1.52665913	2.29716095	8.63995496	9.26398404
STD		0.21244718	0.79588949	0.71342157	0.62268808
	Patient 3 Rest Position (RP) P2			Patient 3 Maximum Voluntary Clenching (MCV) P2	
P2					
1		1.16949002	1.15619416	3.08846847	2.24839051
2		0.83665575	1.21377783	3.66593401	3.36810843
3		1.07037493	1.72282891	4.55687603	4.45677756
4		1.2705123	2.17243919	6.36092192	6.33359526
5		1.01440495	1.58674255	4.92069108	5.45250907
6		1.2496389	3.45921146	4.95617198	7.02802111
7		0.87220317	1.69409027	6.14663629	6.39544943
8		0.92005469	1.4977364	5.20354443	6.96420962
9		0.94520863	2.0264052	4.86313002	8.34048796
10		1.15254249	2.6377424	3.07730197	6.36792814
Mean		1.05010858	1.91671684	4.8612453	6.07856517
STD		0.14830736	0.66488298	0.98515879	1.3912437

	Patient 3 Rest Position (RP) P3			Patient 3 Maximum Voluntary Clenching (MCV) P3	
		Masseter sEMG L integ	Masseter sEMG R integ	Masseter sEMG L integ	Masseter sEMG R integ
		Mean	Mean	Mean	Mean
		µV.s	µV.s	µV.s	µV.s
P3					
1		2.78003235	2.60978147	6.12255237	5.49426385
2		1.51556571	1.97827605	6.31373925	6.33916091
3		1.41067264	2.17587611	8.73746253	7.09590745
4		1.70078885	1.94481044	7.87507203	6.54727996
5		1.87879224	1.90356034	8.73249836	6.86437675
6		2.58632776	3.43340541	7.28473147	6.55426232
7		1.84481708	2.1894397	8.27752804	6.87791995
8		1.36921198	1.65855643	7.74703295	6.7116728
9		1.28416352	1.43949601	6.54431235	5.35002122
10		1.41766314	1.65934055	6.72128877	5.36873187
Mean		1.66755588	2.042529	7.58151842	6.41214814
STD		0.38134611	0.54414134	0.86731372	0.59993622
	Patient 3 Rest Position (RP) P4			Patient 3 Maximum Voluntary Clenching (MCV) P4	
P4					
1		1.08915494	1.4503849	12.5283597	7.34702301
2		2.16754792	2.08563846	18.0427687	9.95218459
3		3.57275525	2.38343662	19.1547062	11.1959201
4		2.08832683	2.19517287	15.3220369	8.20078002
5		1.39260475	1.54011142	11.5433937	6.39104357
6		1.33656009	2.30198659	11.1666041	6.74187211
7		1.3127507	2.29148794	10.9925252	6.44614265
8		1.20076005	1.78505969	10.3719669	6.56700727
9		0.96086179	1.41757053	9.57439997	5.84822076
10		1.76062547	1.9375087	9.73130394	7.00985736
Mean		1.75475476	1.99310809	12.8777451	7.59478093
STD		0.74724769	0.32812764	3.45456105	1.72683152

	Patient 4 Rest Position (RP) P1			Patient 4 Maximum Voluntary Clenching (MCV) P1	
		Masseter sEMG L integ	Masseter sEMG R integ	Masseter sEMG L integ	Masseter sEMG R integ
		Mean	Mean	Mean	Mean
		µV.s	µV.s	µV.s	µV.s
P1					
1		1.238863831	1.11935725	8.60959265	5.85380088
2		1.014537341	0.97367142	7.709159395	4.7015541
3		1.715874319	1.34630912	8.265421404	5.20556632
4		0.890828411	0.85861575	9.172800015	6.01923136
5		0.961667861	1.05285434	8.132505565	6.2072506
6		1.405315545	1.37079735	7.296995786	6.01622269
7		0.931943966	1.00153977	7.292155996	5.60549457
8		0.984139364	1.17326196	6.26463289	5.21969306
9		1.041296168	1.05171694	6.464049976	4.72298002
10		1.033579582	0.89201124	8.834436274	5.49800885
Mean		1.121804639	1.08401351	7.804174995	5.50498024
STD		0.246325847	0.16398741	0.927273783	0.50782769
	Patient 4 Rest Position (RP) P2			Patient 4 Maximum Voluntary Clenching (MCV) P2	
P2					
1		2.019520027	1.48167148	4.165830908	2.71068034
2		1.841408923	1.27928692	4.485349753	3.24422285
3		1.841408923	1.27928692	4.069322397	2.55005218
4		2.13139291	1.9367394	4.606330868	2.82132701
5		1.289684948	0.87882187	5.50108758	3.21456485
6		1.331542973	1.40533452	5.725601605	3.51106768
7		1.331542973	1.40533452	5.190075106	3.3770758
8		1.331542973	1.40533452	4.40843297	2.6636549
9		0.843967874	0.836073	4.574955994	2.88191301
10		0.853523777	0.66224812	4.431729871	3.17103115
Mean		1.48155363	1.25701312	4.776987349	3.04832327
STD		0.433122485	0.35404149	0.527641416	0.3124712

	Patient 4 Rest Position (RP) P3		Patient 4 Maximum Voluntary Clenching (MCV) P3	
	Masseter sEMG L integ	Masseter sEMG R integ	Masseter sEMG L integ	Masseter sEMG R integ
	Mean	Mean	Mean	Mean
	µV.s	µV.s	µV.s	µV.s
P3				
1	1.319816957	0.94612985	6.054358864	4.39489886
2	2.526749913	1.72219556	4.261615686	2.78909329
3	1.398649113	1.01395312	9.156160294	5.2843958
4	1.16636075	0.96263709	7.820454125	4.89702872
5	1.303533585	0.98344556	7.871798025	5.2697667
6	1.411806055	1.44703603	7.412953834	4.85998441
7	1.307763227	1.38982762	2.02524393	1.69965733
8	1.045264327	1.10659935	6.723129709	4.46391713
9	1.387903155	1.86734647	6.293581625	4.51173562
10	0.922615325	1.22658951	6.775157734	4.31220614
Mean	1.385627272	1.30218115	6.482232774	4.23197613
STD	0.433862234	0.31062894	2.019713221	1.13794816
	Patient 4 Rest Position (RP) P4		Patient 4 Maximum Voluntary Clenching (MCV) P4	
P4				
1	1.168528168	1.08890672	10.42714484	8.32359365
2	2.741085297	1.81920402	8.306648634	6.71669789
3	2.425506376	3.71996604	9.836603214	7.8488103
4	1.780443648	1.58887966	8.14352729	7.28311011
5	1.342804585	2.5932632	7.235828545	7.35988748
6	2.069325591	2.15514072	7.258210511	7.60213649
7	1.258474057	1.16623981	9.538659232	8.53314404
8	1.565896178	1.59101042	7.714090852	7.30428111
9	1.306091413	2.45583873	5.275176925	5.27632743
10	1.568712983	4.03739793	5.83702484	5.7736569
Mean	1.664656854	2.41346706	7.604890176	7.12266923
STD	0.382778785	0.95896433	1.492957029	1.00563524

	Patient 5 Rest Position (RP) P1			Patient 5 Maximum Voluntary Clenching (MCV) P1	
		Masseter sEMG L integ	Masseter sEMG R integ	Masseter sEMG L integ	Masseter sEMG R integ
		Mean	Mean	Mean	Mean
		µV.s	µV.s	µV.s	µV.s
P1					
1		1.2477675	1.62402867	4.09342846	6.12711116
2		1.44819564	2.84968879	4.81797118	8.21906032
3		2.23043539	4.56306225	4.49809731	7.13268572
4		2.31902001	4.72260394	5.10048664	7.56899514
5		1.50780484	3.84341114	4.61272731	7.18393225
6		1.58159264	3.81334106	2.54573713	4.52545186
7		1.97152037	3.35839826	4.43665914	7.44741859
8		1.38953745	3.00325115	3.03192072	6.03809306
9		1.29489351	2.39971366	3.17245805	4.99592096
10		1.58567614	2.60384783	3.97499714	6.32484342
Mean		1.65764435	3.27813468	4.02844831	6.55635125
STD		0.36232277	0.92582048	0.80202863	1.11247467
	Patient 5 Rest Position (RP) P2			Patient 5 Maximum Voluntary Clenching (MCV) P2	
P2					
1		1.53243029	2.52779253	3.0681495	5.00071534
2		1.3631891	2.29270404	2.6586769	4.52441964
3		0.99946828	1.45181159	2.68901814	5.4793069
4		1.47355646	1.8126646	3.30938589	7.09620781
5		1.53381793	2.04750552	2.53005062	4.7755714
6		1.52142427	3.57748945	3.41926449	6.29901986
7		0.92679807	1.2390947	2.61469516	4.69756462
8		1.11587145	1.7193303	2.38199212	3.84080168
9		1.19138606	1.76623434	2.1181101	3.0572068
10		1.16588021	2.00520102	2.14387151	3.39344394
Mean		1.28238221	2.04398281	2.65167388	4.79594918
STD		0.21954991	0.62318989	0.42877934	1.24738682

	Patient 5 Rest Position (RP) P3			Patient 5 Maximum Voluntary Clenching (MCV) P3	
		Masseter sEMG L integ	Masseter sEMG R integ	Masseter sEMG L integ	Masseter sEMG R integ
		Mean	Mean	Mean	Mean
		µV.s	µV.s	µV.s	µV.s
P3					
1		0.9407675	0.90885422	6.99869157	6.83714792
2		0.98504058	1.38406343	8.35688127	7.471591
3		1.21225971	1.47564483	6.33108576	6.92116528
4		2.30306068	2.63488505	5.49175637	5.27269752
5		1.29981876	1.8238588	6.00047957	6.0551032
6		1.19487417	1.86628905	4.8224538	5.36613528
7		1.25239191	1.82421637	5.99079292	6.29838408
8		1.78407813	2.64417364	6.251023	6.28636899
9		1.28146213	1.75321895	5.84887512	5.50706651
10		1.07259549	1.3100506	4.98643147	4.81213981
Mean		1.37617573	1.85737786	6.00886437	5.9989613
STD		0.388803	0.46019688	0.96735516	0.80089818
	Patient 5 Rest Position (RP) P4			Patient 5 Maximum Voluntary Clenching (MCV) P4	
P4					
1		0.90357231	0.93847589	6.49015885	10.7941553
2		1.53798198	2.01983925	7.53369065	11.6306951
3		1.68052756	2.54715752	6.23615153	9.28980028
4		1.21438198	1.9395721	6.69951213	8.8292591
5		1.42645166	2.23938172	5.37095139	7.31344218
6		1.68343548	2.4983116	5.57583002	7.93271319
7		1.37138526	2.04063738	4.69221785	5.93040193
8		1.38977749	2.65974217	4.47022228	6.68934165
9		1.25354461	2.10053223	6.00785172	8.48254193
10		1.57771133	3.40923846	4.98391558	6.54643584
Mean		1.45946637	2.3838236	5.50458156	7.62674201
STD		0.1617102	0.43667054	0.72802772	1.12134569

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	Patient 6 Rest Position (RP) P1			Patient 6 Maximum Voluntary Clenching (MCV) P1	
		Masseter sEMG L integ	Masseter sEMG R integ	Masseter sEMG L integ	Masseter sEMG R integ
		Mean	Mean	Mean	Mean
		µV.s	µV.s	µV.s	µV.s
P1					
1		1.85173472	2.01371615	4.96793592	6.32574724
2		1.86480529	1.69795832	4.28042212	4.21181222
3		1.74360993	1.78587573	4.26145415	5.21023892
4		1.56589923	1.56585376	4.43889343	4.68973449
5		1.82804905	2.20677585	4.08033452	4.16176655
6		2.09255325	2.14816852	3.5114793	3.24075073
7		1.6461806	1.78765546	4.22921594	3.85081607
8		1.35269036	1.31883162	3.81808314	2.84885403
9		1.33580198	0.87522042	4.51118073	3.44962713
10		1.12286435	1.1981297	5.05414001	3.61360876
Mean		1.64041888	1.65981855	4.31531393	4.16029561
STD		0.28183521	0.40625498	0.44559513	0.97671178
	Patient 6 Rest Position (RP) P2			Patient 6 Maximum Voluntary Clenching (MCV) P2	
P2					
1		1.76641936	1.90757052	3.44447967	3.21044569
2		1.54254956	1.41745827	4.72199784	3.52439665
3		1.31975619	0.88033067	3.80752744	2.93631974
4		1.14901481	1.21498065	2.65282608	2.27163073
5		1.12922179	1.20112178	3.47507736	3.00600309
6		0.93915764	1.01243478	3.76293551	3.36107152
7		1.31271855	1.33559066	3.63003986	3.02381229
8		1.15169831	1.28150792	3.11198621	2.64064354
9		1.61244297	1.77686477	3.30395215	2.78921693
10		1.38723504	1.16733023	3.58191208	2.75528182
Mean		1.33102142	1.31951902	3.56091717	2.92315292
STD		0.24014558	0.30025984	0.53276251	0.35290049

	Patient 6 Rest Position (RP) P3			Patient 6 Maximum Voluntary Clenching (MCV) P3	
		Masseter sEMG L integ	Masseter sEMG R integ	Masseter sEMG L integ	Masseter sEMG R integ
		Mean	Mean	Mean	Mean
		µV.s	µV.s	µV.s	µV.s
P3					
1		1.36090216	1.10782335	5.76190592	3.9759044
2		1.08613719	1.02139829	6.68609292	4.38006437
3		1.33726254	1.20507053	5.51464986	3.79181308
4		1.1668302	1.1034307	4.42722004	3.13034277
5		1.28821827	1.21354991	4.90564832	3.55391482
6		1.4492323	1.29445982	6.22841656	4.16235659
7		1.48647487	1.61868604	5.70087991	3.85637984
8		1.30339889	1.24876177	5.31789853	3.36007661
9		1.3817288	1.25957383	4.84202756	3.70264456
10		1.28159668	1.10123218	5.68413797	4.24270596
Mean		1.30898664	1.22957367	5.47855241	3.79781096
STD		0.11941755	0.16106058	0.66482585	0.39143291
	Patient 6 Rest Position (RP) P4			Patient 6 Maximum Voluntary Clenching (MCV) P4	
P4					
1		1.03752988	1.09012394	4.64765719	3.38420814
2		1.42458501	1.39294048	6.17168942	4.76019874
3		1.2865361	1.26439311	5.58320231	4.74151985
4		0.89681432	0.9469639	5.88748492	4.42800398
5		1.05767733	1.10758478	3.60586943	2.60712851
6		0.92369732	0.97591458	6.057193	3.93444335
7		1.247405	1.13357722	5.6860062	4.26186173
8		0.89984522	0.91161746	5.82046065	3.88374605
9		1.07988479	1.01042397	5.45353531	3.76169895
10		0.83337276	0.97603839	4.52229084	3.03900026
Mean		1.07220198	1.07993932	5.32700533	3.83217534
STD		0.19454783	0.15205915	0.78351867	0.66280665

	Patient 7 Rest Position (RP) P1			Patient 7 Maximum Voluntary Clenching (MCV) P1	
		Masseter sEMG L integ	Masseter sEMG R integ	Masseter sEMG L integ	Masseter sEMG R integ
		Mean	Mean	Mean	Mean
		µV.s	µV.s	µV.s	µV.s
P1					
1		2.5256002	1.86015251	8.90468731	4.2345601
2		2.20226479	2.07173271	7.91510472	4.55187865
3		2.91279659	2.26617044	9.94954416	5.60302881
4		2.62190917	1.84711393	9.62023034	5.33459222
5		3.01922647	2.37445448	8.79244071	5.91763546
6		2.2363711	1.83229649	11.1751243	6.68025248
7		2.8049543	2.55712697	11.7645128	7.15809754
8		1.48013617	1.8138061	9.5397897	5.2297664
9		2.44156802	2.57721815	8.93440028	5.69371891
10		2.23243177	2.04003159	6.53432602	5.38166412
Mean		2.44772586	2.12401034	9.31301603	5.57851947
STD		0.42361083	0.28518778	1.42424062	0.83173633
	Patient 7 Rest Position (RP) P2			Patient 7 Maximum Voluntary Clenching (MCV) P2	
P2					
1		3.20203504	3.5127521	8.17263763	6.03213032
2		3.2795679	3.38784724	8.0106701	5.09096395
3		2.98852992	2.96256662	9.27432154	5.32584299
4		2.45878093	2.92159736	9.0017565	5.50607022
5		2.38556592	2.89933685	10.6544969	5.62383067
6		2.44730072	3.17725242	11.8184825	6.12607455
7		2.21240315	2.09420051	10.416502	5.18320176
8		3.01150136	3.2210116	8.50997584	5.43816204
9		3.31554294	3.59775407	8.45057254	6.29910505
10		1.90196338	1.65748203	9.20270193	5.80516247
Mean		2.72031912	2.94318008	9.48216443	5.59982374
STD		0.47312902	0.58814438	1.16583066	0.38746705

	Patient 7 Rest Position (RP) P3			Patient 7 Maximum Voluntary Clenching (MCV) P3	
		Masseter sEMG L integ	Masseter sEMG R integ	Masseter sEMG L integ	Masseter sEMG R integ
		Mean	Mean	Mean	Mean
		µV.s	µV.s	µV.s	µV.s
P3					
1		1.08440761	1.30928729	5.94368286	6.44613562
2		1.03325741	1.17318011	5.2185433	5.51950578
3		1.25954014	1.29148293	4.81591779	5.59477955
4		0.7614022	0.97712619	4.02578302	5.5300198
5		1.34501737	1.46575097	5.43964881	6.0041737
6		0.82892041	0.98336883	5.30937941	5.74604965
7		0.90626187	1.03498506	5.38098735	5.77238094
8		0.88167847	1.02004962	5.03312114	5.53672613
9		0.73965823	0.92670402	5.56753062	6.38362946
10		1.27814599	1.40645653	5.2221377	5.86811694
Mean		1.00376468	1.1421227	5.11256102	5.77282022
STD		0.22148578	0.18947085	0.43759539	0.26811478
	Patient 7 Rest Position (RP) P4			Patient 7 Maximum Voluntary Clenching (MCV) P4	
P4					
1		1.00513268	1.41756106	4.01913791	7.92972591
2		0.98118576	1.21420161	4.17216302	8.00969537
3		0.84449676	0.85675523	4.06484246	7.09794318
4		0.81120203	0.98906151	3.71789745	6.99433533
5		1.00574579	1.02368582	3.74427054	7.0798388
6		1.01127198	1.29702407	4.23053219	6.9932582
7		0.92299694	1.09718665	4.68223373	7.80045595
8		0.85658888	1.12783208	4.15306342	6.24631603
9		1.12814198	1.57518716	3.96261471	6.2914661
10		1.01838938	1.01767317	4.84026037	9.27169258
Mean		0.9533355	1.13317859	4.17446436	7.22191327
STD		0.0966072	0.1979381	0.37998897	0.90093406

Table 4.9.

	Patient 8 Rest Position (RP) P1			Patient 8 Maximum Voluntary Clenching (MCV) P1	
		Masseter sEMG L integ	Masseter sEMG R integ	Masseter sEMG L integ	Masseter sEMG R integ
		Mean	Mean	Mean	Mean
		µV.s	µV.s	µV.s	µV.s
P1					
1		1.32213634	1.42593387	3.19619899	4.13868033
2		1.14356372	1.31515003	3.35193522	3.9301188
3		1.18736252	1.23515984	2.77109715	3.54907804
4		1.31057045	1.02268175	4.05824746	5.44101119
5		1.40835728	1.14799081	4.66107612	7.02016421
6		1.10229754	1.20164549	3.1904463	3.86519606
7		1.29819068	1.18665444	2.98999774	3.70728191
8		0.99178631	1.00285849	2.85766336	2.97649429
9		1.37337037	1.25082961	3.26732934	3.91383706
10		1.12291488	1.29980942	2.05215458	2.09774762
Mean		1.22605501	1.20887137	3.23961462	4.06396095
STD		0.12870568	0.12267547	0.6742525	1.27129263
	Patient 8 Rest Position (RP) P2			Patient 8 Maximum Voluntary Clenching (MCV) P2	
P2					
1		0.94219338	0.85769211	2.61064851	1.85359553
2		1.34016262	1.49988305	2.18878178	2.09075024
3		0.97640604	0.97507117	2.77005731	2.57888241
4		1.07735201	1.13872267	2.70909625	2.65237784
5		1.17395944	1.27869027	2.76838716	2.7689012
6		1.41419512	1.18324305	2.17805437	2.1779329
7		1.95480598	1.51824683	2.56350398	2.34120211
8		1.88672646	1.17688512	2.16057123	1.97446697
9		1.38522362	1.18427114	2.7790305	2.33423625
10		1.03821366	1.40137226	3.69970748	3.50461218
Mean		1.31892383	1.22140777	2.64635445	2.49148468
STD		0.34030624	0.20148349	0.4512715	0.43594524

	Patient 8 Rest Position (RP) P3			Patient 8 Maximum Voluntary Clenching (MCV) P3	
		Masseter sEMG L integ	Masseter sEMG R integ	Masseter sEMG L integ	Masseter sEMG R integ
		Mean	Mean	Mean	Mean
		µV.s	µV.s	µV.s	µV.s
P3					
1		1.27541154	1.77637125	3.38787956	4.07730458
2		1.84735288	2.34657393	3.96110844	4.50211076
3		1.26973549	1.54333553	3.78325949	4.37152703
4		1.35374799	3.3391242	3.88754697	4.48135736
5		1.42605271	1.99073856	3.16783244	3.76482928
6		1.1214182	1.26403214	2.61827919	3.16663231
7		1.53485714	1.89702475	3.53555486	4.34831877
8		1.25007247	1.74896621	3.46396345	3.83260965
9		1.10679428	1.19379446	4.50395888	4.80261748
10		1.40665389	2.31322561	4.21807956	4.656951
Mean		1.36852056	1.95964615	3.68217592	4.21410596
STD		0.21480721	0.62099272	0.53315188	0.49263601
	Patient 8 Rest Position (RP) P4			Patient 8 Maximum Voluntary Clenching (MCV) P4	
P4					
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
Mean					
STD					

Patient

	Patient 9 Rest Position (RP) P1			Patient 9 Maximum Voluntary Clenching (MCV) P1	
		Masseter sEMG L integ	Masseter sEMG R integ	Masseter sEMG L integ	Masseter sEMG R integ
		Mean	Mean	Mean	Mean
		µV.s	µV.s	µV.s	µV.s
P1					
1		1.28825646	1.29892783	2.96273455	3.48870047
2		1.31288682	1.52876837	3.06629047	3.70956386
3		1.14881865	1.35202365	2.78940314	3.53008214
4		1.89637399	2.15006699	3.63181211	3.39258524
5		1.46749204	1.79273162	3.48338053	4.3594918
6		1.29613476	1.50953596	3.41326164	4.51106988
7		1.66901141	2.11286437	2.63009593	3.27084289
8		1.98152591	2.23551509	3.20324713	4.00181594
9		2.29864715	2.12543787	2.78579636	3.44207352
10		1.94372269	1.88364306	4.10686102	4.72419733
Mean		1.63028699	1.79895148	3.20728829	3.8430423
STD		0.36446088	0.33656267	0.43280957	0.49467591
	Patient 9 Rest Position (RP) P2			Patient 9 Maximum Voluntary Clenching (MCV) P2	
P2					
1		1.42387835	1.58008877	3.21129255	4.35462954
2		1.30826595	1.57100514	2.08798544	3.13583455
3		0.98145227	0.8441882	2.70134187	3.52776898
4		1.2311657	1.58208853	2.30676966	3.19603977
5		1.32116852	1.85867891	3.1600081	4.45423328
6		1.57942711	1.72565052	2.4912395	2.57847053
7		1.34623158	1.48449853	2.3873262	3.08765055
8		1.34470673	1.30428515	2.59766045	3.41347295
9		1.68710082	2.18178515	2.34462237	2.95338802
10		1.340909	2.04910433	2.51374218	2.25937068
Mean		1.3564306	1.61813732	2.51007731	3.17846992
STD		0.17999031	0.35960801	0.28459913	0.58410307

Table 4.22

	Patient 9 Rest Position (RP) P3			Patient 9 Maximum Voluntary Clenching (MCV) P3	
		Masseter sEMG L integ	Masseter sEMG R integ	Masseter sEMG L integ	Masseter sEMG R integ
		Mean	Mean	Mean	Mean
		µV.s	µV.s	µV.s	µV.s
P3					
1		1.32028231	0.83037991	6.31132149	7.82538008
2		0.73145889	0.81840969	4.81985302	4.68702349
3		0.82537942	0.96694612	5.63591335	5.69606503
4		0.85898568	0.89478481	5.46588517	9.165502
5		0.89733953	0.92105657	6.16730008	8.47550785
6		0.82864287	0.89486592	2.63592551	3.51918231
7		0.85388482	0.88705402	4.46695885	6.1886363
8		1.03513163	1.30450535	3.73337161	5.87011802
9		0.85591076	0.93896632	3.3987446	5.71060121
10		0.78828282	0.92871686	3.0641176	5.55108439
Mean		0.8527796	0.95058952	4.3764522	6.09596896
STD		0.07852763	0.13112217	1.16933782	1.64567182
	Patient 9 Rest Position (RP) P4			Patient 9 Maximum Voluntary Clenching (MCV) P4	
P4					
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
Mean					
STD					

	Patient 10 Rest Position (RP) P1			Patient 10 Maximum Voluntary Clenching (MCV) P1	
		Masseter sEMG L integ	Masseter sEMG R integ	Masseter sEMG L integ	Masseter sEMG R integ
		Mean	Mean	Mean	Mean
		µV.s	µV.s	µV.s	µV.s
P1					
1		1.61074347	1.48985509	5.35574272	9.52564461
2		1.50597665	1.64647712	4.7434334	8.02238396
3		1.4901252	1.65210006	5.37777528	8.27804602
4		1.66010228	1.4216004	5.61428808	7.58636403
5		1.6383791	1.15716053	5.43272392	7.8910746
6		1.74564094	1.74345564	5.83600603	7.72546743
7		1.41132749	2.16637456	5.1908584	7.96352685
8		1.83447056	1.44970258	4.07159143	7.04323939
9		1.68297185	1.67476633	3.85180305	6.63844086
10		1.56455482	1.7141038	4.10777604	8.05789847
Mean		1.61442923	1.61155961	4.95819983	7.87320862
STD		0.0020942	0.25023231	0.67778434	0.72642177
	Patient 10 Rest Position (RP) P2			Patient 10 Maximum Voluntary Clenching (MCV) P2	
P2					
1		2.78327764	2.31502956	6.60050502	6.02574909
2		3.05729602	2.211714	8.51031631	5.20810754
3		3.21629143	2.38435179	6.5499444	6.20603061
4		3.50402281	1.83669726	8.16736617	5.50184958
5		2.63215785	1.86291872	5.05234914	5.34805039
6		2.4450909	1.57577113	6.39114782	4.40533484
7		2.06811465	1.53666701	5.85375078	5.83352047
8		1.85634013	1.90633047	5.07946889	4.59593361
9		3.54404926	1.91381206	8.2141047	5.95730633
10		3.03933601	2.14358968	7.60046802	4.63042765
Mean		2.81459767	1.96868817	6.80194213	5.37123101
STD		0.54078362	0.2754842	1.20891109	0.61721301

Table 4.12

	Patient 11 Rest Position (RP) P1				Patient 11 Maximum Voluntary Clenching (MCV) P1	
		Masseter sEMG L integ	Masseter sEMG R integ		Masseter sEMG L integ	Masseter sEMG R integ
		Mean	Mean		Mean	Mean
		µV.s	µV.s		µV.s	µV.s
P1						
1		2.14696698	1.81017076		3.3513387	2.63486039
2		1.89775776	1.88640913		4.44846705	3.76093559
3		2.34930591	3.64935146		3.24450188	3.19402254
4		2.32372136	2.02102146		4.13733592	3.54097211
5		2.31046858	2.15596018		5.07419934	4.09835982
6		2.17224918	1.53320089		4.77964984	4.67029673
7		1.5832187	1.15181925		3.99852866	3.40340734
8		1.72532068	1.20060215		3.60990432	3.14750304
9		2.19050122	2.13221576		5.1100262	3.53522759
10		2.11917311	1.60391619		3.88917033	2.7618919
Mean		2.08186835	1.91446672		4.16431223	3.4747477
STD		0.0020942	0.66870148		0.6403057	0.5755637
	Patient 11 Rest Position (RP) P2				Patient 11 Maximum Voluntary Clenching (MCV) P2	
P2						
1		2.31502956	1.35755133		3.2379681	3.46688669
2		2.211714	1.62653606		3.08103733	3.08499889
3		2.38435179	2.11775577		3.85237731	4.08280895
4		1.83669726	1.12638678		3.45685684	3.6272137
5		1.86291872	1.23000139		3.18242741	2.93242979
6		1.57577113	1.08934829		2.81581667	2.61218161
7		1.53666701	0.96236369		3.00715923	2.97902293
8		1.90633047	2.1021184		3.6618027	4.64669631
9		1.91381206	1.33449536		3.17959195	3.51491881
10		2.14358968	1.56409343		2.08143735	1.25040937
Mean		1.96868817	1.45106505		3.15564749	3.2197567
STD		0.2754842	0.38186371		0.46232539	0.86610487

	Patient 12 Rest Position (RP) P1			Patient 12 Maximum Voluntary Clenching (MCV) P1	
		Masseter sEMG L integ	Masseter sEMG R integ	Masseter sEMG L integ	Masseter sEMG R integ
		Mean	Mean	Mean	Mean
		µV.s	µV.s	µV.s	µV.s
P1					
1		0.95596702	1.23866711	5.91178155	5.77397936
2		1.66611656	1.84295164	7.98386319	7.21197163
3		0.88794066	1.05804883	7.60987328	6.8603167
4		1.13739405	1.03405371	7.57975277	6.34856659
5		0.95138167	1.08561596	7.73204135	6.22970655
6		1.05600568	1.35296084	6.9807917	6.20712117
7		1.00836523	1.27702142	5.51367694	5.12638525
8		1.75167064	2.41700615	4.57852842	4.22286511
9		0.91003056	1.27702142	6.75451955	6.62631545
10		1.16657277	1.50365527	6.2902134	6.06153646
Mean		1.14914448	1.40870023	6.69350421	6.06687643
STD		0.0020942	0.40603795	1.05327395	0.82158461
	Patient 12 Rest Position (RP) P2			Patient 12 Maximum Voluntary Clenching (MCV) P2	
P2					
1		1.15060487	1.69496664	2.89528632	3.18750647
2		1.03006535	1.07880299	2.60584476	2.68141993
3		0.97063673	0.86513754	3.61254317	2.98270809
4		0.7299086	0.65618532	2.01970592	2.07136704
5		0.89733658	0.87379991	2.12032709	1.69631136
6		0.93727036	0.91933003	2.36359548	2.01276241
7		0.87421912	0.87655003	1.99226685	2.04640631
8		0.93214606	0.89878364	2.0513311	1.98185404
9		1.09787435	1.6565838	3.27889023	2.24575917
10		1.17572211	1.57292142	7.54268409	6.14889848
Mean		0.97957841	1.10930613	3.0482475	2.70549933
STD		0.12984003	0.36240401	1.59019883	1.23436821