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

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10 REFERENCES

1. Nordstrom MA, Miles TS, Gooden BR, Butler SL, Ridding MC, Thompson PD. Motor cortical control of human masticatory muscles. Prog Brain Res. 1999;123:203-14.

2. Miles TS, Nordstrom MA. Fatigue of jaw muscles and speech mechanisms. Adv Exp Med Biol. 1995;384:415-26.

3. Türker KS. Reflex control of human jaw muscles. Crit Rev Oral Biol Med. 2002;13(1):85-104.

4. Gardner N, Newton JP, Mason AG, Cadden SW. Differences between inhibitory jaw reflexes evoked by stimulation of tooth pulp and across the adjacent alveolar process in man. Arch Oral Biol. 2008 Jun;53(6):575-82.

5. Miles TS, Poliakov AV, Flavel SC. An apparatus for controlled stretch of human jaw-closing muscles. J Neurosci Methods. 1993 Mar;46(3):197-202.

6. Ottenhoff FA, van der Bilt A, van der Glas HW, Bosman F. A computer-controlled experimental set-up enabling the quantification of motor performance in man, applied to mastication. J Oral Rehabil. 1994 Jul;21(4):397-410.

7. Türker KS, Brinkworth RS, Abolfathi P, Linke IR, Nazeran H. A device for investigating neuromuscular control in the human masticatory system. J Neurosci Methods. 2004 Jul 30;136(2):141-9.

8. Kubo K, Kawata T, Ogawa T, Watanabe M, Sasaki K. Outer shape changes of human masseter with contraction by ultrasound morphometry. Arch Oral Biol. 2006 Feb;51(2):146-53.

9. Miles T, Nauntofte B, Svensson P. Clinical oral physiology Copenhagen ; London Quintessence; 2004.

10. Muller E, Riedrich P. [Electromyographic studies of the oral region before and after treatment with the function regulator]. Stomatol DDR. 1979 Feb;29(2):128-33.

11. Muller F, Heath MR, Kazazoglu E, Hector MP. Contribution of periodontal receptors and food qualities to masseter muscle inhibition in man. J Oral Rehabil. 1993 May;20(3):281-90.

12. Van Eijden TM, Korfage JA, Brugman P. Architecture of the human jaw-closing and jaw-opening muscles. Anat Rec. 1997 Jul;248(3):464-74.

13. Loucks TM, De Nil LF. The effects of masseter tendon vibration on nonspeech oral movements and vowel gestures. J Speech Lang Hear Res. 2001 Apr;44(2):306-16.

14. Ariji Y, Kawamata A, Yoshida K, Sakuma S, Nawa H, Fujishita M, et al. Three-dimensional morphology of the masseter muscle in patients with mandibular prognathism. Dentomaxillofac Radiol. 2000 Mar;29(2):113-8.

15. Auluck A, Mudera V, Hunt NP, Lewis MP. A three-dimensional in vitro model system to study the adaptation of craniofacial skeletal muscle following mechanostimulation. Eur J Oral Sci. 2005 Jun;113(3):218-24.

16. Bakke M, Tuxen A, Vilmann P, Jensen BR, Vilmann A, Toft M. Ultrasound image of human masseter muscle related to bite force, electromyography, facial morphology, and occlusal factors. Scand J Dent Res. 1992 Jun;100(3):164-71.

17. Close PJ, Stokes MJ, L'Estrange PR, Rowell J. Ultrasonography of masseter muscle size in normal young adults. J Oral Rehabil. 1995 Feb;22(2):129-34.

18. Emshoff R, Bertram S, Brandlmaier I, Scheiderbauer G, Rudisch A, Bodner G. Ultrasonographic assessment of local cross-sectional dimensions of masseter muscle sites: a reproducible technique? J Oral Rehabil. 2002 Nov;29(11):1059-62.

19. Farella M, Bakke M, Michelotti A, Rapuano A, Martina R. Masseter thickness, endurance and exercise-induced pain in subjects with different vertical craniofacial morphology. Eur J Oral Sci. 2003 Jun;111(3):183-8.

20. Farella M, Michelotti A, Carbone G, Gallo LM, Palla S, Martina R. Habitual daily masseter activity of subjects with different vertical craniofacial morphology. Eur J Oral Sci. 2005 Oct;113(5):380-5.

21. Goto TK, Langenbach GE, Hannam AG. Length changes in the human masseter muscle after jaw movement. Anat Rec. 2001 Mar 1;262(3):293-300.

22. Kiliaridis S, Georgiakaki I, Katsaros C. Masseter muscle thickness and maxillary dental arch width. Eur J Orthod. 2003 Jun;25(3):259-63.

23. Kiliaridis S, Mahboubi PH, Raadsheer MC, Katsaros C. Ultrasonographic thickness of the masseter muscle in growing individuals with unilateral crossbite. Angle Orthod. 2007 Jul;77(4):607-11.

24. Konno M, Sato K, Mito T, Mitani H. Relationship between the direction of mandibular growth and masseter muscle conduction velocity. Am J Orthod Dentofacial Orthop. 2005 Jul;128(1):35-43; discussion -4.

25. Kosy E. Reflex Control of Human Masseter Muscle by Axial Stimulation of Periodontal Mechanoreceptors during Orthodontic Tooth Movement [Dissertation]. Adelaide: The University of Adelaide; 2003.

26. Orchardson R, Sime G. Masseter muscle excitation evoked by mechanical stimulation of upper incisor teeth in relaxed human subjects. Arch Oral Biol. 1981;26(6):491-4.

27. Raadsheer MC, Van Eijden TM, Van Spronsen PH, Van Ginkel FC, Kiliaridis S, Prahl-Andersen B. A comparison of human masseter muscle thickness measured by ultrasonography and magnetic resonance imaging. Arch Oral Biol. 1994 Dec;39(12):1079-84.

28. Van Eijden TM, Blanksma NG, Brugman P. Amplitude and timing of EMG activity in the human masseter muscle during selected motor tasks. J Dent Res. 1993 Mar;72(3):599-606.

29. Yoshimi H, Sasaguri K, Tamaki K, Sato S. Identification of the occurrence and pattern of masseter muscle activities during sleep using EMG and accelerometer systems. Head Face Med. 2009;5:7.

30. Hannam AG, McMillan AS. Internal organization in the human jaw muscles. Crit Rev Oral Biol Med. 1994;5(1):55-89.

31. Gaudy JF, Zouaoui A, Bravetti P, Charrier JL, Guettaf A. Functional organization of the human masseter muscle. Surg Radiol Anat. 2000;22(3-4):181-90.

32. Gans C, Gaunt AS. Muscle architecture in relation to function. J Biomech. 1991;24 Suppl 1:53-65.

33. Lam EW, Hannam AG, Christiansen EL. Estimation of tendon-plane orientation within human masseter muscle from reconstructed magnetic resonance images. Arch Oral Biol. 1991;36(11):845-53.

34. Otten E. Concepts and models of functional architecture in skeletal muscle. Exerc Sport Sci Rev. 1988;16:89-137.

35. Zajac FE. Muscle and tendon: properties, models, scaling, and application to biomechanics and motor control. Crit Rev Biomed Eng. 1989;17(4):359-411.

36. Last RJ. Last's Anatomy: regional and applied. 10th ed. Sydney: Churchill Livingstone; 1999.

37. Scott J H DAD. Anatomy for students of Dentistry. 3rd Edn ed. Edinburgh: Churchill Livingstone; 1972.

38. Limwongse V, DeSantis M. Cell body locations and axonal pathways of neurons innervating muscles of mastication in the rat. Am J Anat. 1977 Aug;149(4):477-88.

39. Cruccu G, Berardelli A, Inghilleri M, Manfredi M. Functional organization of the trigeminal motor system in man. A neurophysiological study. Brain. 1989 Oct;112 (Pt 5):1333-50.

40. Dellow PG, Lund JP. Evidence for central timing of rhythmical mastication. J Physiol. 1971 May;215(1):1-13.

41. Lund JP. Mastication and its control by the brain stem. Crit Rev Oral Biol Med. 1991;2(1):33-64.

42. Lavigne G, Kim JS, Valiquette C, Lund JP. Evidence that periodontal pressoreceptors provide positive feedback to jaw closing muscles during mastication. J Neurophysiol. 1987 Aug;58(2):342-58.

43. Komuro A, Morimoto T, Iwata K, Inoue T, Masuda Y, Kato T, et al. Putative feed-forward control of jaw-closing muscle activity during rhythmic jaw movements in the anesthetized rabbit. J Neurophysiol. 2001 Dec;86(6):2834-44.

44. Trulsson M, Johansson RS, Olsson KA. Directional sensitivity of human periodontal mechanoreceptive afferents to forces applied to the teeth. J Physiol. 1992 Feb;447:373-89.

45. Trulsson M. Multiple-tooth receptive fields of single human periodontal mechanoreceptive afferents. J Neurophysiol. 1993 Feb;69(2):474-81.

46. Trulsson M. Sensory-motor function of human periodontal mechanoreceptors. J Oral Rehabil. 2006 Apr;33(4):262-73.

47. Flavel SC, Nordstrom MA, Miles TS. A simple and inexpensive system for monitoring jaw movements in ambulatory humans. J Biomech. 2002 May;35(5):573-7.

48. Miles TS, Flavel SC, Nordstrom MA. Stretch reflexes in the human masticatory muscles: a brief review and a new functional role. Hum Mov Sci. 2004 Oct;23(3-4):337-49.

49. Tippett HL, Dodgson LK, Hunt NP, Lewis MP. Indices of extracellular matrix turnover in human masseter muscles as markers of craniofacial form--a preliminary study. Eur J Orthod. 2008 Apr;30(2):217-25.

50. Suchak A, Hunt NP, Shah R, Sinanan AC, Lloyd T, Lewis MP. Myosin proteins identified from masseter muscle using quantitative reverse transcriptase-polymerase chain reaction--a pilot study of the relevance to orthodontics. Eur J Orthod. 2009 Apr;31(2):196-201.

51. Hartgraves SL, Kelly PH. Role of mesencephalic glycine in locomotor activity. Neurosci Lett. 1985 Dec 4;62(2):175-80.

52. Rowlerson A, Mascarello F, Barker D, Saed H. Muscle-spindle distribution in relation to the fibre-type composition of masseter in mammals. J Anat. 1988 Dec;161:37-60.

53. Eriksson PO, Thornell LE. Relation to extrafusal fibre-type composition in muscle-spindle structure and location in the human masseter muscle. Arch Oral Biol. 1987;32(7):483-91.

54. Lavelle C. Applied Oral Physiology. second ed. Kent, England: Butterworths & Co Ltd; 1998.

55. Lennartsson B. Muscle spindles in the human anterior digastric muscle. Acta Odontol Scand. 1979;37(6):329-33.

56. Kubota K, Masegi T. Muscle spindle supply to the human jaw muscle. J Dent Res. 1977 Aug;56(8):901-9.

57. Sherwood L. Human Physiology from cells to systems. 6th ed. Virginia Thomson Brooks/ Cole; 2007.

58. Thexton AJ. Mastication and swallowing: an overview. Br Dent J. 1992 Oct 10;173(6):197-206.

59. Scutter SD, Türker KS. The role of the muscle spindles in human masseter. Hum Mov Sci. 2001 Nov;20(4-5):489-97.

60. Eriksson PO, Stalberg E, Antoni L. Flexibility in motor-unit firing pattern in the human temporal and masseter muscles related to type of activation and location. Arch Oral Biol. 1984;29(9):707-12.

61. Yemm R. The orderly recruitment of motor units of the masseter and temporal muscles during voluntary isometric contraction in man. J Physiol. 1977 Feb;265(1):163-74.

62. Goldberg LJ, Derfler B. Relationship among recruitment order, spike amplitude, and twitch tension of single motor units in human masseter muscle. J Neurophysiol. 1977 Jul;40(4):879-90.

63. Lund JP, Lamarre Y, Lavigne G, Duquet G. Human jaw reflexes. Adv Neurol. 1983;39:739-55.

64. Miles TS. Postural control of the human mandible. Arch Oral Biol. 2007 Apr;52(4):347-52.

65. Miles TS, Flavel SC, Nordstrom MA. Control of human mandibular posture during locomotion. J Physiol. 2004 Jan 1;554(Pt 1):216-26.

66. Morimoto T, Inoue T, Masuda Y, Nagashima T. Sensory components facilitating jaw-closing muscle activities in the rabbit. Exp Brain Res. 1989;76(2):424-40.

67. Goldberg LJ. Masseter muscle excitation induced by stimulation of periodontal and gingival receptors in man. Brain Res. 1971 Sep 24;32(2):369-81.

68. Ahlgren J. The silent period in the emg of the jaw muscles during mastication and its relationship to tooth contact. Acta Odontol Scand. 1969 Jun;27(3):219-27.

69. Murray GM, Klineberg IJ. Electromyographic recordings of human jaw-jerk reflex characteristics evoked under standardized conditions. Arch Oral Biol. 1984;29(7):537-49.

70. Türker KS, Jenkins M. Reflex responses induced by tooth unloading. J Neurophysiol. 2000 Aug;84(2):1088-92.

71. Ness AR. The mechanoreceptors of the rabbit mandibular incisor. J Physiol. 1954 Dec 10;126(3):475-93.

72. Trulsson M. Force encoding by human periodontal mechanoreceptors during mastication. Arch Oral Biol. 2007 Apr;52(4):357-60.

73. Trulsson M, Gunne HS. Food-holding and -biting behavior in human subjects lacking periodontal receptors. J Dent Res. 1998 Apr;77(4):574-82.

74. Türker KS, Johnsen SE, Sowman PF, Trulsson M. A study on synaptic coupling between single orofacial mechanoreceptors and human masseter muscle. Exp Brain Res. 2006 Apr;170(4):488-500.

75. Goto TK, Nishida S, Yahagi M, Langenbach GE, Nakamura Y, Tokumori K, et al. Size and orientation of masticatory muscles in patients with mandibular laterognathism. J Dent Res. 2006 Jun;85(6):552-6.

76. Ng HP, Foong KC, Ong SH, Liu J, Goh PS, Nowinski WL. A study on shape determinative slices for the masseter muscle. Conf Proc IEEE Eng Med Biol Soc. 2007;2007:5585-8.

77. Higashino R. [Relationship between jaws and the masseter muscle by superimposing MR images on the cephalogram]. Kokubyo Gakkai Zasshi. 2006 Mar;73(1):116-24.

78. Ueki K, Takazakura D, Marukawa K, Shimada M, Nakagawa K, Yamamoto E. Relationship between the morphologies of the masseter muscle and the ramus and occlusal force in patients with mandibular prognathism. J Oral Maxillofac Surg. 2006 Oct;64(10):1480-6.

79. Hultborn H. State-dependent modulation of sensory feedback. J Physiol. 2001 May 15;533(Pt 1):5-13.

80. Moller E. The chewing apparatus. An electromyographic study of the action of the muscles of mastication and its correlation to facial morphology. Acta Physiol Scand Suppl. 1966;280:1-229.

81. Perry HT, Harris SC. Role of the neuromuscular system in functional activity of the mandible. J Am Dent Assoc. 1954 Jun;48(6):665-73.

82. Ahlgren J. An intercutaneous needle electrode for kinesiologic EMG studies. Acta Odontol Scand. 1967 Jun;25(1):15-9.

83. Hück NL, Abbink JH, Hoogenkamp E, van der Bilt A, van der Glas HW. Exteroceptive reflexes in jaw-closing muscle EMG during rhythmic jaw closing and clenching in man. Exp Brain Res. 2005 Apr;162(2):230-8.

84. van der Glas HW, van der Bilt A, Abbink JH, Mason AG, Cadden SW. Functional roles of oral reflexes in chewing and biting: phase-, task- and site-dependent reflex sensitivity. Arch Oral Biol. 2007 Apr;52(4):365-9.

85. Yang J, Türker KS. Jaw reflexes evoked by mechanical stimulation of teeth in humans. J Neurophysiol. 1999 May;81(5):2156-63.

86. Sowman PF. The contribution of periodontal mechanoreceptors to physiological tremor in the human jaw [electronic resource] Adelaide: The University of Adelaide; 2007.

87. Türker KS, Brodin P, Miles TS. Reflex responses of motor units in human masseter muscle to mechanical stimulation of a tooth. Exp Brain Res. 1994;100(2):307-15.

88. Türker KS, Powers RK. The effects of common input characteristics and discharge rate on synchronization in rat hypoglossal motoneurones. J Physiol. 2002 May 15;541(Pt 1):245-60.

89. Sowman PF, Brinkworth RS, Türker KS. Periodontal anaesthesia reduces common 8 Hz input to masseters during isometric biting. Exp Brain Res. 2006 Mar;169(3):326-37.

90. Sowman PF, Türker KS. Methods of time and frequency domain examination of physiological tremor in the human jaw. Hum Mov Sci. 2005 Oct-Dec;24(5-6):657-66.

91. Lobbezoo F, Sowman PF, Türker KS. Modulation of human exteroceptive jaw reflexes during simulated mastication. Clin Neurophysiol. 2009 Feb;120(2):398-406.

92. Fogle LL, Glaros AG. Contributions of facial morphology, age, and gender to EMG activity under biting and resting conditions: a canonical correlation analysis. J Dent Res. 1995 Aug;74(8):1496-500.

93. Ringqvist M. Isometric bite force and its relation to dimensions of the facial skeleton. Acta Odontol Scand. 1973;31(1):35-42.

94. Ingervall B, Thilander B. Relation between facial morphology and activity of the masticatory muscles. J Oral Rehabil. 1974 Apr;1(2):131-47.

95. Ueda HM, Miyamoto K, Saifuddin M, Ishizuka Y, Tanne K. Masticatory muscle activity in children and adults with different facial types. Am J Orthod Dentofacial Orthop. 2000 Jul;118(1):63-8.

96. Garcia-Morales P, Buschang PH, Throckmorton GS, English JD. Maximum bite force, muscle efficiency and mechanical advantage in children with vertical growth patterns. Eur J Orthod. 2003 Jun;25(3):265-72.

97. Morimitsu T, Nokubi T, Nagashima T, Yoshida M, Ikebe K, Okuno Y. [Relationship between orofaciocranial morphologic factors and electromyographic activities of the masticatory muscles]. Nihon Ago Kansetsu Gakkai Zasshi. 1989;1(1):162-71.

98. Türker KS. Electromyography: some methodological problems and issues. Phys Ther. 1993 Oct;73(10):698-710.

99. Tuxen A, Bakke M, Pinholt EM. Comparative data from young men and women on masseter muscle fibres, function and facial morphology. Arch Oral Biol. 1999 Jun;44(6):509-18.

100. Soboleva U, Laurina L, Slaidina A. The masticatory system--an overview. Stomatologija. 2005;7(3):77-80.

101. Ueda HM, Ishizuka Y, Miyamoto K, Morimoto N, Tanne K. Relationship between masticatory muscle activity and vertical craniofacial morphology. Angle Orthod. 1998 Jun;68(3):233-8.

102. Brinkworth RS, Türker KS. A method for quantifying reflex responses from intramuscular and surface electromyogram. J Neurosci Methods. 2003 Jan 30;122(2):179-93.

103. Gibson C. 3D video software the next big thing? Adelaide; 2009 [updated 2009; cited 2009]; Available from: http://www.adelaide.edu.au/adelaidean/issues/33382/news33551.html.

104. van Spronsen PH, Weijs WA, Valk J, Prahl-Andersen B, van Ginkel FC. A comparison of jaw muscle cross-sections of long-face and normal adults. J Dent Res. 1992 Jun;71(6):1279-85.

105. Hussain AM, Packota G, Major PW, Flores-Mir C. Role of different imaging modalities in assessment of temporomandibular joint erosions and osteophytes: a systematic review. Dentomaxillofac Radiol. 2008 Feb;37(2):63-71.

106. Jank S, Rudisch A, Bodner G, Brandlmaier I, Gerhard S, Emshoff R. High-resolution ultrasonography of the TMJ: helpful diagnostic approach for patients with TMJ disorders ? J Craniomaxillofac Surg. 2001 Dec;29(6):366-71.

107. Weijs WA, Hillen B. Correlations between the cross-sectional area of the jaw muscles and craniofacial size and shape. Am J Phys Anthropol. 1986 Aug;70(4):423-31.

108. Hajeer MY, Millett DT, Ayoub AF, Siebert JP. Applications of 3D imaging in orthodontics: part II. J Orthod. 2004 Jun;31(2):154-62.

109. Kau CH, Richmond S. Three-dimensional analysis of facial morphology surface changes in untreated children from 12 to 14 years of age. Am J Orthod Dentofacial Orthop. 2008 Dec;134(6):751-60.

110. Kau CH, Richmond S, Incrapera A, English J, Xia JJ. Three-dimensional surface acquisition systems for the study of facial morphology and their application to maxillofacial surgery. Int J Med Robot. 2007 Jun;3(2):97-110.

111. Broadbent BH. A new x ray technique and its application to orthodontics. Angle Orthod. 1931(1):45-66.

112. Bjork A, Skieller V. Contrasting mandibular growth and facial development in long face syndrome, juvenile rheumatoid polyarthritis, and mandibulofacial dysostosis. J Craniofac Genet Dev Biol Suppl. 1985;1:127-38.

113. Skieller V, Bjork A, Linde-Hansen T. Prediction of mandibular growth rotation evaluated from a longitudinal implant sample. Am J Orthod. 1984 Nov;86(5):359-70.

114. Vig PS, Spalding PM, Lints RR. Sensitivity and specificity of diagnostic tests for impaired nasal respiration. Am J Orthod Dentofacial Orthop. 1991 Apr;99(4):354-60.

115. Trpkova B, Major P, Prasad N, Nebbe B. Cephalometric landmarks identification and reproducibility: a meta analysis. Am J Orthod Dentofacial Orthop. 1997 Aug;112(2):165-70.

116. Mankovich NJ, Samson D, Pratt W, Lew D, Beumer J, 3rd. Surgical planning using three-dimensional imaging and computer modeling. Otolaryngol Clin North Am. 1994 Oct;27(5):875-89.

117. Rueda S, Alcaniz M. An approach for the automatic cephalometric landmark detection using mathematical morphology and active appearance models. Med Image Comput Comput Assist Interv Int Conf Med Image Comput Comput Assist Interv. 2006;9(Pt 1):159-66.

118. Woodside DG, Linder-Aronson S. The channelization of upper and lower anterior face heights compared to population standard in males between ages 6 to 20 years. Eur J Orthod. 1979;1(1):25-40.

119. Chan HJ, Woods M, Stella D. Mandibular muscle morphology in children with different vertical facial patterns: A 3-dimensional computed tomography study. Am J Orthod Dentofacial Orthop. 2008 Jan;133(1):10 e1-3.

120. Kasai K, Richards LC, Kanazawa E, Ozaki T, Iwasawa T. Relationship between attachment of the superficial masseter muscle and craniofacial morphology in dentate and edentulous humans. J Dent Res. 1994 Jun;73(6):1142-9.

121. Bertram S, Rudisch A, Bodner G, Emshoff R. The short-term effect of stabilization-type splints on the local asymmetry of masseter muscle sites. J Oral Rehabil. 2001 Dec;28(12):1139-43.

122. Serra MD, Duarte Gaviao MB, dos Santos Uchoa MN. The use of ultrasound in the investigation of the muscles of mastication. Ultrasound Med Biol. 2008 Dec;34(12):1875-84.

123. Prabhu NT, Munshi AK. Measurement of masseter and temporalis muscle thickness using ultrasonographic technique. J Clin Pediatr Dent. 1994 Fall;19(1):41-4.

124. Kiliaridis S, Katsaros C, Karlsson S. Effect of masticatory muscle fatigue on cranio-vertical head posture and rest position of the mandible. Eur J Oral Sci. 1995 Jun;103(3):127-32.

125. Pereira LJ, Gaviao MB, Bonjardim LR, Castelo PM. Ultrasound and tomographic evaluation of temporomandibular joints in adolescents with and without signs and symptoms of temporomandibular disorders: a pilot study. Dentomaxillofac Radiol. 2007 Oct;36(7):402-8.

126. Farkas L. Anthropometry of the Head and Face. second edition ed. Farkas L, editor. New York Raven Press Ltd; 1994.

127. Raadsheer MC, Kiliaridis S, Van Eijden TM, Van Ginkel FC, Prahl-Andersen B. Masseter muscle thickness in growing individuals and its relation to facial morphology. Arch Oral Biol. 1996 Apr;41(4):323-32.

128. Kiliaridis S, Kalebo P. Masseter muscle thickness measured by ultrasonography and its relation to facial morphology. J Dent Res. 1991 Sep;70(9):1262-5.

129. Hatch JP, Shinkai RS, Sakai S, Rugh JD, Paunovich ED. Determinants of masticatory performance in dentate adults. Arch Oral Biol. 2001 Jul;46(7):641-8.

130. Satiroglu F, Arun T, Isik F. Comparative data on facial morphology and muscle thickness using ultrasonography. Eur J Orthod. 2005 Dec;27(6):562-7.

131. Burke PH, Beard FH. Stereophotogrammetry of the face. A preliminary investigation into the accuracy of a simplified system evolved for contour mapping by photography. Am J Orthod. 1967 Oct;53(10):769-82.

132. Da Silveira AC, Daw JL, Jr., Kusnoto B, Evans C, Cohen M. Craniofacial applications of three-dimensional laser surface scanning. J Craniofac Surg. 2003 Jul;14(4):449-56.

133. Ireland AJ, McNamara C, Clover MJ, House K, Wenger N, Barbour ME, et al. 3D surface imaging in dentistry - what we are looking at. Br Dent J. 2008 Oct 11;205(7):387-92.

134. Kopp S, Kuhmstedt P, Notni G, Geller R. G-scan--mobile multiview 3-D measuring system for the analysis of the face. Int J Comput Dent. 2003 Oct;6(4):321-31.

135. Mah J. 3D imaging in private practice. Am J Orthod Dentofacial Orthop. 2002 Jun;121(6):14A.

136. Arridge S, Moss JP, Linney AD, James DR. Three dimensional digitization of the face and skull. J Maxillofac Surg. 1985 Jun;13(3):136-43.

137. Moss JP, Linney AD, Grindrod SR, Arridge SR, Clifton JS. Three-dimensional visualization of the face and skull using computerized tomography and laser scanning techniques. Eur J Orthod. 1987 Nov;9(4):247-53.

138. Aung M, Sobel DF, Gallen CC, Hirschkoff EC. Potential contribution of bilateral magnetic source imaging to the evaluation of epilepsy surgery candidates. Neurosurgery. 1995 Dec;37(6):1113-20; discussion 20-1.

139. Moss JP. The use of three-dimensional imaging in orthodontics. Eur J Orthod. 2006 Oct;28(5):416-25.

140. Quintero JC, Trosien A, Hatcher D, Kapila S. Craniofacial imaging in orthodontics: historical perspective, current status, and future developments. Angle Orthod. 1999 Dec;69(6):491-506.

141. Lee JY, Han Q, Trotman CA. Three-dimensional facial imaging: accuracy and considerations for clinical applications in orthodontics. Angle Orthod. 2004 Oct;74(5):587-93.

142. Nguyen CX, Nissanov J, Ozturk C, Nuveen MJ, Tuncay OC. Three-dimensional imaging of the craniofacial complex. Clin Orthod Res. 2000 Feb;3(1):46-50.

143. Vallance S. (personal communications) Structured Light technique with Mona Lisa Imaging System. Adelaide; 2009.

144. Halazonetis DJ. Acquisition of 3-dimensional shapes from images. Am J Orthod Dentofacial Orthop. 2001 May;119(5):556-60.

145. Nute SJ, Moss JP. Three-dimensional facial growth studied by optical surface scanning. J Orthod. 2000 Mar;27(1):31-8.

146. Darwis WE, Messer LB, Thomas CD. Assessing growth and development of the facial profile. Pediatr Dent. 2003 Mar-Apr;25(2):103-8.

147. Bourne CO, Kerr WJ, Ayoub AF. Development of a three-dimensional imaging system for analysis of facial change. Clin Orthod Res. 2001 May;4(2):105-11.

148. Clark W. Twin Block Functional Therapy Applications in Dentofacial Orthopaedics. Second ed. London: Mosby; 2002.

149. Sharma AA, Lee RT. Prospective clinical trial comparing the effects of conventional Twin-block and mini-block appliances: Part 2. Soft tissue changes. Am J Orthod Dentofacial Orthop. 2005 Apr;127(4):473-82.

150. Ismail SF, Moss JP, Hennessy R. Three-dimensional assessment of the effects of extraction and nonextraction orthodontic treatment on the face. Am J Orthod Dentofacial Orthop. 2002 Mar;121(3):244-56.

151. Ayoub AF, Xiao Y, Khambay B, Siebert JP, Hadley D. Towards building a photo-realistic virtual human face for craniomaxillofacial diagnosis and treatment planning. Int J Oral Maxillofac Surg. 2007 May;36(5):423-8.

152. Baik HS, Lee HJ, Lee KJ. A proposal for soft tissue landmarks for craniofacial analysis using 3-dimensional laser scan imaging. World J Orthod. 2006 Spring;7(1):7-14.

153. Farkas LG. Accuracy of anthropometric measurements: past, present, and future. Cleft Palate Craniofac J. 1996 Jan;33(1):10-8; discussion 9-22.

154. Farkas LG, Kolar JC. Anthropometrics and art in the aesthetics of women's faces. Clin Plast Surg. 1987 Oct;14(4):599-616.

155. Nechala P, Mahoney J, Farkas LG. Maxillozygional anthropometric landmark: a new morphometric orientation point in the upper face. Ann Plast Surg. 1998 Oct;41(4):402-9.

156. Boom HP, van Spronsen PH, van Ginkel FC, van Schijndel RA, Castelijns JA, Tuinzing DB. A comparison of human jaw muscle cross-sectional area and volume in long- and short-face subjects, using MRI. Arch Oral Biol. 2008 Mar;53(3):273-81.

157. al-Khadra BH. Prediction of the size of unerupted canines and premolars in a Saudi Arab population. Am J Orthod Dentofacial Orthop. 1993 Oct;104(4):369-72.

158. Durgekar SG, Naik V. Evaluation of Moyers mixed dentition analysis in school children. Indian J Dent Res. 2009 Jan-Mar;20(1):26-30.

159. Sambataro S, Baccetti T, Franchi L, Antonini F. Early predictive variables for upper canine impaction as derived from posteroanterior cephalograms. Angle Orthod. 2005 Jan;75(1):28-34.

160. Kneafsey LC, Cunningham SJ, Petrie A, Hutton TJ. Prediction of soft-tissue changes after mandibular advancement surgery with an equation developed with multivariable regression. Am J Orthod Dentofacial Orthop. 2008 Nov;134(5):657-64.

161. Nourallah AW, Gesch D, Khordaji MN, Splieth C. New regression equations for predicting the size of unerupted canines and premolars in a contemporary population. Angle Orthod. 2002 Jun;72(3):216-21.

162. Brinkworth RS, Male C, Türker KS. Response of human jaw muscles to axial stimulation of a molar tooth. Exp Brain Res. 2004 Nov;159(2):214-24.

163. Marple-Horvat DE, Gilbey SL. A method for automatic identification of periods of muscular activity from EMG recordings. J Neurosci Methods. 1992 May;42(3):163-7.

164. Svensson P, McMillan AS, Graven-Nielsen T, Wang K, Arendt-Nielsen L. Modulation of an inhibitory reflex in single motor units in human masseter by tonic painful stimulation. Pain. 1999 Dec;83(3):441-6.

165. Kim YH. Overbite depth indicator with particular reference to anterior open-bite. Am J Orthod. 1974 Jun;65(6):586-611.

166. Barberie JE, Wong AD, Cooperberg PL, Carson BW. Extended field-of-view sonography in musculoskeletal disorders. AJR Am J Roentgenol. 1998 Sep;171(3):751-7.

167. Bland JM, Altman DG. Agreement between methods of measurement with multiple observations per individual. J Biopharm Stat. 2007;17(4):571-82.

168. Castroflorio T, Bracco P, Farina D. Surface electromyography in the assessment of jaw elevator muscles. J Oral Rehabil. 2008 Aug;35(8):638-45.

169. van der Bilt A, Ottenhoff FA, van der Glas HW, Bosman F, Abbink JH. Modulation of the mandibular stretch reflex sensitivity during various phases of rhythmic open-close movements in humans. J Dent Res. 1997 Apr;76(4):839-47.

170. Wang K, Svensson P, Arendt-Nielsen L. Modulation of exteroceptive suppression periods in human jaw-closing muscles by local and remote experimental muscle pain. Pain. 1999 Sep;82(3):253-62.

171. Türker KS. A method for standardization of silent period measurements in human masseter muscle. J Oral Rehabil. 1988 Jan;15(1):91-101.

172. Faist M, Blahak C, Duysens J, Berger W. Modulation of the biceps femoris tendon jerk reflex during human locomotion. Exp Brain Res. 1999 Apr;125(3):265-70.

173. Kearney RE, Lortie M, Stein RB. Modulation of stretch reflexes during imposed walking movements of the human ankle. J Neurophysiol. 1999 Jun;81(6):2893-902.

174. Brooke JD, Collins DF, Boucher S, McIlroy WE. Modulation of human short latency reflexes between standing and walking. Brain Res. 1991 May 10;548(1-2):172-8.

175. Capaday C, Stein RB. Amplitude modulation of the soleus H-reflex in the human during walking and standing. J Neurosci. 1986 May;6(5):1308-13.

176. Larsen B, Mrachacz-Kersting N, Lavoie BA, Voigt M. The amplitude modulation of the quadriceps H-reflex in relation to the knee joint action during walking. Exp Brain Res. 2006 Apr;170(4):555-66.

177. Desmedt JE, Godaux E. Vibration-induced discharge patterns of single motor units in the masseter muscle in man. J Physiol. 1975 Dec;253(2):429-42.

178. McKenna BI, Winzar CF, Kruger BJ. Comparison of two methods of lateral skull radiography for cephalometric analysis. Aust Dent J. 1972 Oct;17(5):340-2.

179. Tourne LP, Bevis RL, Cavanaugh G. A validity test of cephalometric variables as a measure of clinical applicability in anteroposterior profile assessment. Int J Adult Orthodon Orthognath Surg. 1993;8(2):95-112.

180. Ahn SJ, Kim JT, Nahm DS. Cephalometric markers to consider in the treatment of Class II Division 1 malocclusion with the bionator. Am J Orthod Dentofacial Orthop. 2001 Jun;119(6):578-86.

181. Braun S, Kittleson R, Kim K. The G-Axis: a growth vector for the mandible. Angle Orthod. 2004 Jun;74(3):328-31.

182. Nakahara C, Nakahara R. A study on craniofacial morphology of Japanese subjects with normal occlusion and esthetic profile. Odontology. 2007 Jul;95(1):44-56.

183. Polat OO, Kaya B. Changes in cranial base morphology in different malocclusions. Orthod Craniofac Res. 2007 Nov;10(4):216-21.

184. Wu J, Hägg U, Rabie AB. Chinese norms of McNamara's cephalometric analysis. Angle Orthod. 2007 Jan;77(1):12-20.

185. Erum GE, Fida M. A comparison of cephalometric analyses for assessing sagittal jaw relationship. J Coll Physicians Surg Pak. 2008 Nov;18(11):679-83.

186. Brown MC, Engberg I, Matthews PB. The relative sensitivity to vibration of muscle receptors of the cat. J Physiol. 1967 Oct;192(3):773-800.

187. Widmer CG, Lund JP. Evidence that peaks in EMG averages can sometimes be caused by inhibition of motoneurons. J Neurophysiol. 1989 Jul;62(1):212-9.

188. Wallace KR, Kerr GK. A numerical simulation of muscle spindle ensemble encoding during planar movement of the human arm: correlation sensitivity and parameter dependence. Biol Cybern. 1996 Oct;75(4):351-9.

189. Taylor A, Hidaka O, Durbaba R, Ellaway PH. Fusimotor influence on jaw muscle spindle activity during swallowing-related movements in the cat. J Physiol. 1997 Aug 15;503 (Pt 1):157-67.

190. Trpkova B, Major P, Nebbe B, Prasad N. Craniofacial asymmetry and temporomandibular joint internal derangement in female adolescents: a posteroanterior cephalometric study. Angle Orthod. 2000 Feb;70(1):81-8.

191. Kuroda S, Sugawara Y, Tamamura N, Takano-Yamamoto T. Anterior open bite with temporomandibular disorder treated with titanium screw anchorage: evaluation of morphological and functional improvement. Am J Orthod Dentofacial Orthop. 2007 Apr;131(4):550-60.

192. Nielsen HJ, Bakke M, Blixencrone-Moller T. [Functional and orthodontic treatment of a patient with an open bite craniomandibular disorder]. Tandlaegebladet. 1991 Dec;95(18):877-81.

193. Carels C, van Steenberghe D. Changes in neuromuscular reflexes in the masseter muscles during functional jaw orthopedic treatment in children. Am J Orthod Dentofacial Orthop. 1986 Nov;90(5):410-9.

194. Chintakanon K, Türker KS, Sampson W, Wilkinson T, Townsend G. Effects of twin-block therapy on protrusive muscle functions. Am J Orthod Dentofacial Orthop. 2000 Oct;118(4):392-6.

195. Arat FE, Arat ZM, Acar M, Beyazova M, Tompson B. Muscular and condylar response to rapid maxillary expansion. Part 1: electromyographic study of anterior temporal and superficial masseter muscles. Am J Orthod Dentofacial Orthop. 2008 Jun;133(6):815-22.

196. Castroflorio T, Titolo C, Deregibus A, Debernardi C, Bracco P. The orthodontic treatment of TMD patients: EMG effects of a functional appliance. Cranio. 2007 Jul;25(3):206-12.

197. Watanabe K. The relationship between dentofacial morphology and the isometric jaw-opening and closing muscle function as evaluated by electromyography. J Oral Rehabil. 2000 Jul;27(7):639-45.

198. Yabushita T, Zeredo JL, Fujita K, Toda K, Soma K. Functional adaptability of jaw-muscle spindles after bite-raising. J Dent Res. 2006 Sep;85(9):849-53.

199. Klocke A, Nanda RS, Kahl-Nieke B. Anterior open bite in the deciduous dentition: longitudinal follow-up and craniofacial growth considerations. Am J Orthod Dentofacial Orthop. 2002 Oct;122(4):353-8.

200. Benington PC, Gardener JE, Hunt NP. Masseter muscle volume measured using ultrasonography and its relationship with facial morphology. Eur J Orthod. 1999 Dec;21(6):659-70.

201. Hata T, Dai SY, Inubashiri E, Kanenishi K, Tanaka H, Yanagihara T, et al. Real-time three-dimensional color Doppler fetal echocardiographic features of congenital heart disease. J Obstet Gynaecol Res. 2008 Aug;34(4 Pt 2):670-3.

202. Cano J, Campo J, Vaquero JJ, Martinez JM, Bascones A. High resolution image in bone biology I. Review of the literature. Med Oral Patol Oral Cir Bucal. 2007 Oct;12(6):E454-8.

203. Charalampidou M, Kjellberg H, Georgiakaki I, Kiliaridis S. Masseter muscle thickness and mechanical advantage in relation to vertical craniofacial morphology in children. Acta Odontol Scand. 2008 Feb;66(1):23-30.

204. Raadsheer MC, van Eijden TM, van Ginkel FC, Prahl-Andersen B. Contribution of jaw muscle size and craniofacial morphology to human bite force magnitude. J Dent Res. 1999 Jan;78(1):31-42.

205. Ricketts RM, Bench RW, Hilgers JJ, Schulhof R. An overview of computerized cephalometrics. Am J Orthod. 1972 Jan;61(1):1-28.

206. Petrie A BJ, Osborn J. Further Statistics in Dentistry. London: British Dental Association; 2002.

207. Castelo PM, Bonjardim LR, Pereira LJ, Gaviao MB. Facial dimensions, bite force and masticatory muscle thickness in preschool children with functional posterior crossbite. Braz Oral Res. 2008 Jan-Mar;22(1):48-54.

208. Farkas LG, Tompson B, Phillips JH, Katic MJ, Cornfoot ML. Comparison of anthropometric and cephalometric measurements of the adult face. J Craniofac Surg. 1999 Jan;10(1):18-25; discussion 6.

209. Budai M, Farkas LG, Tompson B, Katic M, Forrest CR. Relation between anthropometric and cephalometric measurements and proportions of the face of healthy young white adult men and women. J Craniofac Surg. 2003 Mar;14(2):154-61; discussion 62-3.

210. Burke D, Hagbarth KE, Lofstedt L. Muscle spindle responses in man to changes in load during accurate position maintenance. J Physiol. 1978 Mar;276:159-64.

211. Jeffries JM, 3rd, DiBernardo B, Rauscher GE. Computer analysis of the African-American face. Ann Plast Surg. 1995 Mar;34(3):318-21; discussion 21-2.

212. Landes CA, Sterz M. Evaluation of condylar translation by sonography versus axiography in orthognathic surgery patients. J Oral Maxillofac Surg. 2003 Dec;61(12):1410-7.

213. Emshoff R, Brandlmaier I, Bodner G, Rudisch A. Condylar erosion and disc displacement: detection with high-resolution ultrasonography. J Oral Maxillofac Surg. 2003 Aug;61(8):877-81.

214. Volk J MM, Ovsenik M. Early orthodontic treatment in children with unilateral posterior crossbite. 85th Congress of European Orthodontic Society; 2009; Finlandia Hall, Helsinki, Finland. 2009. p. 16.

215. Hurst CA, Eppley BL, Havlik RJ, Sadove AM. Surgical cephalometrics: applications and developments. Plast Reconstr Surg. 2007 Nov;120(6):92e-104e.

216. Lele S, Richtsmeier JT. Euclidean distance matrix analysis: a coordinate-free approach for comparing biological shapes using landmark data. Am J Phys Anthropol. 1991 Nov;86(3):415-27.

217. Sameshima GT, Melnick M. Finite element-based cephalometric analysis. Angle Orthod. 1994;64(5):343-50.

218. Ferrario VF, Sforza C, Poggio CE, D'Addona A, Taroni A. Fourier analysis of cephalometric shapes. Cleft Palate Craniofac J. 1996 May;33(3):206-12.

219. Altug Z, Iseri H, Bayazit Z, Gogen H. [Evaluation of the changes occurring in the vertical direction of the face in cases treated with activator + occipital headgear combination]. Turk Ortodonti Derg. 1989 Nov;2(2):254-60.

220. Martin AJ, Buschang PH, Boley JC, Taylor RW, McKinney TW. The impact of buccal corridors on smile attractiveness. Eur J Orthod. 2007 Oct;29(5):530-7.

221. Gracco A, Cozzani M, D'Elia L, Manfrini M, Peverada C, Siciliani G. The smile buccal corridors: aesthetic value for dentists and laypersons. Prog Orthod. 2006;7(1):56-65.

222. Togashi K, Kitaura H, Yonetsu K, Yoshida N, Nakamura T. Three-dimensional cephalometry using helical computer tomography: measurement error caused by head inclination. Angle Orthod. 2002 Dec;72(6):513-20.

223. Madsen DP, Sampson WJ, Townsend GC. Craniofacial reference plane variation and natural head position. Eur J Orthod. 2008 Oct;30(5):532-40.

224. Barbera AL, Sampson WJ, Townsend GC. An evaluation of head position and craniofacial reference line variation. Homo. 2009;60(1):1-28.

225. Hartmann J, Meyer-Marcotty P, Benz M, Hausler G, Stellzig-Eisenhauer A. Reliability of a Method for Computing Facial Symmetry Plane and Degree of Asymmetry Based on 3D-data. J Orofac Orthop. 2007 Nov;68(6):477-90.

226. Smith R, Zaitoun H, Coxon T, Karmo M, Kaur G, Townsend G, et al. Defining new dental phenotypes using 3-D image analysis to enhance discrimination and insights into biological processes. Arch Oral Biol. 2008 Jul 19.

227. Brook AH, Pitts NB, Yau F, Sandar PK. An image analysis system for the determination of tooth dimensions from study casts: comparison with manual measurements of mesio-distal diameter. J Dent Res. 1986 Mar;65(3):428-31.

228. Takashima M, Kitai N, Murakami S, Furukawa S, Kreiborg S, Takada K. Volume and shape of masticatory muscles in patients with hemifacial microsomia. Cleft Palate Craniofac J. 2003 Jan;40(1):6-12.

229. Huisinga-Fischer CE, Vaandrager JM, Prahl-Andersen B, van Ginkel FC. Masticatory muscle right-left differences in controls and hemifacial microsomia patients. J Craniofac Surg. 2004 Jan;15(1):42-6.

230. Baumrind S. Taking stock: a critical perspective on contemporary orthodontics. Orthod Craniofac Res. 2004 Aug;7(3):150-6.

231. Cevidanes LH, Franco AA, Gerig G, Proffit WR, Slice DE, Enlow DH, et al. Assessment of mandibular growth and response to orthopedic treatment with 3-dimensional magnetic resonance images. Am J Orthod Dentofacial Orthop. 2005 Jul;128(1):16-26.

232. Martensson B, Ryden H. The holodent system, a new technique for measurement and storage of dental casts. Am J Orthod Dentofacial Orthop. 1992 Aug;102(2):113-9.

233. Papadopoulos MA, Christou PK, Athanasiou AE, Boettcher P, Zeilhofer HF, Sader R, et al. Three-dimensional craniofacial reconstruction imaging. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2002 Apr;93(4):382-93.

234. Terajima M, Endo M, Aoki Y, Yuuda K, Hayasaki H, Goto TK, et al. Four-dimensional analysis of stomatognathic function. Am J Orthod Dentofacial Orthop. 2008 Aug;134(2):276-87.

235. Naini FB, Moss JP. Three-dimensional assessment of the relative contribution of genetics and environment to various facial parameters with the twin method. Am J Orthod Dentofacial Orthop. 2004 Dec;126(6):655-65.

236. Lindquist LW. Prosthetic rehabilitation of the edentulous mandible. A longitudinal study of treatment with tissue-integrated fixed prostheses. Swed Dent J Suppl. 1987;48:1-39.

237. Slagter AP, Bosman F, Van der Bilt A. Comminution of two artificial test foods by dentate and edentulous subjects. J Oral Rehabil. 1993 Mar;20(2):159-76.

238. Haraldson T, Karlsson U, Carlsson GE. Bite force and oral function in complete denture wearers. J Oral Rehabil. 1979 Jan;6(1):41-8.

239. Moss JP. An electromyographic study of post retraction orthodontic patients. Swed Dent J Suppl. 1982;15:171-7.

240. Ioi H KM, Nakata S, Nakasima A. Mechanomyogram and electromyogram analyses for investigating human masseter msucle fatigue. Orthodontic Waves. [Research]. 2006;65:15-20.

241. Seifter J RA, Sloane D. Concepts in Medical Physiology. London: Philadelphia, Pa. ; Lippincott Williams & Wilkins; 2005.

242. Bertram S, Bodner G, Rudisch A, Brandlmaier I, Emshoff R. Effect of scanning level and muscle condition on ultrasonographic cross-sectional measurements of the anterior masseter muscle. J Oral Rehabil. 2003 Apr;30(4):430-5.

243. Kusnoto B, Evans CA. Reliability of a 3D surface laser scanner for orthodontic applications. Am J Orthod Dentofacial Orthop. 2002 Oct;122(4):342-8.

244. Fuhrmann RA, Schnappauf A, Diedrich PR. Three-dimensional imaging of craniomaxillofacial structures with a standard personal computer. Dentomaxillofac Radiol. 1995 Nov;24(4):260-3.

245. Khalaf K, Robinson DL, Elcock C, Smith RN, Brook AH. Tooth size in patients with supernumerary teeth and a control group measured by image analysis system. Arch Oral Biol. 2005 Feb;50(2):243-8.

246. Caldwell S, Cook P. Predicting the outcome of twin block functional appliance treatment: a prospective study. Eur J Orthod. 1999 Oct;21(5):533-9.

247. Nagasaka S, Fujimura T, Segoshi K. Development of a non-radiographic cephalometric system. Eur J Orthod. 2003 Feb;25(1):77-85.

248. Cunningham SJ, Hunt NP. Quality of life and its importance in orthodontics. J Orthod. 2001 Jun;28(2):152-8.

11 Appendix

Professor Kemal S. Türker, Marie Curie Chair of the European Union, GenderReflex laboratories, Center for Brain Research, Ege University, Izmir, Turkey

Journal of Dental Research
Dr. Anthony J. Smith
Editor
School of Dentistry, University of Birmingham
St Chad's Queensway
Birmingham, B4 6NN, UK

11 June 2008

Dear Prof Smith,

We submit herein two manuscripts that utilize the same methodology to investigate how the feedback from the two of the most important receptors that control mastication modulate their inputs to jaw muscle motoneurons during simulated mastication in human volunteers.

The first of the two manuscripts entitled **"JAW REFLEXES DURING SIMULATED MASTICATION; PART 1: PERIODONTAL REFLEX"** by Paul F. Sowman, Shazia Naser-ud-din, Hung Dang and myself. The second manuscript is entitled: **"JAW REFLEXES DURING SIMULATED MASTICATION; PART 2: SPINDLE REFLEX"** by Shazia Naser-ud-din, Paul F. Sowman and myself.

We submit these two manuscripts for consideration for publication in *Journal of Dental Research*. We would like these manuscripts to be treated as back-to-back publications as they use the same methodology and as the methods were not detailed in the second manuscript to save space.

We attest that the procedures followed in the experiments described follow the principles embodied in the Declaration of Helsinki.

Professor Kemal S. Türker, Marie Curie Chair of the European Union, GenderReflex laboratories, Center for Brain Research, Ege University, Izmir, Turkey

In compliance with the Copyright Revision Act of 1976, We warrant that the authors have sole ownership of the work submitted, that the work is original and has never been published, and that the authors have full powers to grant such rights.

Yours sincerely,

[redacted]

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Manuscript Draft

Manuscript Number:

Title: MASSETER LENGTH DETERMINES MUSCLE SPINDLE REFLEX EXCITABILITY DURING JAW CLOSING MOVEMENTS

Article Type: Original Article

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Abstract: INTRODUCTION
The masticatory muscles are considered to be important determinants of facial form but little is known of the muscle spindle reflex characteristics and their relationship, if any, to face height. The aim of the study was to determine whether spindle reflexes, evoked by axial mechanical stimulation of an incisor tooth and recorded on the masseter muscle, correlated with different facial patterns.
METHODS
Twenty eight adult volunteers (16 females; age range 19-38 years) were subjected to 2 N tap stimuli to their upper left central incisor during simulated mastication. The reflexes were recorded during local anaesthesia of the stimulated tooth to eliminate the reflex contribution from periodontal mechanoreceptors (PMR's). Surface electromyograms (SEMG) of the reflex responses of the jaw muscles to these taps were recorded via bipolar electrodes on the masseter muscle and interpreted using spike-triggered averaging of the SEMG. Lateral cephalometric analysis was carried out with Dolphin®10.5 and Mona Lisa® software.
RESULTS
2N tooth taps produced principally excitatory reflex responses with a latency of about 17ms post-stimulus. Correlation analysis showed a significant relationship existed between the muscle spindle reflexes and facial heights; specifically, the shorter face height individuals were associated with stronger spindle reflexes. This correlation was strongest between the derived measure of masseter length and spindle reflex strength during jaw closure ($r = -0.49$, $p = 0.008$).

CONCLUSIONS
These results suggest that a similar muscle spindle stimulus will generate a stronger reflex activation in the jaw muscles of shorter faced individuals compared with the longer faced individuals. This finding may help explain the higher incidence of clenching/bruxism in short-faced individuals and also may in the future influence the design of orthodontic appliances and or dental prosthesis.

8 August 2009

Dear Editor,

We submit herein a manuscript entitled: "MASSETER LENGTH DETERMINES MUSCLE SPINDLE REFLEX EXCITABILITY DURING JAW CLOSING MOVEMENTS" for consideration for publication in the American Journal of Orthodontics & Dentofacial Orthopedics.

I attest that the procedures followed in the experiments described follow the principles embodied in the Declaration of Helsinki.

In compliance with the Copyright Revision Act of 1976, we warrant that the authors have sole ownership of the work submitted, that the work is original and has never been published, and that the authors have full powers to grant such rights.

Yours sincerely,

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MASTICATORY MUSCLE REFLEX ACTION IN DIFFERING FACE TYPES

S Naser-ud-Din[1], W J Sampson[2] & K S Türker[3]
Research Centre for Human Movement Control & School of Dentistry, University of Adelaide, SA 5005, AUSTRALIA

INTRODUCTION

- Non-invasive tools such as EMG (electromyography) has helped us understand jaw muscles action [1-3].
- Muscles of mastication are directly related to Facial Types and are important aetiological factor for some malocclusions.
- Differences in vertical proportions dictate choice of treatment modalities.
- The present study aims to examine the relationship between different facial patterns (Vertical Dimensions) and jaw reflexes.

AIMS

- To understand differences in reflexes originating from muscle spindles and periodontal mechanoreceptors (PMR's) in different facial types
- To understand the underlying receptor role in bite force

HYPOTHESIS

- **The feedback from Muscle Spindles to the jaw closer motoneurons decreases during opening phase of mastication**
- **As face height increases spindle contribution to the jaw closers decreases during opening phase of mastication**

METHODOLOGY

The Human Ethics Committee of The University of Adelaide approves all experiments and details can be obtained by contacting Associate Professor Dr. Kemal Türker.

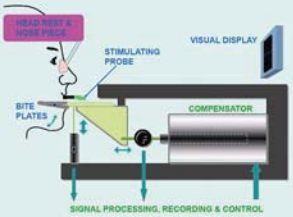

Fig.1 Schematic representation of the Testing Machine with tooth Stimulation and Jaw Chewing Simulation

- A convenience sample of 35-40 students from the University of Adelaide will be divided into 3 groups i.e Brachyfacial, Dolichofacial and Average.
- Stringent selection and exclusion criteria is outlined in order to standardize the participants.

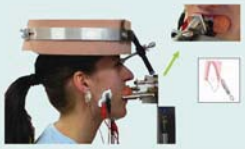

Fig.2: Subject seated comfortably throughout the experiment session. EMG recorded bilaterally from the masseter and the digastric muscles, bitting on a custom made impression, and left central incisor mechanically stimulated by an orthogonal probe. Local anaesthetic was infiltrated into the periodontium during the LA trials. An ear clip provided the ground.

METHODOLOGY cont.

- Upper teeth are positioned in fixed relation to the stimulation probe (Fig. 2).
- Surface bipolar electrodes are placed on bellies of the left and right masseter and digastric muscles to record the SEMG (Surface EMG) in the bandwidth 20-500 Hz.
- Bite force is recorded using a strain gauge and data are recorded on computer (LabView® system) at 2,000 Hz (Fig. 1 & 3).
- Jaw reflexes evoked by mechanical stimulation of an upper left central incisor with the masticatory device developed by Türker *et al* (2004) [8].
- The tooth is stimulated with mixed pulses and triggers (Fig. 4). A computer conveys the profiles of the stimuli to the upper incisal tooth via a fine probe. Stimulation of the upper teeth is preferred to the lower teeth since it induces negligible movement of the lower jaw.
- Pre and Post Infiltration Anesthesia helps differentiate between the PMR and Muscle Spindle contribution to the reflexes

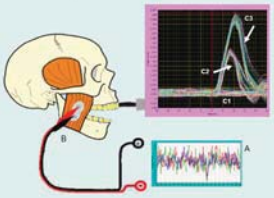

Fig.3: EMG (A) was recorded from the left masseter (B) during both Non LA and LA trials. Examples of control (continuous 0.2N: C1), low (0.8N: C2) and high (1.6N: C3) force stimulations are shown.

PRELIMINARY RESULTS

After recording the data under the Dynamic and Static conditions, pre and post Local anesthetic infiltration - a series of LabView ® based analysis programs are performed. Normalization and CUSUMS of reflexes are attained (Fig.5). The reflexes are presented for High and Low stimulus during the open and close movements of the jaw. These can be then compared with pre- and post-anesthesia reflexes.

Triggers are generated each time the jaw passes through a fixed degree of jaw position. While some triggers generate High or Low stimuli other triggers do not induce stimuli and are used as controls (Fig.3).

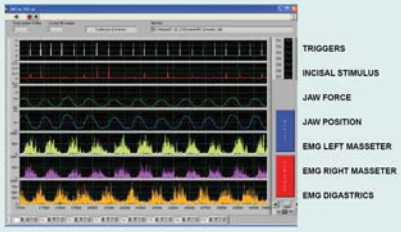

Fig.4 Online profile for stimulus , jaw force and EMG's for the different muscle groups. Recorded with LabView ®

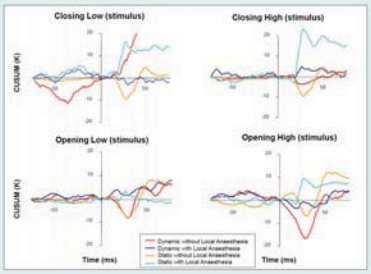

Fig.5: CUSUM of left masseter reflex response to mechanical stimulation of left central incisor. Results from one subject with Average Face Height (same subject as Fig. 2)

CLINICAL IMPLICATIONS

Overall, the experiments aim to elucidate any differences which may be present in the different facial forms. The current literature is lacking in this area and would greatly benefit from new information that would be added to our pool of knowledge and understanding of the complex muscles of mastication. Comprehending muscles of mastication is of particular interest to the profession both from the basic diagnostic ability and characterization of patients to evolutionary improvement of treatment modalities.

REFERENCES

1. Farella M, Michelotti A, Carbone G, Gallo LM, Palla S, Martina R. Habitual daily masseter activity of subjects with different vertical craniofacial morphology. Eur J Oral Sci 2005;113:340-345.
2. Ueda HM, Ishiyaka Y, Miyamoto K, Morimoto N, Tanne K. Relationship between masticatory muscle activity and vertical craniofacial morphology. Angle Orthod 1996;66:233-238.
3. Ueda HM, Miyamoto K, Saifuddin M, Ishiyaka Y, Tanne K. Masticatory muscle activity in children and adults with different facial types. Am J Orthod Dentofacial Orthop 2000;118:63-66.
4. Brodin-north RG, Mate C, Türker KS. Response of human jaw muscles to axial stimulation of a molar tooth. Exp Brain Res 2004;159:214-224.
5. Brodin-north RG, Türker KS. EMG, force and discharge rate analysis of human jaw reflexes in response to axial stimulation of the incisor. Exp Brain Res 2005;161:145-154.
6. Brodin-north RG, Türker KS. Jaw movement alters the reaction of human jaw muscles to incisor stimulation. Exp Brain Res 2005;164:165-176.
7. Türker KS. Reflex control of human jaw muscles. Crit Rev Oral Biol Med 2002;13:85-104.
8. Türker KS, Brodin-north RG, Abolfathi P, Lowe PR, Naperian H. A device for investigating neuromuscular control in the human masticatory system. J Neurosci Methods 2004;139:141-148.
9. Türker KS, Brodin P, Miles TS. Reflex responses of motor units in human masseter muscle to mechanical stimulation of a tooth. Exp Brain Res 1994;100:307-316.

ACKNOWLEDGEMENT

This Laboratory is supported by the National Health & Medical Research Council (NH&MRC) of Australia

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2 Professor & Begg Chair School of Dentistry, University of Adelaide, S.A. 5005, Australia.
3Senior Fellow NH&MRC, Physiology, University of Adelaide, S.A. 5005 Australia.

Presented at 32nd Australian Dental Association Congress Sydney March 16-20, 2007

Poster Presentation " Masticatory Muscle Reflex Action in Differing Face Heights" 32nd Australian Dental Association Congress, Convention Centre Sydney, NSW Australia (March 16-19,2007)

Abstract for the 47th Annual Meeting **IADR** joined FDI World Dental Federation, WHO, & Zealand Division annual meeting
Sept.23-26,2007 Barossa Valley, SA, Australia

MODULATION OF INPUT FROM MUSCLE SPINDLES DURING SIMULATED CHEWING

S Naser-ud-Din[1], W J Sampson[2], K S Türker[3], C W Dreyer[4]

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[2]Professor & Begg Chair, School of Dentistry, University of Adelaide, S.A 5005, Australia
[3]Senior Fellow NH&MRC, Physiology, University of Adelaide, S.A 5005, Australia
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Objective: The aim of the current study was to evaluate the modulating effect of jaw movement on muscle spindle-evoked reflexes in the masseter during simulated chewing.
Background: To date most investigations of human masticatory reflexes have been performed under static mandibular conditions. It is not known whether muscle spindle reflexes would be modulated during simulated chewing[1].
Methods: In 28 consenting informed adult volunteers with no neuromuscular or dental problems, we delivered 1 and 2 N taps to the upper central incisor each time the mandible went through individualized jaw separation (~ 14-16mm) during both jaw opening and closing. Responses of the jaw muscles to these taps were examined by assembling spike triggered averages of the masseteric electromyogram (EMG) around the time of the stimulus. To examine the possibility of reflex modulation by jaw movement, static tests were also performed using EMG feedback. EMG during static trials was matched to that which occurred at the stimulus delivery time of both the opening and closing phases of the dynamic trial.
Results: We have found that stimulation of muscle spindles does elicit a significant excitatory reflex during chewing. There is a significant reduction of this reflex excitation during the jaw-closing phase while during the jaw-opening phase, no significant modulation was evident.
Discussion and Implications: While these findings differ from those of several limb studies where muscle spindle-evoked reflexes are shown to be significantly down-regulated during lengthening movements of the homonymous muscle, similar findings have been documented during static studies on muscles of mastication [2].

1. Türker KS. Reflex control of human jaw muscles. Crit Rev Oral Biol Med 2002;13.
2. Scutter SD, Türker KS. Muscle spindle afferent input to motoneurons in human masseter. J Neurophysiol 1999;82.

Modulation Of Input From Muscle Spindles During Simulated Chewing

S Naser-ud-Din[1], W J Sampson[1], KS Türker[2] , C W Dreyer[1]

THE UNIVERSITY OF ADELAIDE AUSTRALIA

[1] Orthodontic Department, School of Dentistry, University of Adelaide, South Australia
[2] Research Centre for Human Movement Control, University of Adelaide, South Australia

INTRODUCTION

- The basic rhythm of mastication is produced by a Central Pattern Generator (CPG) [Dellow 1971].
- The central pattern for mastication is subject to reflexive modulation by both periodontal mechanoreceptors (PMR's) and muscle spindles.
- The efficacy of these reflexes is known from animal studies to be modulated during functional jaw movements.
- To date all human reflex studies have been performed under static jaw conditions.
- The current study evaluates the extent to which jaw elevator muscle spindle reflexes are modulated during *function* (Simulated Chewing) in a human model.

HYPOTHESIS

- Muscle Spindle reflexes elicited by mechanical tooth stimulation are smaller during functional jaw movements than under static conditions.

METHOD

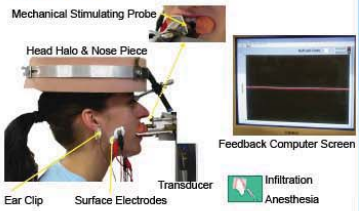


Fig 1: Experiment Setup. Subject's simulated mastication on a mechanical mastication device. Teeth were supported by a custom made dental impression. EMG was recorded from surface electrodes referenced to an ear clip electrode. The left central incisor was mechanically stimulated by an orthogonal probe. Infiltration anaesthesia eliminated PMR reflexes. Visual feedback was provided via a computer monitor.

- Subjects were seated upright with their heads fixed by an adjustable halo and a fixed nose piece (Fig 1).
- Teeth rested in a custom made impression in Express™, 3M ESPE, Germany.
- The upper left central incisor was orthogonally stimulated with high (2N) and low (1N) forces.
- 200 stimuli (100 each during opening and closing phases) (Fig 2).
- 2 sets of experiments were conducted:

i. Pre- and post test local anaesthesia of the peri-incisal periodontium. LA results represent the Muscle Spindle-only contribution to the evoked reflex.
ii. Static and Dynamic data were collected.

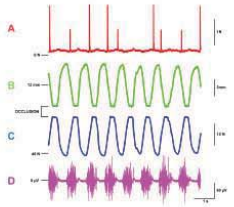


Fig 2: Raw Data recorded from Single Subject during DYNAMIC experiment. A. Profile for stimulus 1N-2N applied to the incisor tooth (red), B. Jaw gap measured as inter-incisal distance (green) C. Mandibular resistance force in Newtons (blue) D. EMG from left Masseter (pink).

- Surface electrodes were used to record electromyographic (EMG) activity Left Masseter.
- Data were streamed to a computer hard-drive via a custom-designed LabView® acquisition system.
- The raw EMG data were rectified, averaged and peri-stimulus CUSUMs constructed.
- The strength of the reflex was calculated from the CUSUM of the averaged evoked reflex.

RESULTS

- Muscle spindle reflexes in masseter were excitatory (Fig 3).
- Larger stimuli (2N) evoked significantly larger reflexes (Fig 4).
- A significant reduction of muscle spindle reflexes occurred during the jaw-closing phase.
- No modulation occurred in the jaw-opening phase.

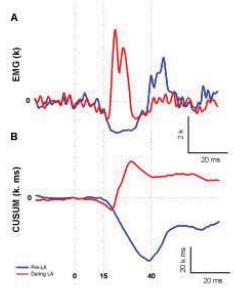


Fig 3: Muscle Spindle Reflex: Single subject data for evoked reflexes. (A) Average rectified EMG normalized to average pre-stimulus (60ms). The blue trace is a combination of PMR and muscle spindles. Muscle Spindle response only revealed by removal of PMR's post LA (red trace) (B) CUSUMs (Cumulative Sums) for the trace above; excitation of spindles in red after subtraction from blue(PMR+ Muscle Spindles)

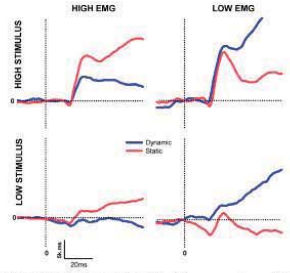


Fig 4: Population Reflex Response by Condition. Reflexes averaged across 28 subjects. Net excitation of muscle spindles following LA. More pronounced reflexes for higher stimulation (2N). Conditions Static (red) & Dynamic (blue) plotted together.

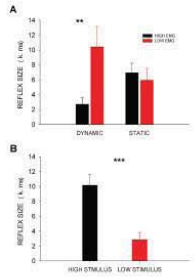


Fig 6: Interaction between EMG (High & Low) and conditions (Dynamic & Static). (A) Significant difference for Dynamic condition (**p < 0.01) during closing compared with static. (B) Reflex size significantly larger (***p < 0.001) for High Stimulus as compared to low stimulus. Overall excitatory for all conditions.

DISCUSSION

- A protective role can be attributed to the muscle spindles of the jaw elevators.
- Active when there is a threat to the integrity of the oro-facial structures.
- Hence PMR and muscle spindle in conjunction provide a dual protective effect.

CLINICAL IMPLICATIONS

- This study reinforces the protective and peripheral input of muscle spindles in conjunction with PMR's.
- The second part of this study will look at Cephalometric norms of the subjects and correlate to the muscle spindle reflexes.
- If there is a significant difference between different facial heights the information could be exploited to enhance the efficacy of Functional Orthopaedic Appliances.

References:
1. Dellow PG, Lund JP. Evidence for central timing of rhythmical mastication. J Physiol 1971;215:1-13.
2. Turker KS, Brinkworth RS, Abolfathi P, Linke IR, Nazeran H. A device for investigating neuromuscular control in the human masticatory system. J Neurosci Methods 2004;136:141-149.
3. Brinkworth RS, Male C, Turker KS. Response of human jaw muscles to axial stimulation of a molar tooth. Exp Brain Res 2004;159:214-224.
4. Scutter SD, Turker KS. The role of the muscle spindles in human masseter. Hum Mov Sci 2001;20:489-497.

Presented at the 47th Annual Meeting of the Australian and New Zealand Division – International Association of Dental Research, Barossa Valley, South Australia – September 23-26, 2007

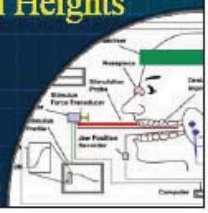
Poster Presentation " Modulation of Input from Muscle Spindles During Simulated Chewing". 47th Annual Meeting of IADR – Australian & New Zealand Division, Barossa Valley, SA (Sep23-26, 2007)

Modulation of Input from Muscle Spindles during Simulated Chewing and Correlation with Different Facial Heights

Supervisors:

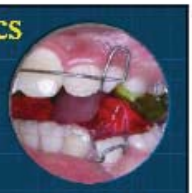
- Prof Dr W J Sampson
- Dr K S Türker
- Dr C W Dreyer

PhD Candidate:
Shazia Naser-ud-Din



Applied Orthodontics

Functional Changes in Muscles of Mastication

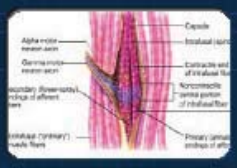


Using New Tools of Investigation

Acknowledgements:
Prof A Darendeliler & Dr Paul Taylor for Magnoglide picture

Literature Review

- Intrafusal Fibers
- Stretch Reflex
- Force Generation



- Bite Forces (Ingervall 1978, Profitt 1983)
- EMG studies of Muscles of Mastication (Moller 1966)
- Protrusive Mandibular Forces (Chintakanon, Türker, Sampson, Townsend, Wilkinson, 1999)
- Review Article (Pepicelli, Woods & Briggs 2005)

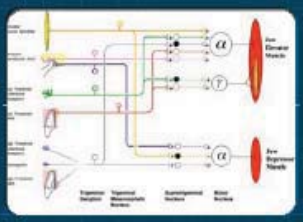
Hypothesis

Part One:

The reflexes evoked by muscle spindles in jaw-closing muscles changes during mastication

Part Two

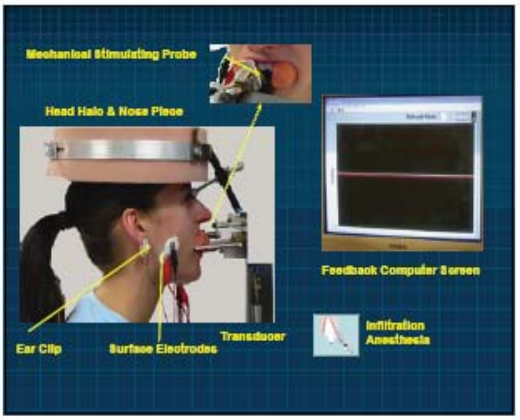
Different Facial Heights modulate muscle input to the motoneuron pool differently



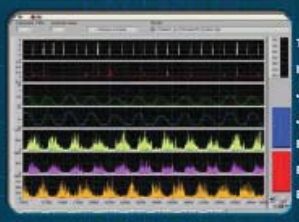
The Human Ethics Committee of the University of Adelaide approves all experiments

Bite Plate and Stimulator

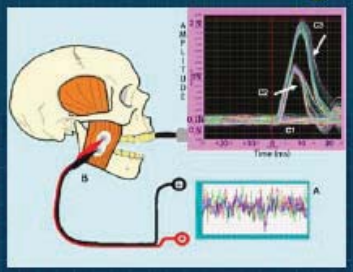
- Dental impression
- 3M Express Vinyl PolySiloxane Putty
- Flat lower platform no drag during chewing



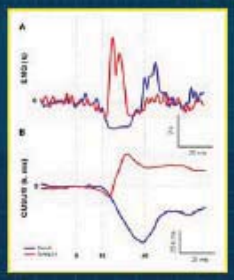
Online Profile for Stimulus Jaw Force and EMGs



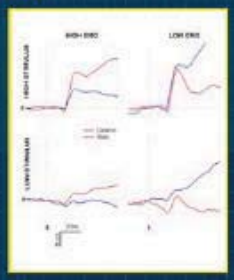
Stimulus Profile and Raw EMG Recording



Results



Muscle Spindle Reflex

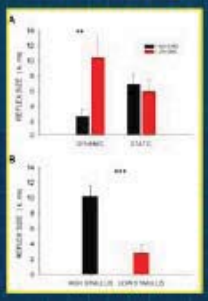


Population Reflex Response

Interaction between EMG (High & Low) and Conditions (Dynamic & Static)

A. Significant difference for Dynamic condition (**p < 0.01)(i.e. jaw-closing) compared with static.

B. Reflex size significantly larger (***p < 0.001) for 2 N compared with 1 N stimulus.



Is Facial Height Important?

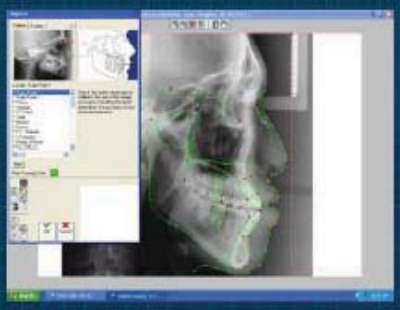
- Dolichofacial
- Average

- Brachyfacial

Measurements

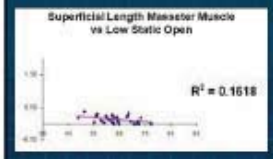
- Superficial Masseter
  - Anterior end of Zygomatic process
- Intermediate Masseter
  - Posterior aspect of Zygomatic arch
- Gonial angle

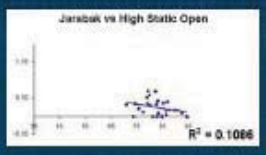
Dolphin® Package

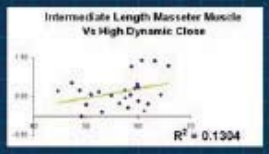


Results

Weak R^2 for Muscle Spindles EMG %







Conclusions

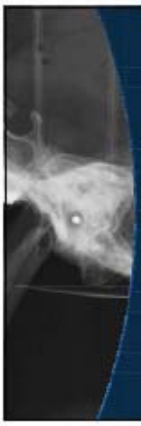
Part I

- The reflexes evoked by muscle spindles in jaw-closing muscles *change* during mastication. **YES**

Part II

- Different Facial Heights modulate reflexes evoked by muscle spindles in jaw-closing muscles *differently*. **NO**

Recommendations



- More sophisticated tools for evaluation.
  Underlying neuronal organisation
- Severity of the conditions - Orthognathic cases.
  Greater sample size

Oral Presentation “Modulation of Input From Muscle Spindles During Simulated Chewing & Correlation With Different Facial Heights” 21st ASO Congress, Convention Centre Gold Coast, QLD, Australia (March 2, 2008)

RESEARCH DAY 2008
SUBMISSION OF ABSTRACT

Oral Presentation

Title of study: **Modulation Of Input From Muscle Spindles During Simulated Chewing And Correlation With Different Facial Heights**

Authors & Affiliations:

S Naser-ud-Din, PhD Candidate, School of Dentistry, University of Adelaide, S.A 5005, Australia
W J Sampson,
Professor & Begg Chair, School of Dentistry, University of Adelaide, S.A 5005, Australia
K S Türker, Senior Fellow NH&MRC, Physiology, University of Adelaide, S.A 5005, Australia
C W Dreyer Orthodontic Department, School of Dentistry, University of Adelaide, S.A 5005, Australia

Presenter is (circle): S Naser-ud-Din Postgraduate Student

Abstract:

Introduction: Current study aims to evaluate the modulating effect of jaw movement on muscle spindle-evoked reflexes from masseter during simulated chewing and correlating with different facial heights. No work has been done to characterize a relationship if there exists any between muscle spindles and different facial heights.

Methods: 28 consenting participants were included in the study. Reflexes were evoked by 1 and 2 N taps to the upper central incisor. Responses of the jaw muscles to these taps were analysed with IZZY® software. Standardized Lateral Cephalometric radiographs were taken from the participants and analysed for any existing correlation between muscle spindle response and wide spectrum of facial heights.

Results: We have found that stimulation of muscle spindles does elicit a significant excitatory reflex during chewing. There is a significant reduction of this reflex excitation during the jaw-closing phase while during the jaw-opening phase, no significant modulation was evident. However, it remains to be seen if there is a significant difference in spindle response in different facial proportions.

Conclusions: Orthodontic implications can be wide if such a relationship exists. This paper will elicit the importance of physiological studies in order to better understand the underlying function that could be exploited for the cause and effect of different Orthodontic modalities.

Abstract for Poster Presentation at the WFO Sydney 2010

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

NASER-UD-DIN, S., SOWMAN, P.F, DANG, H, TÜRKER, K.S,. THOIRS K,

DREYER C.W., SAMPSON W.J.

University of Adelaide, SA, Australia

Form and function are inextricably intertwined in orthodontics. **AIM:** The current study aimed to objectively evaluate the masseter muscle- one of the key elevator muscles in the human masticatory system. **METHODS:** Study used electromyography (EMG), ultrasonography (US) and 3-D imaging (Mona Lisa®). Standard lateral cephalometrics was used as the gold standard. The first part of the study (n=28) evaluated masseter muscle spindle responses with EMG and correlated it to the vertical facial dimensions. 2N tooth taps produced principally excitatory reflex responses with a latency of about 17ms post-stimulus. In the second part of the study the same cohort participated in US evaluations where EFOV (Extended Field of View) scanning was utilized. Finally, 3D optical scanning was utilized and previous data correlated. **RESULTS:** Correlation was strongest between the derived measure of masseter length and spindle reflex strength during jaw closure ($r = -0.49$, $p = 0.008$). Spearman's rank order correlations showed statistical significance for area from US and ramus height (Ar-Go) with $r= 0.85$ ($p<0.001$). Overall, repeatability for thickness of the masseter muscle was good (Dahlberg 1.17). Pearson correlation coefficients showed significant relations with Co-Go and area of masseter muscle derived from ultrasonography $r=0.81$ ($p=0.01$), and for Go-Me to facial width from 3D imaging with $r=0.83$ ($p=0$). High statistical significance ($p< 0.0001$) for curvilinear measurements was present as compared to the linear counterpart with paired t-test. **CONCLUSIONS:** The study endeavoured to develop predictive equation to be used as non-radiographic surrogate values for facial proportions without multiple investigations.

AUSTRALIAN DENTAL RESEARCH FOUNDATION

(Incorporated in the ACT)

PROGRESS REPORT

1. Name of the Researcher / s

Professor Wayne Sampson
Dr Shazia Naser-Ud-Din
Dr Kemal Türker

2. Title of Project

REFLEX CONTROL OF MASTICATION BY MUSCLE SPINDLES IN DIFFERENT CRANIO-FACIAL HEIGHTS

3. Date of Commencement of the Project

July 2006

4. Progress (2nd Report)

The experiments were conducted at the Physiology Dept Medical North, University of Adelaide and were completed on time (Jan 07-Aug07). We managed to recruit 34 subjects for the study and utilized data for analysis from 28. The data was analysed with the special software to rectify and analyse the EMGs from simulated chewing cycles. Two papers have so far been generated from the experiments and recently been submitted to JDR for review.

- Sowman PF, Naser-ud-Din S, Dang H, Türker KS, Jaw Reflexes During Simulated Mastication. Part 1: Periodontal Reflex (Sent for review to JDR June 2008)
- Naser-ud-Din S, Sowman PF, Türker KS, Jaw Reflexes During Simulated Mastication. Part 2: Spindle Reflex(Sent for review to JDR June 2008)

Also the preliminary results were presented at the ASO, Gold Coast Congress in March 2008 as oral presentation. It was well received and appreciated.

Oral Presentation "Modulation Of Input From Muscle Spindles During Simulated Chewing & Correlation With Different Facial Heights" 21st ASO Congress, Convention Centre Gold Coast, QLD, Australia (March 2, 2008)

Our conclusions so far with the muscle spindle and craniofacial heights correlation are inconclusive. This may be due to the fact that underlying neurophysiology or the wiring is similar, as the functional requirements are the same for all, even though the underlying architecture varies in different individuals. Third paper is work in progress and will be submitted for publication in an Australian Journal.

5. Details of Expenditure against the grant

Please see attached Budget

6. Anticipated date of completion of project

March 2009 in process of writing up a paper of Australian Journal of Orthodontics

We thank ADRF for their support for the project.

AUSTRALIAN DENTAL RESEARCH FOUNDATION INC

FINAL REPORT COVERSHEET

1. Name of Researchers: Sampson WJ, Naser-Ud-Din S, Dreyer CW, Sowman PF, Turker K

2. Title of Project: Reflex control of mastication by muscle spindles in different craniofacial heights

3. Date of Commencement: 01/01/2008

4. Date of Completion: 23/03/2009

5. This final report coversheet must be submitted together with either:

i) **An article in a form suitable for publication in the *Australian Dental Journal* or**
ii) **An abstract in a form suitable for publication in the Special Research Supplement of the *Australian Dental Journal* as described in the Conditions Governing Research Grants**

6. Is publication intended in another scientific journal? **Yes**

If Yes; Name of Journal To be determined

7. Has this research been presented at any scientific meetings or symposia? **No**

If Yes; Where _____

8. Has all expenditure been claimed against the grant? **No**

(Note all submissions for unclaimed funds must be made within 12 months of submitting this Final Report)

THE UNIVERSITY OF ADELAIDE

Faculty of Sciences
Discipline of Physiology
Oral Neurophysiology Laboratory

INFORMATION SHEET FOR VOLUNTEERS

REFLEX CONTROL OF THE HUMAN MUSCLES

Background to the laboratory: This laboratory investigates the control of human muscles. Muscles are controlled by two fundamental mechanisms: (1) the central pattern generator (CPG) that sets the pattern of contraction by sending electrical impulses to muscles; and (2) the peripheral control that modulates the output of the CPG. The peripheral modulation of the CPG ensures that optimum forces are developed. The peripheral control mechanisms originate from the receptors within the skin and muscles. These receptors monitor contraction forces and modify the activity of muscles in order to facilitate movement of the limb and prevent damage to tissues. To investigate their connections to motoneurons (the nerves that innervate muscles), we stimulate these receptors electrically and/or mechanically in consenting adult volunteers. The responses of the muscles to the stimulus are recorded using intramuscular fine wire and surface electrodes. These studies contribute to a better understanding of the neuronal circuitry of the neuromuscular system.

Significance of the experiments: Movement is one of the most fundamental functions of humans. Despite its fundamental importance, the neurological mechanisms that control movement are not yet understood. Once these mechanisms are well understood, they can be used for the diagnosis and treatment of muscle / joint disorders, fatigue, and tremor. In the jaw experiments we are also investigating whether face shapes and jaw reflexes are correlated.

EXPERIMENTAL PROTOCOL: You will be asked to take part in one or two of the four experiments that are taking place in the laboratory at present. The other experiments that you will not be taking part in are crossed out for clarity.

Jaw experiments (Static and Dynamic); Leg experiments; Pain experiments.

Static jaw experiments: In these experiments you will be asked to bite on bite bars. Your teeth, skin or oral mucosa will be stimulated using mechanical and/or electrical stimuli. The mechanical stimulus is applied via a probe attached to a vibrator, and the electrical stimulus is delivered using intramuscular or surface electrodes. The electrical activity of your jaw muscles is recorded using surface and intramuscular electrodes. In experiments where mechanical tooth stimulation is used, local anaesthetic block is applied around the stimulated tooth to study the dispersion of the stimulus to neighbouring tissues.

Dynamic jaw experiments: All protocol is the same as above except that the participant will open or close his/her mouth while the bite bars either do not resist the action (simulation of simple jaw movement) or resist the movement with a defined force (simulating biting on a piece of food). In

other experiments, the lower bite bar will occasionally apply very small and defined opening or closing perturbations to the lower jaw so that the stretch or unloading reflex can be studied.

If you are participating in jaw experiments, you may also be asked to agree to have a radiograph taken to show head and jaw structure. This will enable the researchers to match muscle and jaw responses with variations in the shape and size of your face.

Leg experiments: In these experiments you will be asked to push against a transducer (foot plate) with your foot. One or two of your leg muscles will then be stimulated using mechanical and/or electrical means. While mechanical stimulus is applied via a probe attached to a vibrator, electrical stimulus is delivered using intramuscular or surface electrodes. The electrical activity of your leg muscles will be recorded using surface and intramuscular electrodes. In experiments where mechanical stimulation is used, local anaesthetic block may be applied around the stimulated site to study the dispersion of the stimulus to neighbouring tissues.

Pain experiments In these experiments you will be performing either one of the two jaw experiments or the leg experiments as stated above. During the experiment, an injection of a pain inducing substance (hypertonic saline) or a non-pain inducing substance (isotonic saline) will be injected into the muscles or joints. The injection will last for about 20 minutes and the pain will disappear within about 1-2 minutes after the injection stops.

General procedures that applies to all experiments:

- Surface recording involves the cleaning of your skin over the muscles and taping electrodes onto the skin surface.
- The intramuscular electrodes are very fine wires that are inserted into the muscle with the help of a thin surgical needle (23 - 25G). Once the electrode is in place, the needle is withdrawn from the muscle leaving the wires in the muscle. These wires do not cause pain during the experiment and they are withdrawn at the end of the experiment.
- Mechanical stimuli will be applied using a vibrator. The force of the stimulus is so arranged that it feels like a tap.
- Electrical stimulus to the muscle will be applied either by surface electrodes or by tungsten wire electrodes. The stimulus strength is so adjusted that it can only stimulate some of the nerve fibres in the muscle. This stimulus feels like a contraction of your muscle without involving pain.
- X-rays of your jaws will be taken by experienced radiographers and only requires you to attend an appointment for the short time it takes to produce the radiograph. This requires you to stand briefly in a device, which holds the head steady while the radiograph is taken.

POSSIBLE RISKS ARE:

- Although the radiograph is a routine film taken for many medical and dental procedures such as orthodontic treatment, there is a low radiation risk similar to two days exposure to natural background radiation. If you are pregnant, this procedure will not take place.
- There is a small possibility that you may break your teeth during the bite task. To overcome this possibility your teeth will be examined by a registered dentist. This process excludes from the study any participant who has had major restoration on, or have done, major damage to, their teeth. Furthermore, the dental impression of your teeth is built on the bite bars to reduce the risk of damage. Despite all the above-mentioned precautions, if any damage to your teeth does occur during the experiment, your teeth will be repaired at no cost to you. It may be comforting to know that in over 500 experiments to date there has been no damage to any teeth reported.

- The experiments using intramuscular electrodes may cause minor bleeding and tenderness of the muscle for up to a couple of days.
- There is a low risk of infection. Again it may be comforting to know that in over 500 to date, no one has developed any form of infection.
- When the local anaesthetic block is administered (by a registered dentist) some discomfort may result.
- Pain inducing and occasionally the placebo substances do induce a short lasting experimental pain that subsides within a few minutes after the cessation of injection. They do not induce any long lasting effects.
- The force of the mechanical stimulation that is applied on the teeth will feel like a tap on your teeth. There is no risk of damaging the teeth and support structure.
- Electrical stimulation of your muscle may produce a sharp sensation to begin, but does not cause pain and does not have any side effects.

With the exception of the low risks mentioned above, there appears to be no risk of permanent damage.

- **PARTICIPANTS SHOULD NOT TAKE ASPIRIN OR BLOOD THINNING MEDICATION FOR 72 HOURS BEFORE THEIR EXPERIMENT.**
- **YOU ARE WARNED ABOUT THE POSSIBLE RISKS ABOVE**
- **YOU CAN WITHDRAW FROM THE EXPERIMENTS AT ANY TIME AND WITHOUT EXPLANATION.**
- **YOU ARE ASKED TO READ AND KEEP CONTACTS / COMPLAINTS DOCUMENT ATTACHED**

Contacts: Associate Professor Kemal S. Türker,
Discipline of Physiology, The University of Adelaide, South Australia 5005, Australia.

Tel: Int 61 8 83035311Fax: Int 61 8 83033356
E-mail: kemal.turker@adelaide.edu.au

Dr. Shazia Naser-ud-din
PhD student
Dental School, The University of Adelaide, South Australia 5005, Australia.

PARTICIPANTS NEEDED

We need people who:

- Are aged 18 – 30 years
- Have NO neurological disorders
- Have healthy teeth and gums
- Have had **NO** previous orthodontic treatment
- Not pregnant

At the Oral Neurophysiology Laboratory, Department of Physiology in Adelaide University we are conducting world-leading research into human reflexes. The results of which will increase our understanding of how muscles work and may lead to better diagnosis and treatment for muscle/nerve related disorders. Currently we are looking for participants aged over 18 years who have never had orthodontic treatment (e.g. braces, or repositioning of front teeth) to participate in a study.

The experiment will involve participants biting on moulds of their teeth mounted on two metal bars as the upper front left tooth is (gently) tapped. Recordings will be taken from the left cheek and will involve a small needle being inserted for a brief time to facilitate the insertion of two small recording wires. A local anaesthetic patch is used so there is very little discomfort.

The experiment has the full approval of the ethics committee and should take no more than three hours of which only one hour will be spent on the bite bars.

TIME SPENT IN THE LAB WILL BE REMUNERATED

If you, or any of your friends, are interested in becoming a participant contact
Kemal Türker on 8303 5311 or
E-mail: kemal.turker@adelaide.edu.au

5

THE UNIVERSITY OF ADELAIDE HUMAN RESEARCH ETHICS COMMITTEE
STANDARD CONSENT FORM
FOR PEOPLE WHO ARE PARTICIPANTS IN A RESEARCH PROJECT

1. I, ... *(please print name)*

   consent to take part in the research project entitled: **REFLEX CONTROL OF HUMAN MUSCLES**

2. I acknowledge that I have read the attached Information Sheet entitled:

   .....

3. I have had the project, so far as it affects me, fully explained to my satisfaction by the research worker. My consent is given freely.

4. Although I understand that the purpose of this research project is to improve the quality of medical care, it has also been explained that my involvement may not be of any benefit to me.

5. I have been given the opportunity to have a member of my family or a friend present while the project was explained to me.

6. I have been informed that, while information gained during the study may be published, I will not be identified and my personal results will not be divulged.

7. I understand that I am free to withdraw from the project at any time and that this will not affect medical advice in the management of my health, now or in the future.

8. I am aware that I should retain a copy of this Consent Form, when completed, and the attached Information Sheet.

.....
(signature) *(date)*

WITNESS

I have described to ..... *(name of participant)* the nature of the research to be carried out. In my opinion she/he understood the explanation.

Status in Project: .....

Name: .....

.....
(signature) *(date)*

Consent Form

Ultrasound measurements of the muscles of the jaw
(A new method to assess orthodontic braces)

Researcher's Name **Dr Shazia Naser-ud-Din**
Supervisor's Name **Prof W Sampson & Dr C Dreyer**

- ☐ I have read the Participant Information Sheet and the nature and purpose of the research project has been explained to me. I understand and agree to take part.
- ☐ I understand the purpose of the research project and my involvement in it.
- ☐ Although I understand that the purpose of this research project is to improve the quality of medical care, it has also been explained to me that my involvement may not be of any benefit to me.
- ☐ I consent to the researchers accessing data and radiographs arising from my participation in a previous study performed at Adelaide University; "Reflex control of jaw muscles by periodontal mechanoreceptors in differing craniofacial patterns".
- ☐ I have been given the opportunity to have a member of my family or a friend present while the project was explained to me.
- ☐ I understand that I may withdraw from the research project at any stage and that this will not affect my status now or in the future.
- ☐ I understand that while information gained during the study may be published, I will not be identified and my personal results will remain confidential.
- ☐ I understand that ultrasound images will be taken as part of the study and that these records will be stored securely in a locked filing cabinet at the Dental School, University of Adelaide
- ☐ I understand that I should keep a copy of this Consent Form when completed, and the attached Participant Information Sheet.

- ☐ I give/do not give the researcher my permission to refer my ultrasound results to my General Medical Practitioner if the sonographer detects pathology in my results.

    - If providing consent for previous point please provide name of General Medical Practitioner .....
- ☐ I am over the age of eighteen years
- ☐ I would like a summary report of the finding forwarded to me

Name of Participant.....

Signed .....**Date**.....

I have provided the information about the research to the participant and believe that they understand what is involved.

Researcher's signature ..... Date .....

THE UNIVERSITY OF ADELAIDE HUMAN RESEARCH ETHICS COMMITTEE

STANDARD CONSENT FORM
FOR PEOPLE WHO ARE PARTICIPANTS IN A RESEARCH PROJECT

1. I, ... *(please print name)*

   consent to take part in the research project entitled:

   .....

2. I acknowledge that I have read the attached Information Sheet entitled:

   .....

3. I have had the project, so far as it affects me, fully explained to my satisfaction by the research worker. My consent is given freely.

4. Although I understand that the purpose of this research project is to improve the quality of medical care, it has also been explained that my involvement may not be of any benefit to me.

5. I have been given the opportunity to have a member of my family or a friend present while the project was explained to me.

6. I have been informed that, while information gained during the study may be published, I will not be identified and my personal results will not be divulged.

7. I understand that I am free to withdraw from the project at any time and that this will not affect medical advice in the management of my health, now or in the future.

8. I am aware that I should retain a copy of this Consent Form, when completed, and the attached Information Sheet.

   .....
   (signature) *(date)*

WITNESS

I have described to ..... *(name of participant)*

the nature of the research to be carried out. In my opinion she/he understood the explanation.

Status in Project: .....

Name: .....

.....
(signature) *(date)*

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THE UNIVERSITY OF ADELAIDE AUSTRALIA

Dr S Naser-ud-Din MSc
Prof. Dr WJ Sampson FDRCS
Dr CW Dryer PhD

SCHOOL OF DENTISTRY
THE UNIVERSITY OF
ADELAIDE

INFORMATION SHEET FOR PARTICIPANTS

3-D Facial Imaging

Background

Three dimensional Imaging or simply 3D imaging is an important addition to the armamentarium available for the diagnostic clinician. Previously two dimensional conventional x-rays provided information regarding the facial form. However, it had its short comings as the extrapolation to the real scenario was limited. With the introduction of 3D imaging nearly two decades ago it is finding use more in clinical dentistry. It is a safe non-invasive tool to evaluate the soft tissue dimension and changes over a period of time. This is particularly important with regards to growth or in major facial surgical reconstructions.

Aims of the Project

To utilise Mona Lisa 3D for assessing facial forms and comparing them with the conventional lateral Cephalometrics. Such studies add to our understanding of how to best incorporate new investigating tools in clinical practice.

Experimental Protocol

After written and verbal consent is provided by you we shall have you seated comfortably in a chair with natural head posture. You will be asked to keep your eyes closed during the recording session. White grid light will be shine on your face for couple of seconds and an image will be generated. The entire period spent in the recording room shall not be more than 30min.

Possible Risks

To date no risks have been documented with 3D imaging and hence it is considered a very safe method. However if you feel the light intense even with closed eyes we will provide you extra rest period of eye patches in severe scenarios.

Withdrawal Policy

This project has been approved by the Human Ethics Committee at the University of Adelaide. You have the right to withdraw from the experiments at anytime without explanation.

Contacts and Complaints documents are attached for your kind reference.

Contacts:

1.Prof Dr WJ Sampson

Begg Chair
Orthodontic Department
Room No. 5 214
Dental School, University of Adelaide
Frome Road, SA 5005
Tel (08) 8303 3293
Fax (08) 8303 3444
Email: wayne.sampson@adelaide.edu.au

2. Dr CW Dreyer

Orthodontic Department
Room No. 5 214
Dental School, University of Adelaide
Frome Road, SA 5005
Tel (08) 8303 3293
Fax (08) 8303 3444
Email: craig.dreyer@adelaide.edu.au

3. Dr John Fricker
Private Practice
Ist Floor ANZ Bank Building
27 Bougainville St Manuka
ACT 2603
Tel: 0262994812
Email: frickerj@tidbinbilla.com

4. Dr S Naser-ud-Din

Orthodontic Department
Room No. 5 219
Dental School, University of Adelaide
Frome Road, SA 5005
Tel (08) 8303 4279
Fax (08) 8303 3444
Email: shazia.naser-ud-din@adelaide.edu.au

THE UNIVERSITY OF ADELAIDE HUMAN RESEARCH ETHICS COMMITTEE
LIST OF HEADINGS APPLYING TO ALL APPLICATIONS

Guidance information for completion of this form is notated in (*italics)* under each heading. Please complete all headings.

APPLICATIONS MUST BE TYPED

1. TITLE

Correlation Studies of Masseter Muscle dimensions from

Ultrasonography and 3D Imaging Scans

2. INVESTIGATORS & QUALIFICATIONS

1.Prof Dr WJ Sampson

BDS, BSciDent (Hons), MDS, FDSRCS (Eng), FICD, FADI
Begg Chair
Orthodontic Department
Room No. 5 214
Dental School, University of Adelaide
Frome Road, SA 5005
Tel (08) 8303 3293
Fax (08) 8303 3444
Email: wayne.sampson@adelaide.edu.au

2. Dr CW Dreyer

PhD, MDS, BDS, FRACDS, FICD, G Cert Ed (HE)
Orthodontic Department
Room No. 5 214
Dental School, University of Adelaide
Frome Road, SA 5005
Tel (08) 8303 3293
Fax (08) 8303 3444
Email: craig.dreyer@adelaide.edu.au

3. Dr S Naser-ud-Din

PhD Candidate Orthodontics (University of Adelaide, Australia)
FICCDE, DCPSP –HPE, MSc Orthodontic, DPH Dent, CFD,BDS

Orthodontic Department
Room No. 5 219
Dental School, University of Adelaide
Frome Road, SA 5005
Tel (08) 8303 4279
Fax (08) 8303 3444
Email: shazia.naser-ud-din@adelaide.edu.au

3. PURPOSE OF THE STUDY

- Aims
  To evaluate non-invasive tools for assessment of facial soft tissues in particular the Masseter muscle

- Rationale *To assist in future diagnosis and treatment planning. Moreover, it will provide safe tools for sequential recordings particularly in growing children. This last feature will be of great benefit especially in routine in orthodontic evaluations.*

4. BACKGROUND

Ultrasonography

Ultrasonography or Ultra-sound as it is commonly referred to has been used in medical investigations for over two decades. Primarily used for foetal assessments and considered extremely safe [Duck 2007] as compared to ionizing radiations, is now finding application in broader medical diagnosis and treatment planning. However, it has not found the same degree of acceptance yet in dentistry and it will be valuable if it provides vital information to the dental fraternity due to its two main advantages: safety and cost-effectiveness. Work is in progress with published studies looking into diagnosing different conditions with Ultrasonography [Pancherz 1994, Jank et al 2006, Emshoff 2003].

3D Imaging

The 3D imaging is a system utilising structured light technique, whereby a grid projected as a wave across the face with recordings in stereo with digital video cameras. This provides 3D coordinates as well as photo realistic, natural colour imaging of the face. The software Mona Lisa 3 D® permits rotation of the image so that it can be viewed from any perspective. The coordinate system allows for volumetric documentation of changes, be they growth, treatment or otherwise. These images may also be superimposed for a "*heat-map style*" of colour differences to reflect the changes in facial topography. When taking the image, the head is standardised in the natural head position as per the visual axis. The scanning system is non invasive with the projection of white light to the face and video recording, The risks to the subject are no greater than that of flash photography. 3 D imaging is making its way into mainstream treatment planning in both orthodontics and surgical planning [Ireland et al. 2008, Kau et al 2007]

Current Study

To evaluate non-invasive tools for assessment of the masseter muscle. Both these modalities had limited use with respect to masseter muscle evaluation. The findings can provide clinicians with additional soft tissue recordings not thus far available in mainstream diagnosis particularly in Orthodontics. The muscles of the face are difficult to measure but we aim to use ultrasound technology to determine size and shape of the main chewing muscle (the masseter). Furthermore, the 3-D recording of a person's face is increasingly important in clinical practice and we aim to scan volunteer subject's faces to compare the external dimensions with the underlying muscles to see how closely the structures actually relate to each other. This has importance in surgery and orthodontic treatment.

5. PARTICIPANTS

- Source Volunteers from University of Adelaide
- Number 30 students
- Age range 18-36 years
- Selection & exclusion criteria *Young healthy adults with no previous pathology, extractions, Temporomandibular dysfunctions, or large restorations*

6. PARTICIPANT RECRUITMENT

- Procedures *Previous cohort from Part 1 of the study conducted in 2007. They have provided with their contact details for subsequent project participation. Dr S Naser-ud-Din has the access and will approach through calls and emails to recruit again.*
- Material *not relevant this time – previous contact details*
- Payment *Time spent will be renumerated at acceptable rate*

7. PRELIMINARY STUDY (if any)

Pilot was run on Ultrasonography on skulls and chicken fillets simulating the masseter muscle to assess the recordings for validation.

8. STUDY PLAN & DESIGN

Ultrasonography
Each participant will have verbal and written consent. Thereafter in approx 30 min session Ultrasonography (U/s) recordings will be made from the left masseter with a probe and gel application –standard for any U/s. Both the length and thickness of the left masseter will be recorded in the soft ware. The dimensions will be calculated and used in statistics against the previous measurements of lateral Cephalometrics.

3-D imaging will be conducted at School of Dentistry with Mona Lisa 3D and will take approximately 30min. Its painless procedure with the subject seated and eyes closed without strain. The images will be analysed and correlated with previous data.

9. DRUGS not applicable

10. EFFICACY

Considered a safe and non-invasive method- no adverse reactions documented thus far.

11. DATE OF PROPOSED COMMENCEMENT

Early Dec 2008

12. ETHICAL CONSIDERATIONS

All participants will be given the choice to withdraw if experiencing discomfort from any source. Overall a very safe and non-invasive methodology is being evaluated. In case of white light intensity eye pads (airline type) can be used.

13. SAFETY & ECOLOGICAL CONSIDERATIONS

The safety guidelines will be adhered to for the equipment in use i.e Ultrasongraphic recordings and Mona Lisa 3 D.

14. RESEARCH DATA RECORDING & STORAGE

Ultrasound recordings will be stored at the UniSA Centenary Building East Campus and copies for data analysis will be made available to Dr S Naser-ud-Din and stored with confidentiality in School of Dentistry. Backup will be made on DVD's. Likewise 3D images will be stored at the School of Dentistry and confidentiality ensured.

15. ANALYSIS & REPORTING OF RESULTS

Descriptive statistics and Multi-modal analysis will be conducted along with correlation statistics. Findings will be published in the PhD Thesis for Dr S Naser-ud-Din and journal articles will be submitted with strict consideration to de-identification of the subjects. If the subjects request for image copies, those will be made available to them on one to one basis.

16. OTHER RELEVANT INFORMATION

No previous study has looked into such diverse but non-invasive investigating tools for the same population.

17. OTHER ETHICS COMMITTEES TO WHICH PROTOCOL HAS BEEN SUBMITTED

Uni SA East Branch, Frome Road, Adelaide

18. PROPOSED FUNDING SOURCE

University of Adelaide and ADRF (Australian Dental Research Foundation)

19. *REFERENCES*

Duck FA, (2005)
Ultrasound exposure measurement: a hidden science?
Br J Radiol: 78, 289-291

Ruf S, Pancherz H, Kirschbaum M, (1994)
Facial Morphology and the size and activity of the masseter muscle
Fortschr Kieferorthop 55(5): 219-27

Emshoff et al, (2003)
Condylar Erosion and Disc Displacement: Detection with High Resolution Ultrasonography
J Oral Maxillofac Surg 61: 877-881

Jank S et al, (2007)
Sonographic Investigation of the Temporomandibular Joint in Patients with Juvenile Idiopathic Arthritis: A Pilot Study
Arthritis and Rheumatism 57:213-18

Ireland et al, (2008)
3D surface imaging in dentistry-what are we looking at
BDJ *Vol 205(7): 387-393*

Kau et al, (2007)
Three dimensional surface acquisition systems for the study of facial morphology and their application to maxillofacial surgery.
The International Journal of Medical Robotics and Computer Assisted Surgery
Vol 3: 97-110

THE UNIVERSITY OF ADELAIDE
HUMAN RESEARCH ETHICS COMMITTEE

Document for people who are participants in a research project

CONTACTS FOR INFORMATION ON PROJECT AND INDEPENDENT COMPLAINTS PROCEDURE

The Human Research Ethics Committee is obliged to monitor approved research projects. In conjunction with other forms of monitoring it is necessary to provide an independent and confidential reporting mechanism to assure quality assurance of the institutional ethics committee system. This is done by providing research participants with an additional avenue for raising concerns regarding the conduct of any research in which they are involved.

The following study has been reviewed and approved by the University of Adelaide Human Research Ethics Committee:

Project title:

Correlation Studies of Masseter Muscle dimensions from Ultrasonography and 3D Imaging

1. If you have questions or problems associated with the practical aspects of your participation in the project, or wish to raise a concern or complaint about the project, then you should consult the project co-ordinator:

   Name: ***Prof Dr W J Sampson***
   telephone: **(08) 8303 3293**

2. If you wish to discuss with an independent person matters related to
   - making a complaint, or
   - raising concerns on the conduct of the project, or
   - the University policy on research involving human participants, or
   - your rights as a participant

contact the Human Research Ethics Committee's Secretary on phone (08) 8303 6028

secretariat\ethics\human\complain.doc

EPA
South Australia

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Radiation Protection Division
PO Box 721, Kent Town SA 5071
(103 King William Street
Kent Town SA 5067)

Telephone (08) 8130 0700
Facsimile (08) 8130 0777

Professor Wayne Sampson
Chair, Orthodontics
School of Dentistry
The University of Adelaide
ADELAIDE 5005

Dear Professor Sampson

RE: APPROVAL OF RESEARCH STUDY

Title: 'Reflex Control of Jaw Muscles by Periodontal Mechanoreceptors in Differing Craniofacial Patterns'

I refer to your application seeking approval of the above research study which involves exposure of humans to ionizing radiation.

Pursuant to Regulation 45 of the Radiation Protection and Control (Ionising Radiation) Regulations 2000, the above research study is approved provided that the study be carried out in accordance with the application and information submitted.

Yours sincerely

[redacted]

Graeme Palmer
ACTING DIRECTOR
RADIATION PROTECTION DIVISION
ENVIRONMENT PROTECTION AUTHORITY

Date: 25 January 2007

HEALTH PHYSICS SERVICES Pty Ltd
Specialists in Medical Radiation Physics and Radiation Protection
ACN: 072 469 875

148 Marlborough St Henley Beach, 5022
Telephone: 041 212 6596 or (08) 8353 8550
Email: hps@picknowl.com.au

ABN: 31 072 469 875

RADIATION SAFETY REPORT

Title:
Reflex control of jaw muscles by periodontal mechanoreceptors in differing craniofacial patterns.

Investigator:
Dr S. Naser-Ud-Din, Dr W. Sampson and Dr K. Turker.

Studies performed:
The subjects will have a standard lateral cephalogram.

Effective Dose (ED)

The lateral Skull radiograph data from Wall et al (reference) was used for the effective dose estimate for a lateral cephalogram.

Skull Lateral = 10 μSv

Comment:

The radiation burden for the study is approximately 10 μSv (compared to the annual background radiation dose of approximately 2000 μSv).

References:

Wall, BF and Hart, D. *Revised radiation doses for typical X-ray examinations.* Brit J Radiology, 70,437-439, 1997

[redacted]
P.J. Collins, MSc
09 January 2007

THE UNIVERSITY OF ADELAIDE
AUSTRALIA

RESEARCH BRANCH
RESEARCH ETHICS AND COMPLIANCE UNIT

SABINE SCHREIBER
SECRETARY
HUMAN RESEARCH ETHICS COMMITTEE
THE UNIVERSITY OF ADELAIDE
SA 5005
AUSTRALIA

TELEPHONE +61 8 8303 6028
FACSIMILE +61 8 8303 3417
email: sabine.schreiber@adelaide.edu.au
CRICOS Provider Number 00123M

14 December 2006

Dr KS Türker
Physiology

Dear Dr Türker

PROJECT NO: *Reflex control of human muscles*
H-29-2001

Thank you for your email dated 28.11.06 requesting a variation to the above project.

I write to advise you that on behalf of the Human Research Ethics Committee I have approved the variation request to obtain a radiograph showing the head and jaw structure of consenting participants. Approval is subject to some minor modification to the participant information sheet.

The ethical endorsement for the project applies for the period until 30 June 2007.

Yours sincerely

[redacted]

Professor Garrett Cullity
Convenor
Human Research Ethics Committee

PROJECT NO: H/

THE UNIVERSITY OF ADELAIDE HUMAN RESEARCH ETHICS COMMITTEE
ETHICS APPLICATION COVER SHEET

SUMMARISING THE PROTOCOL AND INCLUDING INVESTIGATORS' SIGNATURES

COVER SHEET AND APPLICATIONS MUST BE TYPED

Applications will be considered according to requirements of the National Statement on Ethical Conduct in Human Research (2007).
An application should include: (1) this **cover sheet**; (2) the proposal addressing the **list of headings**; (3) participant **information sheet**; (4) participant **consent form**, and (5) **independent complaints procedure statement** (please access these online at http://www.adelaide.edu.au/ethics/human/guidelines/applications/).
Submit **ELEVEN** copies of the application to the Secretary, Human Research Ethics Committee, Research Ethics and Compliance Unit, Research Branch, Level 7, 115 Grenfell Street, The University of Adelaide SA 5005 Ph. (08) 8303 6028, Fax (08) 8303 7325, email sabine.schreiber@adelaide.edu.au

Please attach this to the front of the application.

APPLICANT Name include title Professor/Dr/Ms/Mr **and Position**

Prof W J Sampson, Begg Chair , Orthodontic Unit
If this is a student project the principal supervisor is to be the applicant.

DEPARTMENT including campus/institution contact address
Orthodontics , School of Dentistry, University of Adelaide, Frome Road SA 5005

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OTHERS INVOLVED

Dr Craig Dreyer , Co-supervisor, Orthodontic Unit, School of Dentistry, University of Adelaide
Dr Kerry Thoirs, Collaborator, Uni SA , East Campus, Frome Road, Adelaide
Dr Shazia Naser-ud-Din, PhD Candidate, Orthodontic Dept, School of Dentistry, University of Adelaide

If this is a student project please indicate name/department/candidature

PROJECT TITLE

Correlation Studies of Masseter Muscle dimension from Ultrasonography and 3D Imaging

LOCATION OF RESEARCH
Uni SA for Ultrasonography & School of Dentistry University of Adelaide 3 D Imaging

DATE PROJECT TO BEGIN
Dec 2008 (early)

ESTIMATED DURATION OF PROJECT 6 months

SOURCE OF FUNDING University of Adelaide & ADRF grants

AIMS OF PROJECT please give concise description in lay terms

To evaluate photographic and ultrasound methods for assessment of the masseter muscle. Both these modalities have had limited use with respect to masseter muscle evaluation. The findings can provide clinicians with additional soft tissue recordings not thus far available in mainstream diagnosis, particularly in Orthodontics. The muscles of the faces are difficult to measure but we aim to use ultrasound technology to determine size and shape of the main chewing muscle (the masseter). Furthermore, the 3-D recording of a person's face is increasingly important in clinical practice and we aim to scan volunteer subjects' faces to compare the external dimensions with the underlying muscles to see how closely the structures actually relate to each other. This has importance in surgery and orthodontic treatment.

PLAN/DESIGN OF PROJECT brief description in lay terms

30 participants from an earlier study by the same research student (Dr Shazia Naser-ud-Din) will be recalled and asked to volunteer. Previously, muscle reflex recordings and radiographs were used to assess the relation between masseter muscle reflex and different facial types (Previous Ethics granted H -29-2001 & EPA approved on January 25, 2007- Ru/03/004)
Each subject will be provided with information sheet and consent will be obtained.
After approval, the Ultrasound measurements will be made at UniSA with Dr K Thoirs, each subject having one 30 min session (or less).
During the week, another session with 3D photographic imaging will be conducted by Dr S Naser-ud-Din at the School of Dentistry lasting approx 30min.
The participants may be remunerated for their time spent in the sessions.
The Ultrasound recordings and the 3-D imaging are not considered invasive procedures and do not involve x-rays.

PARTICIPANTS

- Source: University of Adelaide Students both males and females
- Age range: 18-36 years
- Selection criteria: Volunteers Healthy young adults
- Exclusion criteria : any pathologies, TMD(Temporomandibular Dysfunctions), previous extractions or major restorative work

These people have already participated in the first part of this study (H-29-2001) conducted in 2007

ETHICAL IMPLICATIONS OF PROJECT

All are non-invasive procedures and will not be detrimental to any ones health and well being.

Volunteer participation

Verbal and written information will be given and written consent will be obtained from each individual

DRUGS

Will drugs be administered to participants?	YES / NO
• If so give name of drug(s)	
• Dosage:	
• Method of administration	
Is the administration for therapeutic purposes?	YES / NO
Will the project be conducted under the	
Clinical Trials Notification (CTN) Scheme?	YES / NO
Clinical Trials Exemption (CTX) Scheme?	YES / NO
Is Commonwealth Department of Health permission required?	YES / NO
If so, has permission been obtained?	YES / NO

SIGNATURE OF ALL INVESTIGATORS NAMED IN THE PROTOCOL

Date

EXPERIMENTAL PROTOCOL

Starting

Short cut to PID

Operate RT:0

Open again White Arrow RUN

Exit without closing

IZZY

Load settings Shazia Set

RECORD

Put in the correct file name Date subject initials and type of recording

1. Record Noise (use continuous triggers)
2. Record Static Max
3. Record Dynamic Max in device (add value to controller 2, amplified at 1)
4. Click on "Convert Dat to Continuous Text" and then on display, add gain and offset values to channel 4 (Jaw Position)
5. Read channel 4 and record the approximate mid-opening (i.e. 17mm)
6. Correspond this value to the calibration sheet to get the voltage value

7. Go to "Create pattern" and click on "Standard"
8. Load the waveform named "pulse" (pulse with stimulus)
9. Click on "Show all settings" and add the value from step 6 into the "Rising" and "Falling" and finish ensure phase is "both"

1

10. Then go to "Settings" and create file name to record dynamic
11. Now go to "PID controller" and load the waveform named "pulse"
12. Click on "Record data" and record approximately 3-4 minutes of data

13. Go to [redacted] and click on the recently recorded dynamic Dat file (Dynamic_no_stimulus)
14. On the filter page fill on gain and offset value into channel 4 (both are negative) and all the values for all the EMG channels (Channel 5 will have both gain and offset with bandpass filter between 20-500Hz) and finish
15. Go to "Create Trigger Channel" in the folder "Programs for opening and closing"
16. Click on run and chose channel 4
17. Re-scale the x-axis to a value of 20 and the width to 100
18. Adjust the yellow (top) and red (bottom) lines to get as much opening and closing cycles as possible, preferably all – use scroll bar to check this and then click on "Save triggers"

19. Then go to "My computer" and the corresponding folder to ensure that opening and closing text files have been created
20. Go to "Add triggers program" in the folder "Programs for opening and closing"
21. Click on run and follow screen commands – Dat file that was filtered in step 13, then closing and opening text files generated in step 18; this will generate a Dat file

22. Click on "Extract data around trigger" in Izzy and chose the Dat file generated in the previous step
23. Before exporting the data – Pre-trigger = 0, Post-trigger = 500, Min trigger point = 0.3 and Trigger channel will be 8 (for closing)

24. Then export and ensure gain and offset values are in for channel 4 and that all EMG channels are rectified, then finish

25. Go to "My computer" and then "Added triggers" folder and the text files and open channel 4 in excel and go the average value found in step 5 (the mid-opening) and record the time which corresponds
26. Then open the text file for channel 5 in excel, copy the first two columns and paste them in a new spreadsheet
27. In the third column, in cell number 7 type in, =average(cell#2,cell#7), then drag it down
28. Then go down to the time value which was achieved in step 25 and record the average EMG value – this will be the EMG value that will be used for Static Closing
29. Then repeat steps 23-28 but in step 23 that trigger channel will be 9 (for opening) and this will give you the EMG value for Static Opening

30. Then go to "Settings" and create file name to record static closing
31. Now go to "PID controller" and load the waveform named "pulse_static"
32. Set "subject feedback" and ensure that feedback is from channel 5 and set the value corresponding to the EMG value for closing
33. Click on "Record data" and record for 50 triggers (approximately 1m 15sec)
34. Repeat steps 30 to 33 (except for step 31) but for step 30 set the file name for static opening and for step 32 the value for EMG opening

ANALYSIS

35. Place all Dynamic data into a new folder 'Dynamic'
36. Extract around triggers
37. Select 'Dynamic' folder
38. Insert 'Position' gain and offset and rectify EMG
39. Export
40. You will now have a folder under the Dynamic folder called 'Text'
41. Analyse Txt File
42. Time domain analysis
43. Text
44. Run 'Movement' program
45. You will now have a folder called 'Movement' under the Text folder
46. Split the 'Movement' file into two folders: 'Stimulus' 'No Stimulus' and place appropriate files into these folders
47. Split the 'Stimulus' folder into: 'Close' and 'Open' folders and insert appropriate files into them
48. Split the 'No Stimulus' folder into: 'Close' and 'Open' folders and insert appropriate files into them
49. Run 'Normalization' program and follow screen commands (one folder at a time)
50. Make sure that you only have three channels on the screen
51. Calculate 'Noise'
52. Move all 'Rest' txt files into a folder called 'Noise'
53. Run 'Analyse Text program
54. Choose 'Edit' function
55. Choose 'Down Sample' function
56. Insert original number of samples as 'down sample' option
57. Read out the noise from the excel
58. Run 'Reflex' program
59. Insert the file to be used

4

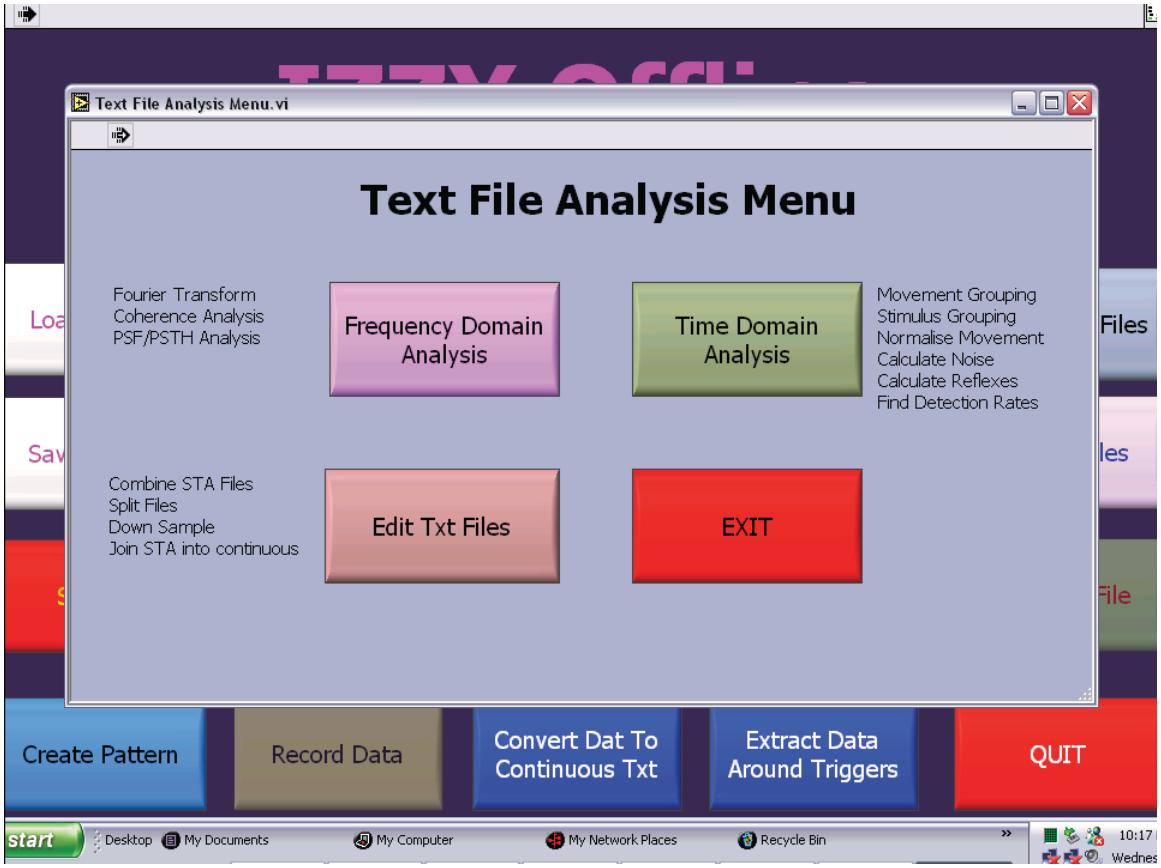
ANALYSIS

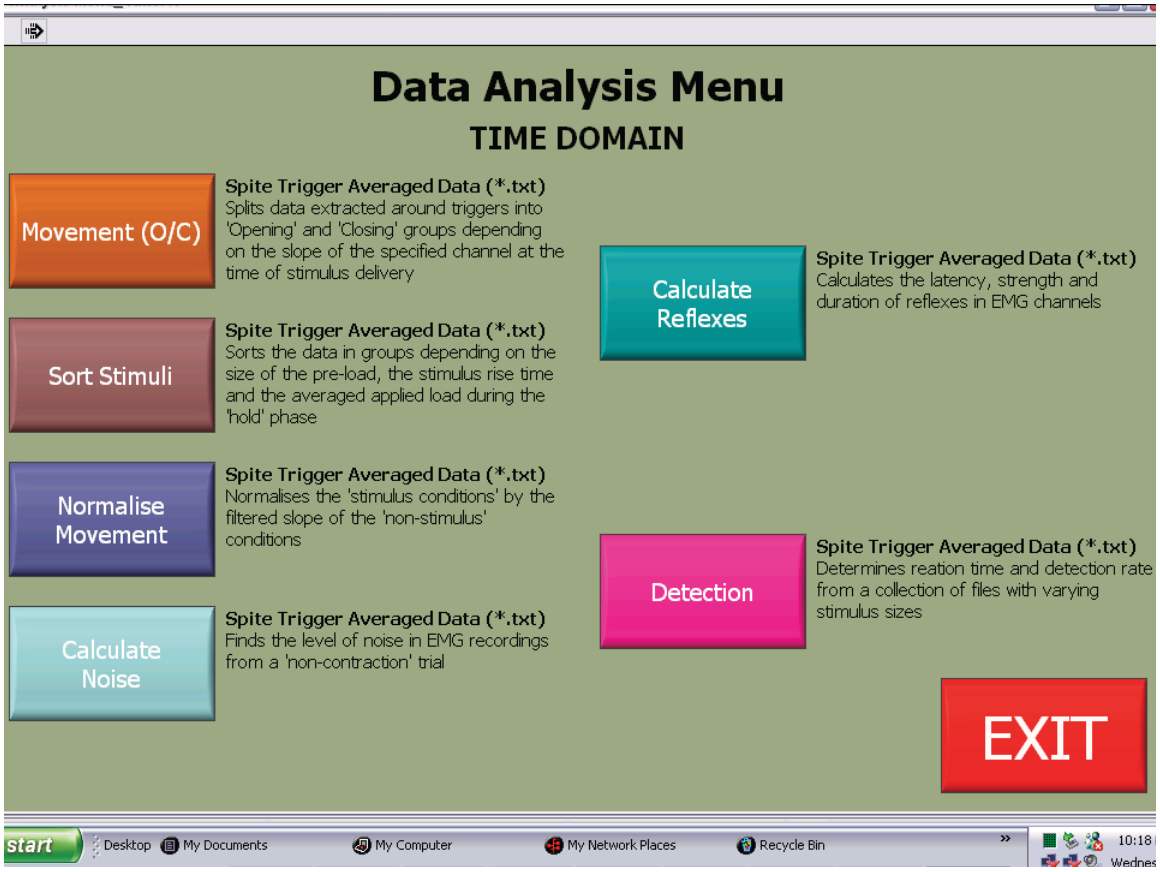
The following steps were used to extract the relevant data for PMR and Spindle response.

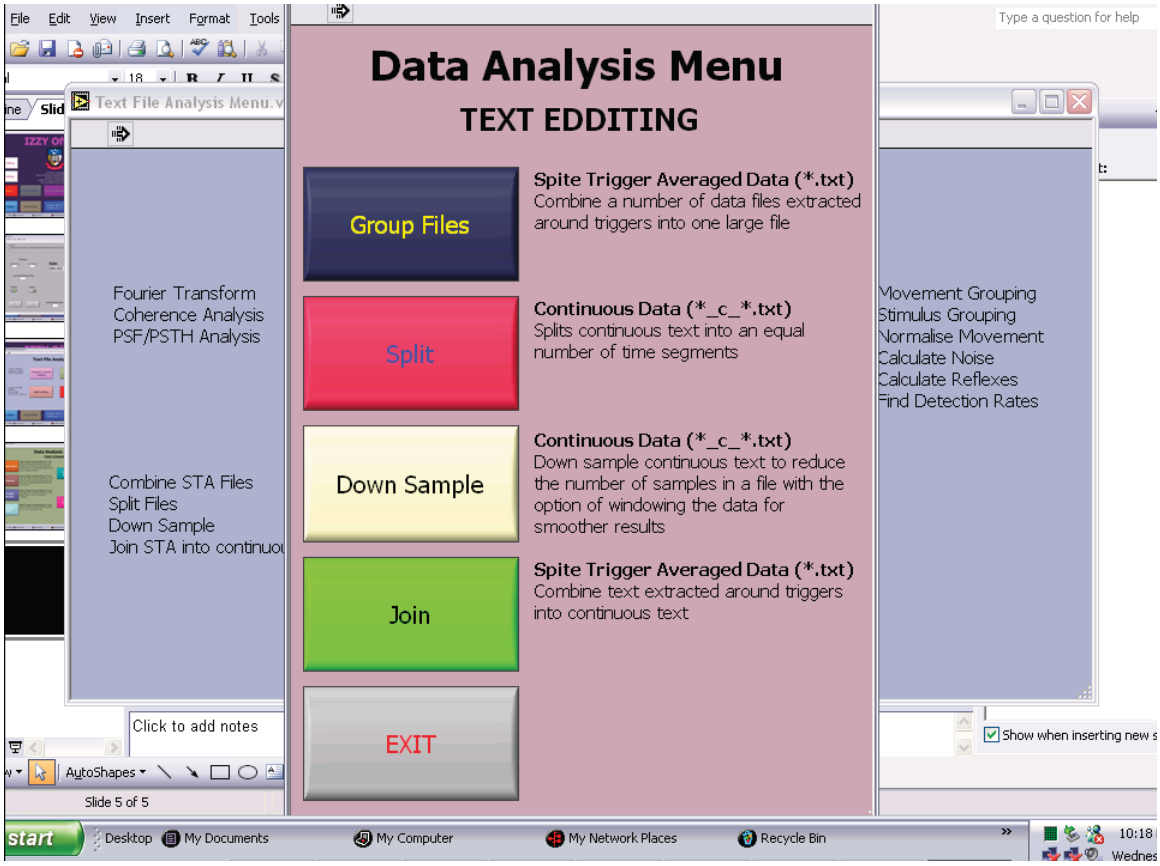
1. All recorded data was converted into txt files
2. Dynamic and static folders were created
3. Control and Local Anaesthetic folders were in turn made with in the dynamic and static
4. Special Sorting program Sort III was utilized to pick up control, high and low stimuli
5. All dynamic files were Normalized, this does not apply to static variables
6. Finally reflexes were calculated for each of the 16 variables in both EMG and CUSUMS
7. Following graphical evaluation of each subject, averages were calculated for 29 subjects that qualified the cut off point for inclusion criteria.
8. Arithmetic differences pre- and post Anaesthesia provide the PMR response and can be then compared with overall and spindle response
9. Responses from Dynamic versus Static were also calculated
10. Continuous timeline will assess the responses from spindles from different facial heights.

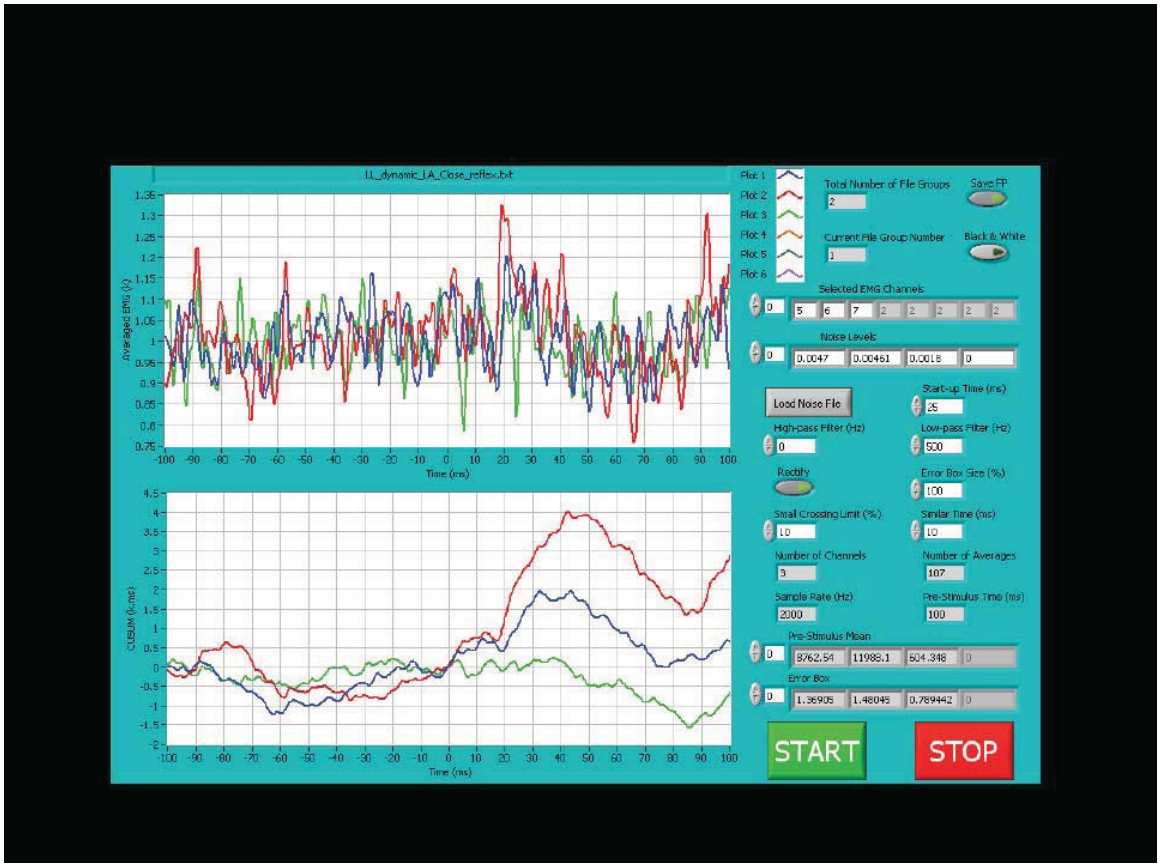

IZZY Offline
SUB CRUCE LUMEN
University of Adelaide
School of Molecular and Biomedical Sciences
Dicipline of Physiology
Centre For Human Movement Research
Oral Neuralphysiology Laboratory
Load Settings
Save Settings
Analyse Txt Files
Edit Dat Files
Settings
PID Controller
Online Calibration
Offline Calibration
Play Back File
Create Pattern
Record Data
Convert Dat To Continuous Txt
Extract Data Around Triggers
QUIT
start
Desktop
My Documents
My Computer
My Network Places
Recycle Bin


Offline Cal.vi
File Edit Operate Tools Window Help
Offline Cal
File Name
C:\Documents and Settings\Dr. Shazia\Desktop\Offline LabVIEW Analysis Program\07_02_14A\Text\BC_Max_static_c_4.txt
Filtering
High Cutoff (Hz)
500
Low Cutoff (Hz)
20
Gain
280.423
Offset
-0.010399
Low Pass Filtering (Hz)
1
Rectify
Invert
Start
Exit
Scaled lower limit
0
Scaled upper limit
100
start
Desktop
My Documents
My Computer
My Network Places
Recycle Bin


Text File Analysis Menu.vi
Text File Analysis Menu
Fourier Transform
Coherence Analysis
PSF/PSTH Analysis
Frequency Domain Analysis
Time Domain Analysis
Movement Grouping
Stimulus Grouping
Normalise Movement
Calculate Noise
Calculate Reflexes
Find Detection Rates
Combine STA Files
Split Files
Down Sample
Join STA into continuous
Edit Txt Files
EXIT
Create Pattern
Record Data
Convert Dat To Continuous Txt
Extract Data Around Triggers
QUIT
start
Desktop
My Documents
My Computer
My Network Places
Recycle Bin


Data Analysis Menu
TIME DOMAIN
Movement (O/C)
Spite Trigger Averaged Data (*.txt)
Splits data extracted around triggers into 'Opening' and 'Closing' groups depending on the slope of the specified channel at the time of stimulus delivery
Sort Stimuli
Spite Trigger Averaged Data (*.txt)
Sorts the data in groups depending on the size of the pre-load, the stimulus rise time and the averaged applied load during the 'hold' phase
Normalise Movement
Spite Trigger Averaged Data (*.txt)
Normalises the 'stimulus conditions' by the filtered slope of the 'non-stimulus' conditions
Calculate Noise
Spite Trigger Averaged Data (*.txt)
Finds the level of noise in EMG recordings from a 'non-contraction' trial
Calculate Reflexes
Spite Trigger Averaged Data (*.txt)
Calculates the latency, strength and duration of reflexes in EMG channels
Detection
Spite Trigger Averaged Data (*.txt)
Determines reation time and detection rate from a collection of files with varying stimulus sizes
EXIT
start
Desktop
My Documents
My Computer
My Network Places
Recycle Bin


Data Analysis Menu
TEXT EDDITING
Group Files
Spite Trigger Averaged Data (*.txt)
Combine a number of data files extracted around triggers into one large file
Split
Continuous Data (*_c_*.txt)
Splits continuous text into an equal number of time segments
Down Sample
Continuous Data (*_c_*.txt)
Down sample continuous text to reduce the number of samples in a file with the option of windowing the data for smoother results
Join
Spite Trigger Averaged Data (*.txt)
Combine text extracted around triggers into continuous text
EXIT
Fourier Transform
Coherence Analysis
PSF/PSTH Analysis
Combine STA Files
Split Files
Down Sample
Movement Grouping
Stimulus Grouping
Normalise Movement
Calculate Noise
Calculate Reflexes
Find Detection Rates
Text File Analysis Menu.v
Click to add notes
Slide 5 of 5
Type a question for help
Show when inserting new s
start
Desktop
My Documents
My Computer
My Network Places
Recycle Bin


LL_dynamic_LA_Close_reflex.txt
Time (ms)
Total Number of File Groups
Save FP
Current File Group Number
Black & White
Selected EMG Channels
Noise Levels
Load Noise File
Start-up Time (ms)
High-pass Filter (Hz)
Low-pass Filter (Hz)
Rectify
Error Box Size (%)
Small Crossing Limit (%)
Similar Time (ms)
Number of Channels
Number of Averages
Sample Rate (Hz)
Pre-Stimulus Time (ms)
Pre-Stimulus Mean
Error Box
START
STOP