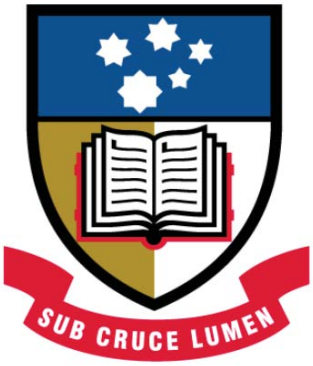
Analysis and Correlation Study of Human Masseter Muscle with EMG, Ultrasonography & 3D Imaging



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Doctor of Philosophy

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Abstract

Form and function are inextricably intertwined in orthodontics. Our understanding of the hard tissue relationship has been comprehensive, with extensive clinical trials both cross sectional and longitudinal over the past several decades. The majority of studies have used standardized cephalograms that reflect our current concepts. However, the same cannot be stated for soft tissues and, more specifically, the muscles that envelope the skeletal bases.

The aim of the current study was to objectively evaluate the masseter muscle – one of the key elevator muscles in the human masticatory system with innovative diagnostic tools like electromyography (EMG), ultrasonography (US) and 3-D imaging (Mona Lisa®). Standard lateral cephalometrics were used as the gold standard for measuring the vertical facial dimensions and correlating the findings to the above mentioned modalities. This extensive study comprised three major components and involved subjects from the same cohort.

Firstly, the masseter muscle spindle reflexes were studied in dynamic chewing and the responses recorded with EMG in 28 human subjects. These were then analysed and correlated to the vertical facial proportion from standardized lateral cephalograms. Although substantial work has been done to evaluate the various trigeminal reflexes[1-3], limited research has investigated the reflexes from the muscle spindles in different facial proportions[4]. This is primarily due to the inherent complexity of the neurophysiology compounded by noise within the experimental models. Most often the method used to elicit a muscle spindle reflex in the human jaw involves a brief mechanical depression of the mandible, either by use of a tendon

hammer or, if a more controlled stimulus is required, a computer-controlled stretching device[5-7]. In the current study, a sophisticated apparatus was utilized to deliver precise profile stimulus at predetermined intervals. Significant correlations were observed between the muscle spindle response and selected vertical proportions.

The second phase of study was to utilize US for measuring masseter muscle dimensions in the same cohort and once again correlate the various dimensions of the masseter muscle to the facial proportions generated by the lateral cephalometrics. US has been studied in dentistry for over four decades and it has been established as a safe, non-invasive, comfortable and cost-effective diagnostic implement. Also, US produces high resolution images of soft tissues more readily than MRI and CT scans[8]. Among the limitations for US there is the concern about reproducibility and standardization particularly between operators. Hence, it is advisable to have a single operator for data collection in order to preclude inter-examiner variability. Future use of US in dentistry will be favoured especially where periodic evaluation is needed and there are concerns about radiation.

Finally, for a more holistic assessment, 3D optical scanning was used in the same sample cohort to analyse and correlate masseter muscle dimensions to vertical and transverse facial proportions. Regression equations were generated, albeit from the convenience sample, to explore a mathematical model for deriving variables of interest rather than physically conducting the individual measurements, particularly if that required radiation. Current work shows strong correlations between lateral cephalometric and 3D imaging variables, but relatively weak associations with the ultrasonography. The findings from this study support the use of predictive equations from 3D imaging for lateral cephalometric variables but larger scale studies are required to confirm reproducibility. Moreover, curvilinear measurements from 3D

images were significantly different ($p < 0.0001$) to the linear and should be adopted for more meaningful representation of the soft tissues.

These findings are relevant to facial form and function assessment which is used in orthodontic diagnosis and treatment planning; in particular, orthodontic functional appliance therapy. Analyses of the face can be carried out with a myriad of cephalometric packages; however, the role of the elevator muscles is often overlooked and their contribution to changes and/or characteristics that could benefit the orthodontic treatment is not fully appreciated. Thus, the assessment not only of anatomical but also physiological variations in the masseter muscles is important in the management of different facial patterns. The above tools provide a means to evaluate muscle functions which would be of particular interest in growing children and where functional orthopaedic appliances utilize forces from the muscles of mastication. Furthermore, periodic evaluation of such cases is generally desirable and needs to be safe, radiation free and cost-effective.

DECLARATION

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution to *Shazia Naser-ud-Din* and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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*The following papers have been generated from this research and are submitted/ or to be submitted to the journals in parenthesis:

- Modulation of Masseteric Reflexes by Simulated Mastication (**accepted Journal of Dental Research**).
- Masseter length determines Muscle Spindle Reflex excitability during jaw closing movements (submitted American Journal of Orthodontics and Dentofacial Orthopedics).
- Study of function and form for human masseter muscle with ultrasonography and lateral cephalometrics (to be submitted Investigative Radiology).
- Analysis and correlations of human masseter muscle with 3D imaging, ultrasonography and lateral cephalometrics (to be submitted American Journal of Orthodontics and Dentofacial Orthopedics).

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Co-Author Contributions

Prof WJ Sampson

Professor Wayne Sampson is the principal supervisor and has assisted in conceptualization and realization of the project, supporting development of the research and managing funding. He has provided pivotal support with interdisciplinary liaison, vital feedback, essential corrections and comments throughout the research project.

Dr CW Dreyer

Dr Craig Dreyer has been the co-supervisor and provided assistance with proof reading and constructive criticism of the thesis, along with reading the drafts for the publications.

Prof KS Türker

Prof Kemal Türker is co-supervisor and instrumental in the EMG study with his custom-made device. Soon after the experiments concluded he left for Turkey but has continued his supervisory role and provided valuable feedback from across the globe and on his annual visits to Adelaide.

Dr P F Sowman

Dr Paul Sowman was a research associate with Prof Türker and has provided in depth analyses of the raw data for the study of muscle spindles. With his strong physiology background his contribution to papers on EMG have been indispensable.

Dr K Thoirs

Dr Kerry Thoirs provided expertise for the ultrasound investigations and has been immensely helpful with the information related to its application in orthodontics research. She helped with the ultrasound sections in the papers and her contributions are duly acknowledged.

Permission for papers to be included in Thesis

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Thesis Format

This work is in accordance with the guidelines for University of Adelaide 2009 thesis by publication. This thesis is a combination of the conventional narrative and submission by publication only. Hence, there are four chapters reflecting the publications along with comprehensive literature review, aims and objectives, materials and methods followed by general discussion. Two articles have already been submitted to peer reviewed journals of which one has been accepted for publication by the Journal of Dental Research.

Dedication

This work is dedicated to my Abbi Prof Dr Naser-ud-Din whose quest for academic excellence, brilliant mind, youngest PhD at University of Peshawar, Presidential Award for Scientific endeavours in Pakistan, art of teaching with humour and simplicity inspired myself to walk his path.

The 3D chemistry model, frequent visits to the Chemistry Dept. as a toddler and young child, visiting different continents of the world with him on his post-doctoral projects, intriguing story of the benzene ring discovery ignited my passion for academia.

I am very blessed to have got this rare opportunity to be able to complete my long felt desire of doctorate and am grateful for this extraordinary journey in life.

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