THE INFLUENCE OF THE LEAF GAUGE ON JAW MUSCLES, EMG

ROBERT SANTOSA

A treatise submitted in partial fulfillment of the requirements for the degree of Master of Dental Science (Prosthodontics)

Faculty of Dentistry, University of Sydney
November 2001

Statement of Authorship

I declare that all the work presented in this treatise is my own, unless otherwise stated. The work of colleagues is acknowledged in general terms within the *Acknowledgements* and specifically within the body of the text, wherever it is appropriate.

Robert Santosa

November 2001

Acknowledgement

I would like to acknowledge the following people for their contributions to this treatise:

Dr. Milad Azizi
Professor Iven J Klineberg
Associate Professor Greg Murray
Mr. Kamal Wanigaratne
Ms.Terry Whittle
Dr. Intira Phanachet
Dr. Eric Huang
Mr. Ken Tyler

and

Dental Board of NSW for the research grant to Professor Klineberg

INDEX PAGE

LITERATURE REVIEW

INTRODUCTION

The leaf-gauge (LG) and anterior jig (AJ) technique are used in dental practice for the registration of jaw records in centric relation (CR). In LG recordings, the leaves are placed between the incisor teeth and held with varying degrees bite-force. Leaves are added to ensure that the posterior teeth are not in contact. It is claimed that this procedure allows for greater ease in jaw guidance and ensures that the condyle is in its most stable position for recording purposes. AJ recordings use a similar concept, where an acrylic resin jig is attached to the upper anterior incisors and allows disclusion of the posterior teeth.

Long (1973) first described a technique to locate CR with an LG. He stated that the LG, when placed between the anterior teeth, aids the patient in retruding the mandible and forces the condyles against the menisci. It was believed that CR is the most "retruded- superior" position for the condyle. However, the relationship between the condyle and articular eminence as a result of the LG was speculative and not objectively studied in his paper.

1. CENTRIC RELATION or median retruded relation, retruded contact position, retruded axis position.

CR has been advocated in the past to be the ideal jaw position for fixed prosthodontic and complete denture reconstructions, TMJ therapy, orthodontics and facial pain treatment Keshvad and Winstanley (2000).

Celenza (1973) pointed out the dilemma of treatment of severely disorganized occlusions, and the difficulty in determining the original tooth contact position. Hence, the need to determine a jaw position that is *reproducible* for treatment and physiologically stable. Celenza asked the question whether retruded position (RP) and CR were two different positions, since CR was described as the most retruded position.

The definition of CR has undergone substantial changes over the past 50 years (Glossary of Prosthodontic Terms 1956, 1960, 1968, 1977, 1987, 1994, 1999), despite the fact that the same methods are used and claimed to be valid and compatible with recent definitions.

The ever-changing definition of CR highlights the difficulty of clinicians and academics to study the dynamic functional movement of the condyle, as asked by Keshvad and Winstanley (2000), " Perhaps it is the TMJ that adapts itself to the scientists' definition each time it changes, or is the TMJ accepting any position?"

The Glossary of Prosthodontic Terms (5th edition) in 1987, introduced the change of condyle position from the most *postero-superior* position to the most *antero-superior* position. Little research has been conducted since to validate or confirm this statement.

The current definitions of CR described in the Glossary of Prosthodontic Terms from the Academy of Prosthodontics (1999) is: "the maxillomandibular relationship in which the condyles articulate with the thinnest avascular portion of their respective disks with the complex in the anterior-superior position against the slopes of the articular eminences. This position is independent of tooth contact. This position is clinically discernible when the mandible is directed superior and anteriorly. It is restricted to a purely rotary movement about the transverse horizontal axis". However, there is no mention of the EMG activity of jaw muscles when the condyle is in CR position.

The RP is the spatial position of the jaw when the condyles are located in their close-packed position within the glenoid fossa at an acceptable vertical dimension of occlusion. Ideally, RP should be the position of the mandible at tooth contact where the condyles are in a physiologically acceptable position (i.e. biologically stable but not a fixed position long-term) for *reproducible* transfer recordings (Klineberg 1991). This jaw position is specific for each individual. RP describes the jaw position with the condyles in CR.

Many studies report that CR is the ideal treatment position, however the need for recording CR depends on the clinical treatment required. In a descriptive paper on CR, Carroll et al (1988) stated the significance and advantages of being able to place the jaw and condyles into CR are as follows:

1. "CR is usually an easily reproducible and comfortable position."

The reproducible position of the condyle allows construction of prostheses in the absence of the original tooth position.

2. "When the condyles are retruded, the mandible is capable of repeatedly making a purely rotational movement through an incisal separation of 10-25 mm permitting location and transfer of this axis to an articulator."

The condyle may be guided repeatedly along a rotational path whilst in CR as it is braced against the eminence. However this rotational hinge axis path is not a static position. Ferrario et al (1996) stated that pure rotation around the intercondylar hinge axis does not exist in open-close movements in the human temporomandibular joint (TMJ).

3. “Patients appear to function comfortably in CR, after CR occlusal equilibration, after full mouth rehabilitation, during occlusal splint therapy and wearing complete dentures.”

Occlusal equilibration, which is usually directed at removing the IP-RP slide, may often require extensive tooth reduction to harmonize the tooth contact position in CR. This provides a specific occlusal scheme. Extensive tooth reduction is questionable and not recommended (De Boever et al 2000).

Full mouth rehabilitation, may involve the establishment of a new vertical dimension of occlusion and requires the use of CR (Becker et al 2000). The CR record is often taken using the bimanual guidance technique with the patient in the supine position (Dawson 1989). CR must be comfortable, repeatable and involve condylar rotational movement.

Stabilizing occlusal splints are designed to have a flat contact surface with opposing cusp tips; this does not restrict the jaw to CR. In the case of complete dentures, the instability of the denture bases does not require a restricted occlusion. However, there is a need for stability in IP (jaw position at which the teeth are in static contact) and balanced contacts in lateral excursions. An ideal complete denture occlusion should enhance the stability of the bases as indicated by Fish (1952).

4. “Numerous TMJ disturbances , including pathological changes, may occur or are triggered when malocclusion exists because of tooth movement, dental restorations or inadequate orthodontic treatment.”

It has been clearly shown by Pullinger et al (1993) that “occlusion cannot be considered the unique or dominant factor in defining TMD populations”. In addition, Sim et al (1995) concluded in their review paper “ there is no increased risk of TMD associated with any type of orthodontic mechanics”.

5. “Patients with painful TMJs frequently report surprisingly quick relief of their pain and other symptoms after wearing an occlusal splint, biting on a LG for several minutes or after a dentist has removed the tooth or teeth which were prematurely contacting in the CR position.”

Dao et al (1994) concluded in their controlled clinical trial, on the efficacy of oral splints in the treatment of myofascial pain of the jaw muscles, “the gradual reduction in the intensity and unpleasantness of myofascial pain, as well as the improvement of quality of life during the trial was non-specific and not related to the type of treatment.” Barghi et al (1979) also concluded that occlusal discrepancies causing lateral deflection of the mandible might not be a sufficient etiological factor in either nocturnal bruxism or myofascial pain dysfunction.

1.1 Centric relation registration methods

The question arises as to whether the jaw position obtained by different jaw guidance techniques is biologically acceptable to the neuromuscular system in the long-term. Each technique claims to allow accurate maxillo-mandibular relationship recordings. Despite research studies to determine condylar position during CR recordings, it has proven to be difficult.

Different methods have been described in the literature. In her review article Dixon (2000) described 4 categories of recording CR for *complete denture* construction:

1. Direct interocclusal records

   These are also referred to as the physiologic records. Of importance to the success of the direct recording method is the dentist's ability to recognize CR position and that the recording material directly influences the pressure developed in the recording. Swallowing was often used as a guide to obtain the CR in complete dentures.

2. Intraoral and Extraoral graphic recordings

   These recordings include Gothic- arch (arrow- point tracings), which apply mostly to complete denture construction.

3. Functional recordings

Functional methods of recording CR were designed to attempt to record the jaw relationship physiologically without operator guidance. Under these conditions there is a need for the bases to be particularly stable. If the base is dislodged, the record will obviously be inaccurate. Some clinicians including Boos (1954) have used maximal biting pressure to simulate functional biting positions. However, Boos changed his mind later and recommended CR records be taken with no pressure.

4. Cephalometrics

These radiographs have been used to determine CR and the appropriate vertical dimension of occlusion. This practice, however, has not gained widespread application.

According to Dawson (1989) who described the use of a bilateral manual technique, the temporomandibular ligament appears to act as the posterior limit and a fulcrum. He claims that the downward force of the thumbs on the chin together with the upward supporting force of the fingers along the lower border of the jaw help seat the condyles in the antero-superior portion of the glenoid fossa.

1.1.1 ANTERIOR JIG

The AJ was first introduced by Lucia (1964) to facilitate interocclusal records. The jig is usually made of auto-polymerising acrylic resin on mounted casts and adjusted in the mouth.

Lucia indicated that clinical adjustment is necessary to train the patient in an easily guided hinge axis closure. By repeated adjustment, it is assumed that the patient will bring the condyles to their uppermost position against the articular eminence and rearmost to the full extension of the temporomandibular ligament. The adjustment is accomplished, according to Lucia, by marking with carbon paper. The patient is instructed to move the mandible forward and backward and to each side to scribe a Gothic arch. With a rubber wheel the wings and the tail of the tracing are carefully removed, until only a circle at the apex is left. It is preferred that the jig has a slight upwards and backwards slant on the surface in order to make it easier to hold the position while CR is recorded.

Lucia claimed "the jig disconnects the reflex circuit, thereby preventing the patient from making incorrect closures of long-standing habit". The jig was believed to eliminate proprioceptive responses, to permit the muscles to act freely and to allow the condyles to be moved into an unstrained position. It is presumed that the muscles will then rotate the mandible anteriorly and superiorly.

Such claims cannot be substantiated since neurophysiological research indicates that neuromuscular control of jaw movement is not only influenced by dental and periodontal sensory input. Feedback from the muscles, joints, ligaments, periosteum and skin also plays a role.

Other clinicians used the jig or anterior bite stop for relaxation of jaw muscles and relief of muscle pain (Long 1995). It is claimed that as the jig is engaged by the lower incisors with the closing muscles continuing to contract, the condyles are more likely to be seated in their middle and most superior positions (Carroll et al 1988).

Klineberg and Murray (1999) refer to McCloskey (1978) who described the process of “corollary discharge” which is thought to provide the sensation of muscular force or effort, which accompanies centrally, generated voluntary motor commands, such as voluntary biting. These authors indicate that in edentulous individuals, muscle spindle afferents may provide the dominant control supported by afferents from TMJ capsules and mucosal-periosteal mechanoreceptors. Despite the loss of teeth, most complete denture users appear to adapt and develop an altered pattern of jaw control to allow function. However, a proportion of individuals have adaptation difficulties leading to ongoing complaints about prosthesis inadequacy (Fiske et al 1998).

1.1.2 Leaf gauge

Long (1973) described the leaf-gauge which consisted of leaves (usually ten) of acetate or other plastic material, 0.1 mm thick. The leaves are placed between the anterior teeth and more leaves added until no posterior tooth contact is felt. Separation of the posterior teeth for a sufficient period of time (as yet to be determined) is alleged to allow a stable position of the jaw and condyles.

Long claimed that as posterior tooth contacts are eliminated, feedback mechanisms change and CR can be more readily recorded. According to Long, this minimizes the error caused by transferring the clinical record to an articulator, which is usually caused by the thickness of the wax. The deviation in the closing path is reduced because the closing distance to bring the teeth into contact is minimized by the thickness of the LG. The main difference between the AJ and the LG is that the latter allows easy adjustment to secure minimal separation of the posterior teeth.

Golsen and Shaw (1984) also described "tripodation" of the mandible with the leaf-gauge and condyles forming the three components of the tripod, which may allow the musculature to function freely without proprioceptive guidance from tooth contacts (Fig 1). These authors believed condyle position to be midmost, rearmost and uppermost. However, this condyle position suggests that the condyle is not in contact with the eminence, which does not comply with the suggested optimal position that was described by Dawson (1989) and Klineberg (1991).

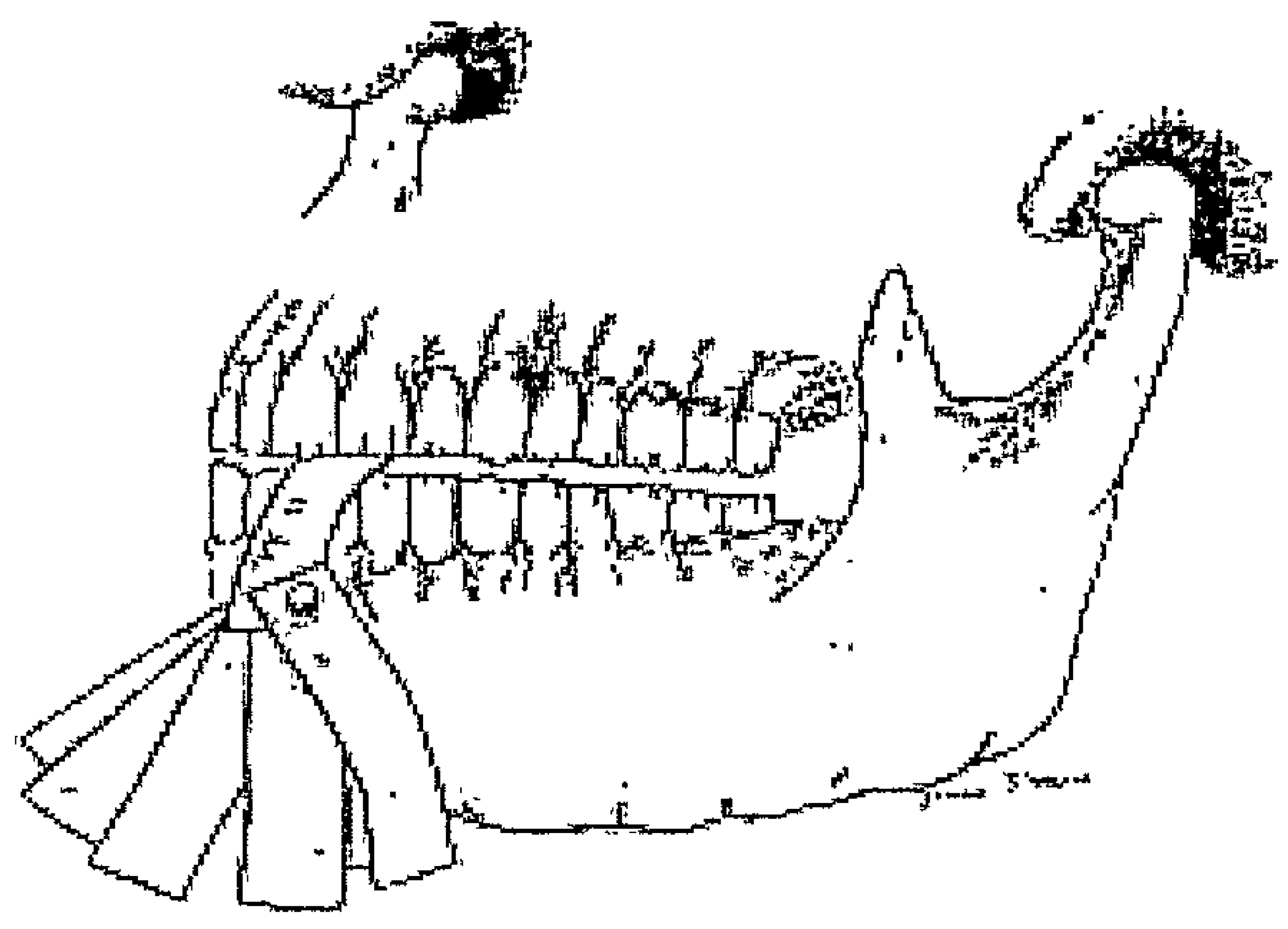


Figure1: Tripodation of the mandible with the LG. The two condyles and the LG form the tripodation of the mandible (Golsen and Shaw 1984).

1.1.3 Anterior teeth relationship

Golsen and Shaw (1984) stated several contraindications to the use of the LG:

1. Class II div II malocclusion
2. Patients with history of traumatic injury to the TMJ or TMJ surgery.
3. Patients with intracapsular pain on palpation dorsal to the TMJ.

In their opinion, with Class II div II malocclusion, the condyles are more likely to be displaced “down and back if an inclined plane is placed between the incisors”. In our study we aimed to select a subject with an Angle Class II Div II incisor relationship, in order to address our hypothesis that the condyle will not move postero-inferiorly. On the other hand, interocclusal records should not be taken when TMJ pain is present.

1.3. Bite force and CR

Different bite forces have been used with the LG technique. Bite forces ranging from "biting comfortably" (Donegan et al., 1990, Carr et al., 1991), "swallowing" (Golsen et al., 1984), "half hard" (Braun et al, 1997), "maximum bite" (Williamson et al., 1980) and "firmly" (Lucia 1964, Long, 1973, Woelfel, 1986), have been used and described in publications.

These different levels of bite forces are very subjective. Lundeen (1974) studied the effect of different intensities of muscular contraction in recording CR using several methods. He found that different degrees of muscle activity produced different CR recordings. He added that heavy muscular contraction in a patient with a rigid anterior stop, seats the condyles in the most superior position.

Williamson et al (1980) conducted a study to monitor the effect of bite-force on the position of the condyles during CR recording. They used an LG to eliminate posterior tooth contact, then asked the subjects to bite with different pressures to observe any difference in condylar position.

Electromyography (EMG) was used in their study to indicate muscle activity in biting on the LG, and "influencing jaw position". They concluded, "Interocclusal record made with the patient biting easy on the LG appears to allow physiologic placement of the condyles in the glenoid fossa". "The temporalis muscles have more influence upon CR condylar position than the masseter (Mas) muscles when an anterior guidance appliance is used". No significant difference was found between different bite forces.

Golsen and Shaw (1984) recommended that the bite force applied to the LG should be the same as that exerted during swallowing. The use of swallowing was firstly to train subjects to bite with the same force on the LG; secondly, the authors believed that excessive bite-force could force one or both condyles inferiorly and posteriorly. It seems that they concurred with Williamson and his colleague's (1980) conclusion that "Interocclusal records made with the LG and with the patient biting hard tend to cause mandibular condyles to be forced posteriorly and away from the articulating surface of the eminence".

There is also variation of time required for the LG and AJ recordings. Long (1973) in his descriptive paper on the use of LG, recommended to "continue the process until the occlusion is perfected in CR". There was no mention on what is "perfect occlusion", and the standardised time frame for the recording. Golsen and Shaw (1984) recommend holding the LG for "three to five minutes" prior to taking the interocclusal record. Woefel (1986) described the technique for recording CR with an LG. He asked the patient to bite for "30 second or longer" to ensure posterior disclusion. Donegan et al., (1990) asked the subjects to bite on an LG for 15 minutes and then relax for 8-10 minutes with the LG in place, before being removed, and subsequent to EMG recording.

There are no standard bite force levels and duration of recording, recommended for LG use, reported in the literature. There is a need to study the effects of bite force on LG recording.

3. ELECTROMYOGRAPHY (modified from Miller 1991)

EMG is the recording of extracellular signals generated by muscle fibres and transmitted through the tissue. A brief but significant change occurs in the muscle fibre membrane potential (i.e. depolarisation) and propagates as a wave of activity along and around the muscle membrane embracing the whole muscle fibre, from the region adjacent to the efferent innervation. The muscle depolarisation potential is of the order of 50 to 80 mV.

EMG signals are usually recorded in bipolar fashion with two electrodes. Signals are directed to an amplifier, which renders an algebraic summation of the signal that occurs simultaneously at both electrodes. The amplifier provides a signal representing the difference in voltages at each electrode at each time point. The electrodes have their signals referenced to a ground electrode, usually placed over an area of skin with no underlying muscle.

EMG signals vary in duration and amplitude dependent upon the type of electrode and whether it is placed within the muscle for intramuscular recordings, or on the skin over the muscle for surface readings. While individual muscle fibres are the primary source of the signals, they are derived from a functional group of fibres defined as a motor unit.

The level of EMG activity suggests that the muscle develops more force, but muscle force or tension may not be directly related to the level of EMG. The closest correlation between muscle activity and muscle tension occurs when the muscle does not change length. For instance, this occurs during intercuspal clenching on posterior teeth developing isometric bite forces.

Common approaches to quantifying EMG signals include visualizing by taking the basic positive and negative peaks and rectifying them to one polarity. The area under the peaks is then calculated by integration, which directly relates the slope of a line to the area under the curve.

EMG recordings have provided an accurate indication of muscle activity to complement anatomical and histochemical studies, and define a particular function for individual craniomandibular muscles. Only EMG provides dynamic information of muscle fibre recruitment and muscle sequencing for specific tasks.

2.1 Types of electrodes *(Basmijan, 1979)*

Surface electrodes

Surface electrodes are small plates made of silver or stainless steel attached on the skin overlying the muscle to measure the electrical potential difference between the plates. The skin is cleaned with alcohol swabs prior to placement, and electro-conducting "electrode jelly" is used to increase the electrical conductance from skin to electrode. These electrodes are used in pairs for superficial muscles.

Fine- wire electrodes

Bipolar fine wire electrodes are also used for clinical EMG. A stainless steel hypodermic needle acts as carrier for the two insulated fine wires with insulation removed from the tips. The distal ends are staggered and folded over the needle tip, to help retain the fine- wires in the muscle when the carrier is withdrawn. The electrodes are secured with adhesive tape at the emergence point from the skin.

These electrodes have the advantage of being when extremely fine and will have minimal effect on muscle activity (compared with indwelling needle electrodes) and can be specifically used for a target muscle (Basmijan and Stecko, 1962.

2.2. JAW MUSCLE ACTIVITY AND CR RECORDING TECHNIQUES

Duthie & Yemm (1982) showed that, with the head erect, "active" (i.e. by the patient) CR positioning induces activity in both temporal muscles and in the supra-hyoid and infra-hyoid muscles, with little contribution from the Mas and lateral pterygoid muscles. It was also shown that the anterior temporalis appears to act as a "stabilizer", while the middle and posterior temporal retrude the mandible in association with the supra-hyoid muscles.

The infra-hyoid muscles stabilize the hyoid bone and the lateral pterygoid muscle stabilizes the temporomandibular disc.

Woelfel (1986) and Carroll et al (1988) stated that an LG can be used periodically by the patient to relieve painful spasms of the lateral pterygoid muscles. However, these were clinical observation only and were not thoroughly investigated. These studies did not record the role of lateral pterygoid muscles when an LG was used.

Murray et al (1999) studied the electromyographic activity of the human lateral pterygoid muscle during contralateral and protrusive jaw movements. They concluded that:

1. The lateral pterygoid is the major jaw muscle that moves the condyle downwards and forwards during contralateral movements and is an important muscle in protrusion.
2. The variation in electromyographic data between participants may reflect the different neural strategies required to control muscle movement in individuals with different facial morphologies and skeletal muscle architectures.
3. The inferior head of the lateral pterygoid muscle tends to be more active than the superior head in moving the condyle forward along the articular eminence during protrusion and contralateral movements.

Orfanos et al (1996) described a technique to record the lateral pterygoid muscle using fine needle electrodes. The accuracy of the location in the muscle was verified with computer tomography (CT).

According to Wood et al (1986 and 1987), the inferior head contributes to forward jaw movement and clenching, with little activity seen with vertical intercuspal clench. To date, there are no studies conducted examining the effect of the LG on the lateral pterygoid muscles.

Carr et al (1991) conducted a three-dimensional electrognathographic study of an incisor point to "detect peripheral correlates of the jaw elevator muscles". This is interpreted to mean the influence of jaw position and other variables on jaw muscles. A leaf-gauge was held comfortably for 10-15 minutes between the incisor teeth which discluded the posterior teeth by about 2 mm. These authors concluded that on the basis of EMG and electrognathography, the short-term and non-fatiguing use of a leaf-gauge would not alter normal mandibular movement patterns and normal contraction patterns of the jaw muscles. They were unable to demonstrate a so-called "adaptive" jaw closure pattern that was changed through the use of an LG. This conclusion questions the basis for the use of the leaf-gauge as a jaw muscle "deprogramming" device, as proposed by Long (1973).

Conversely, Hickman et al (1993) studied the differences in the EMG activity between the Mas and temporalis muscles for four jaw relations:

1- Use of LG.
2- Manual guided CR.
3- Centric occlusion (CO).
4- Neuromuscular maximal static clench.

The LG position consistently demonstrated the lowest EMG activity, while the neuromuscular position displayed the highest. The LG was the only technique that eliminated posterior contacts, which Williamson and Lunquist (1983) indicated, reduces Mas muscle activity.

Becker et al (1999) studied the effect of a prefabricated flat AJ on the electromyographic activity of jaw muscles in clenching and grinding. They found that the jig evoked a decrease in EMG activity for the anterior and posterior temporalis, and Mas muscles. The study unfortunately did not involve the recording of lateral pterygoid muscles.

CONCLUSION

It is clear that both confusion and ambiguity surround the use and recording of the CR position. Some clinicians are enthusiastic about the use of the LG and AJ, whereas others remain cautious. Several studies have attempted to identify the effect of the LG and the AJ on the electromyographic activity of the jaw muscles (Carr et al 1991, Williamson et al 1980, Lundeen 1974, Hellsing & McWilliam 1985, Golsen and Shaw 1984). Conversely, the effect of various incisor relationships has not been adequately addressed. Research is necessary to define the action of the LG, which may lead to confirmation or modification of the technique. In this study, we aim to look at several variables in relation the use of these devices, including jaw muscle EMG, bite-force and the effect of the incisor relationship. This is a pilot study that will hopefully form the basis of further larger studies.

REFERENCES:

Barghi N, Rugh JD and Drago CJ. Experimentally induced occlusal disharmonies. J Dent Res 1979; 58: 317

Basmijan JV and Stecko GA. A new bipolar indwelling electrode for electromyography. J App. Physiology 1962; 17: 849-851

Becker CM, Kaiser DA and Schwalm C. Mandibular centricity: Centric relation. J Prosthet Dent 2000; 83; 158-60

Becker I, Tarantola G, Zambrano J, Spitzer and Oquendo D. Effect of a prefabricated anterior bite stop on electromyographic activity of masticatory muscles. J Prosthet Dent 1999; 82: 22-26

Braun S, Marcotte MR, Freudenthaler JW and Honigle K. An evaluation of condyle position in centric relation obtained by manipulation of the mandible with and without leaf gauge deprogramming. Am J Ortho Dentofac Orthop 1997; 111: 34-37

Boos RH. Basic anatomic factors of jaw position. J Prosthet Dent 1954; 4: 200-203

Carroll WJ, Woelfel JB and Huffman RW. Simple application of anterior jig or leaf gauge in routine clinical practice. J Prosthet Dent 1988; 59: 611-616

Carr AB, Donegan SJ, Christensen LV and Ziebert GJ. An electrognathographic study of aspects of deprogramming of human jaw muscles. J Oral Rehabil 1991; 18: 143-148

Celenza FV. The centric position: Replacement and character. J Prosthet Dent 1973; 30: 591-598

Dao TTT, Lavigne GJ, Charbonneau A, Feine JS and Lund JP. The efficacy of the oral splints in the treatment of myofascial pain of the jaw muscles: a controlled clinical trial. Pain 1994; 56: 85-94

Dawson PE. Evaluation diagnosis and treatment of occlusal problems. 2nd ed. St Louis: CV Mosby 1989: p 28-55

De Boever JA, Carlsson GE and Klineberg IJ. Need for occlusal therapy and prosthodontic treatment in the management of temporomandibular disorders. Part I. Occlusal interferences and occlusal adjustment. J Oral Rehabil 2000; 27: 367-379

Dixon DL. Overview of articulation materials and methods for the prosthodontic patient. J Prosthet Dent 2000; 83:235-247

Donegan SJ, Carr AB, Christensen LV and Ziebert GJ. An electromyographic study of aspects of deprogramming of human jaw muscles. J Oral Rehabil 1990; 17: 509 – 518

Duthie N and Yemm R. Muscle involved in voluntary mandibular retrusion in man. J of Oral Rehabil 1982; 9: 155-160

Ferrario VF, Sforza C, Miani JR A, Serrao G and Tartaglia G. Open-close movements on the human temporomandibular joint: does a pure rotation around the intercondylar hinge axis exist? J Oral Rehabil 1996; 23: 401-408

Fish EW. Principles of full denture prosthesis. London: Staples Press 1952: p26

Fiske J, Davis DM, Frances C and Gelbier S. The emotional effects of tooth loss in edentulous people. Brit Dent J 1998; 184: 90-93

Golsen LF, and Shaw AF. Use of leaf gauge in occlusal diagnosis and therapy. Quintess Internat 1984; 6: 611-621

Hellsing G and McWilliam S. Repeatability of the mandibular retruded position. J Oral Rehabil 1985; 12: 1-8

Hickman DM, Cramer R and Stauber WT. The effect of four jaw relations on electromyographic activity in human masticatory muscles. Archs Oral Biol 1993; 38: 261-264

Keshvad A and Winstanley RB. An appraisal of the literature on centric relation. Part I. J Oral Rehabil 2000; 27: 823-833

Klineberg I. Occlusion: Principles and assessment. Oxford 1991; Butterworth-Heinemann p 13, 70

Klineberg I. and Murray G. Dental deafferentation – a paradox in proprioception. In: Osseoperception and musculo-skeletal function, E Williams, B Rydevik, R Johns, P-I Bränemark eds, Gothenburg : The Institute of Applied Biotechnology 1999:p 34-48

Long JH. Locating centric relation with a leaf gauge. J Prosthet Dent 1973; 29: 208-210

Long JH Jr. Interocclusal splint designed to reduce tenderness in lateral pterygoid and other muscles of mastication. J Prosthet Dent 1995; 73: 316-318

Lucia VO. A technique for recording centric relation. J Prosthet Dent 1964; 114: 492-505

Lundeen HC. Centric relation records: The effect of muscle action. J Prosthet Dent 1974; 31: 245-251

McCloskey DI. Kinesthetic sensibility. Physiol Rev 1978; 58: 763-820

Miller A.J.. Craniomandibular muscles: Their role in function and form. CRC Press, Boca Raton, Florida 1991: p 45-66

Murray GM, Orfanos T, Chan JY, Wanigaratne K and Klineberg IJ. Electromyographic activity of the human lateral pterygoid muscle during contralateral and protrusive jaw movements. Archs Oral Biol. 1999; 44: 269-285

Orfanos T, Sarinnaphakorn L, Murray GM and Klineberg IJ. Placement and verification of recording electrodes in the superior head of the human lateral pterygoid muscle. Archs of Oral Biol 1996; 41: 493-503

Pullinger AG, Selligman DA and Gornbein JA. A multiple logistic regression analysis of the risk and relative odds of temporomandibular disorders as a function of common occlusal features. J Dent Res 1993; 72: 968-979

Sim Y, Carlson DS and McNamara JA. Jr. Condylar adaptation after alteration of vertical dimension in adult rhesus monkeys, Macaca mulatta. Cranio 1995; 13: 182-187

The Academy of Prosthodontics. The Glossary of prosthodontic terms.7th edition. J Prosthet Dent 1999; 81: 39-110

Williamson EH, Steinke RM, Morse PK and Swift TR. Centric relation: A comparison of muscle-determined position and operator guidance. Am J Orthod. 1980; 77: 133-145

Williamson EH and Lundquist DO. Anterior guidance: Its effect on the electromyographic activity of the temporal and masseter muscles. J Prosthet Dent 1983; 49: 816-823

Woefel JB. New device for accurately recording centric relation. J Prosthet Dent 1986; 56: 716-727

Wood, WW Takada K and Hannam AG. The electromyographic activity of the inferior part of the human lateral pterygoid muscle during clenching and chewing. Arch of Oral Biol 1986; 31: 245-253

Wood, W.W. A review of masticatory function. J Prosthet Dent 1987; 57: 222-232

RESEARCH PROJECT

1. Introduction

The leaf gauge (LG) technique is used in dental practice for the registration of jaw records in centric relation (CR). The LG was described first by Long (1973), where leaves (usually ten) of acetate or other plastic material, 0.1mm thick are placed between the anterior teeth and more leaves added to ensure disclusion of the posterior teeth. The LG is believed to provide:

(a) A reproducible CR recording, allowing an optimal and stable jaw position for treatment (prosthodontic or orthodontic) (Williamson 1980; Braun et al 1997);

(b) A means for determining "occlusal discrepancies" in mandibular dysfunctions (Long 1973; Golsen et al 1984);

(c) For "deprogramming of jaw muscles including the lateral pterygoids" (Carroll, 1988; Carr 1991).

These are clinical observations only and are not supported by well-controlled research. Controlled studies such as those by Barghi et al 1979 and Pullinger et al 1993 confirm that occlusal discrepancies do not cause mandibular dysfunction. However, the LG is regarded as a technique to provide a so called *"reproducible"* jaw relation recording for prosthodontic or orthodontic treatment.

Different bite forces have been used with the LG technique. Bite forces ranging from "biting comfortably" (Carr et al 1991), "swallowing" (Golsen et al 1984), "half hard" (Braun et al 1997), "maximum bite" (Williamson et al 1980) and "firmly" (Long, 1973, Woelfel, 1986), have been used and described in publications.

Several studies have attempted to identify the effect of the LG on the electromyographic activity of the jaw muscles (Lundeen 1974, Williamson et al 1980, Hellsing & McWilliam 1985, Carr et al 1991).

Hypothesis

AJ and LG increases EMG activity of the superior and inferior heads of the lateral pterygoid (SHLP and IHLP); and decreases EMG activity of the masseter (Mas), anterior temporalis (AT), posterior temporalis (PT) EMG activity, in relation to biteforce.

Aims

(a) To examine the effect of the LG on jaw muscle electromyographic activity. Muscles to be examined: anterior digastric (Dig); Mas; PT; AT; SHLP and IHLP.

(b) To determine the effect of the LG with different bite forces (half maximum and maximum).

(c) To determine the effect of anterior tooth relationships (Angle Class I, Class II div II and edge to edge bite or Class III) and LG on jaw muscle EMG

2. Materials and Methods

2.1 Participants

Five volunteers were selected from dental students and staff (all males, with age range 23 to 32 years old); without signs or symptoms of craniomandibular disorders (for criteria, see Klineberg, 1991). Informed consent was obtained from all participants. The Western Sydney Area Health Service Ethics Committee of Westmead Hospital and the Human Ethics Committee of the University of Sydney approved experimental procedures. Alginate impressions were taken and diestone (Hard-stone, Ainsworth Dental Co. Pty Ltd, Roseberry, Australia) models of upper and lower jaws were made for each participant. From the study models, an AJ and upper and lower clutches for condylar recording were constructed.

Three pilot recordings were performed on 2 subjects, twice on subject RS and one on subject MA. Eight recordings were performed in total. The data from the first three recordings were used to refine the recording techniques and this data are not included in the analysis. In one subject (subject PA), data for the condylar movements could not be used due to a technical problem during the trial.

Subjects RS, SF and PA had Angle Class I incisor relationship with minimal overjet and overbite. Subject MA had Angle Class II div II incisor relationship with a deep (60%) overbite, whilst subject SP had a Class III (edge to edge) incisor relationship.

2.2 Anterior Jig Construction

A 1kN (102.0kgf) (Kyowa Electronic Instruments Co., Ltd. Tokyo, Japan) force transducer was used to guide EMG amplitude levels at specific bite force readings. The transducer in a stainless steel housing was positioned intraorally attached to the upper incisors with an acrylic jig (Duralay: Dental Mfg, IL, USA).

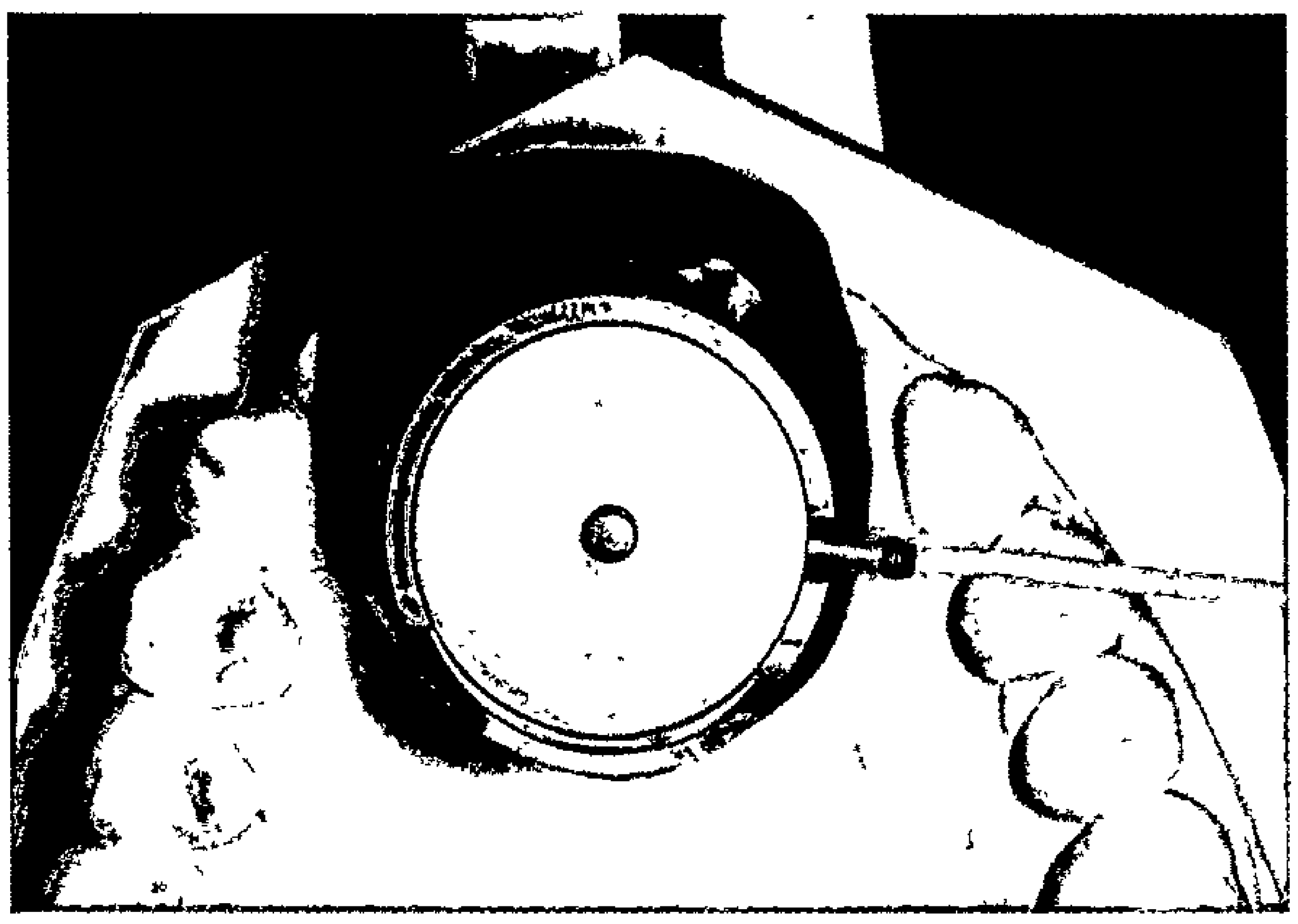
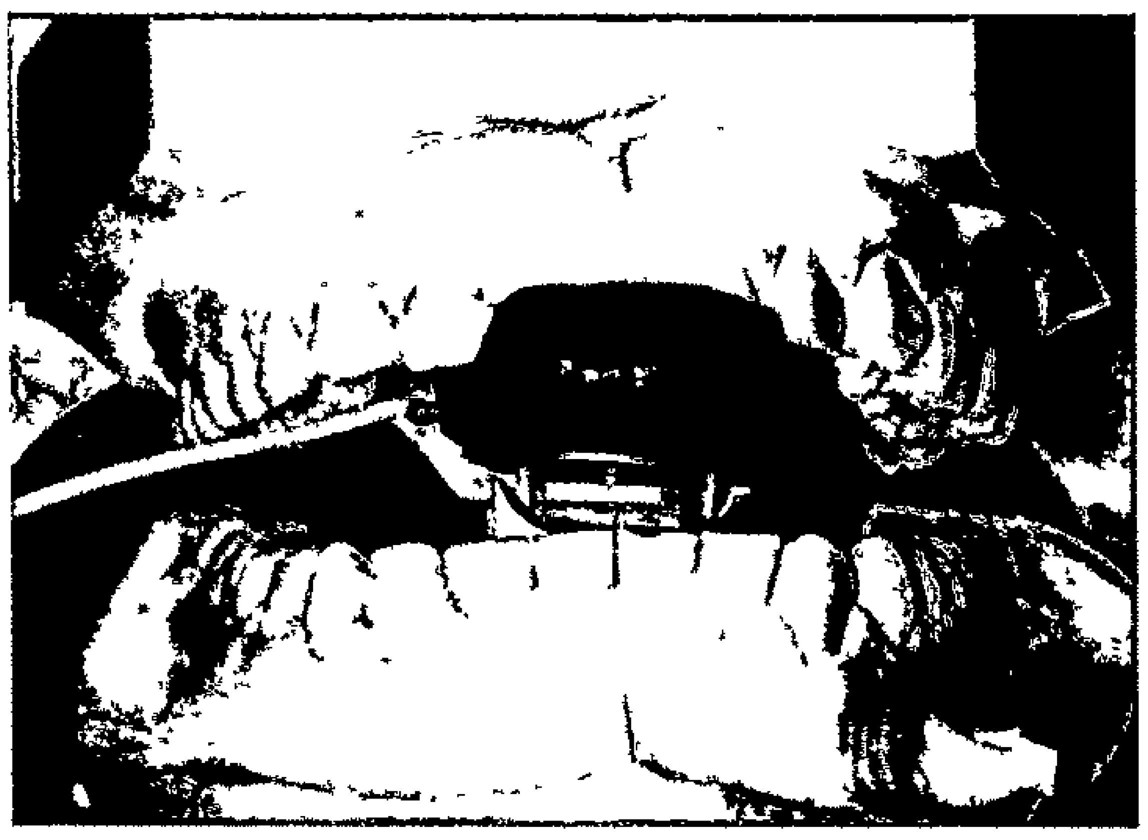


Fig 1. Load cell with stainless steel housing and anterior Duralay resin jig

Subjects were asked to bite on a stainless steel platform attached to the steel housing and positioned as close as possible parallel to the lower occlusal plane. As a result, the direction of bite force recorded by the transducer was the same as that of the lower incisor teeth. The platform extended anteriorly to rest above the incisal edge of the lower incisors. This ensured that the bite force from the upper incisors, which contacted the platform, was directed down the center of the transducer housed in the stainless steel casing. The jig was relined intraorally on the day of the experiment.



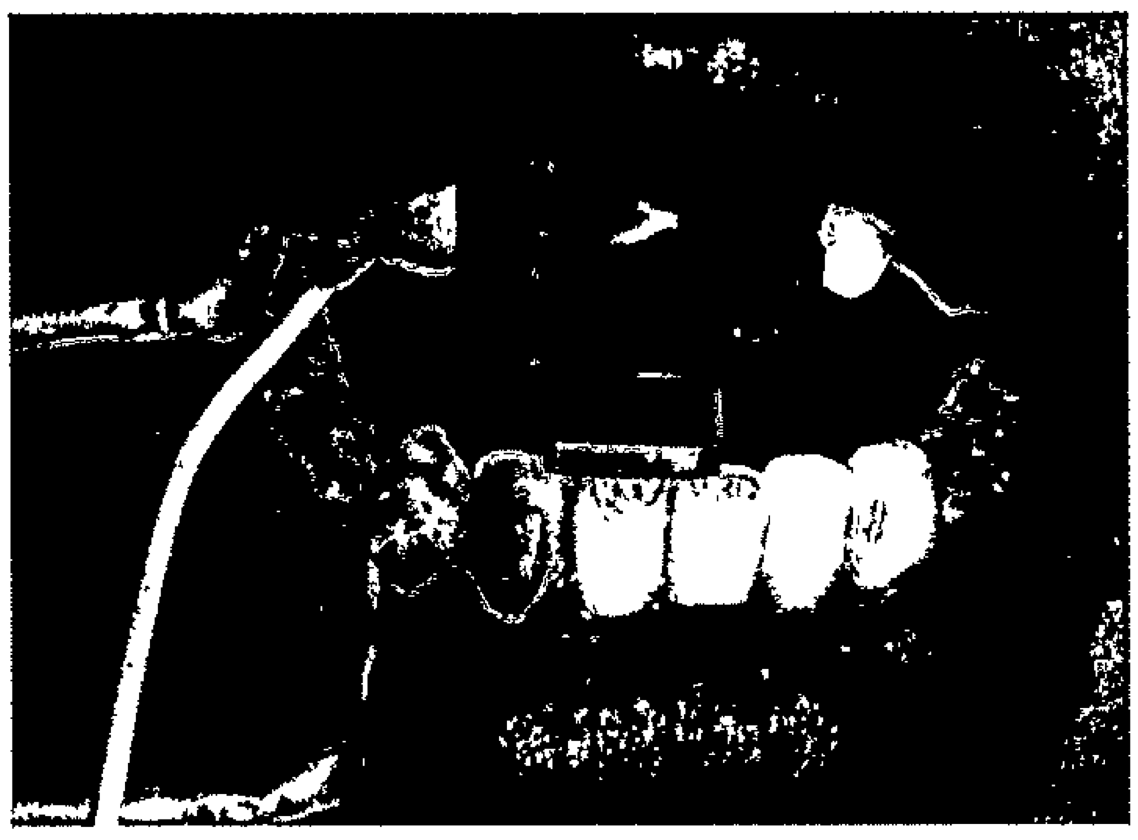


Fig 2a. Anterior jig on the model
Fig 2b. Anterior jig and clutches in the mouth. Note the clearance of the clutches away form the jig

During preliminary recordings the subjects complained of discomfort while biting on the platform at maximum bite force. A celluloid strip was placed on the biting surface of the platform to improve tooth contact comfort.

The AJ was used to train each subject to bite at the different bite force levels of maximum and half maximum. However, the AJ and the LG were made at a different vertical dimension of occlusion. Hence the jig only provided "subjective" bite force levels. Visual feedback was used to assist in subject training. An AMLAB data-acquisition system (Associative Measurements, North Ryde, Sydney, Australia) at a sampling rate per channel of 4200 samples/s and with a bandwidth of 100 Hz, was used to determine bite force level.

2.3 Leaf gauge recording

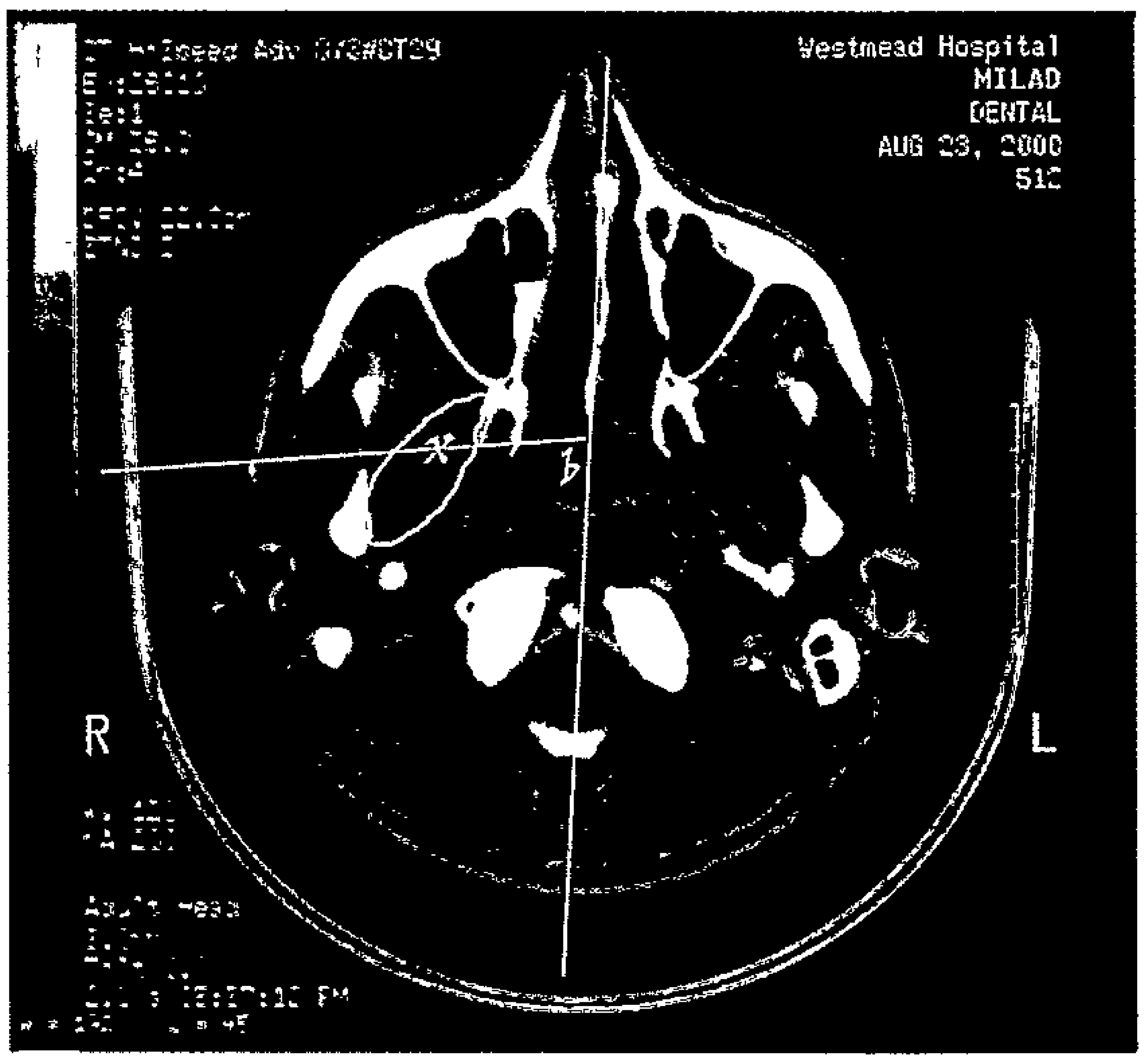
In these series of recordings, the mandible was held closed on the LG for 5 seconds with two levels of bite force: maximum bite force (hard), and half maximum bite force (moderate). If the subject sensed posterior tooth contact, additional leaves were added to avoid posterior tooth contact, and the process repeated. The mandibular incisors occluded on the LG, and this anterior tooth contact influenced spatial jaw position and that of the condyles, to help to "optimally position them three dimensionally" (Long, 1973). In clinical treatment, this approach is used to assist condyle placement for jaw recording.

Fig 3. The subject holding the leaf gauge with complete experiment set up.

2.4 EMG Recording

Superior head of the lateral pterygoid

Computed tomography (CT) was carried out for all subjects for placement and verification of electrode location in the superior head of the lateral pterygoid muscle (SHLP) (see Orfanos et al 1996, and Murray et al 1999). One series of CT scans provided craniometric measurements to determine the trajectory path for extra- oral placement of the fine wire electrodes into the SHLP muscle.



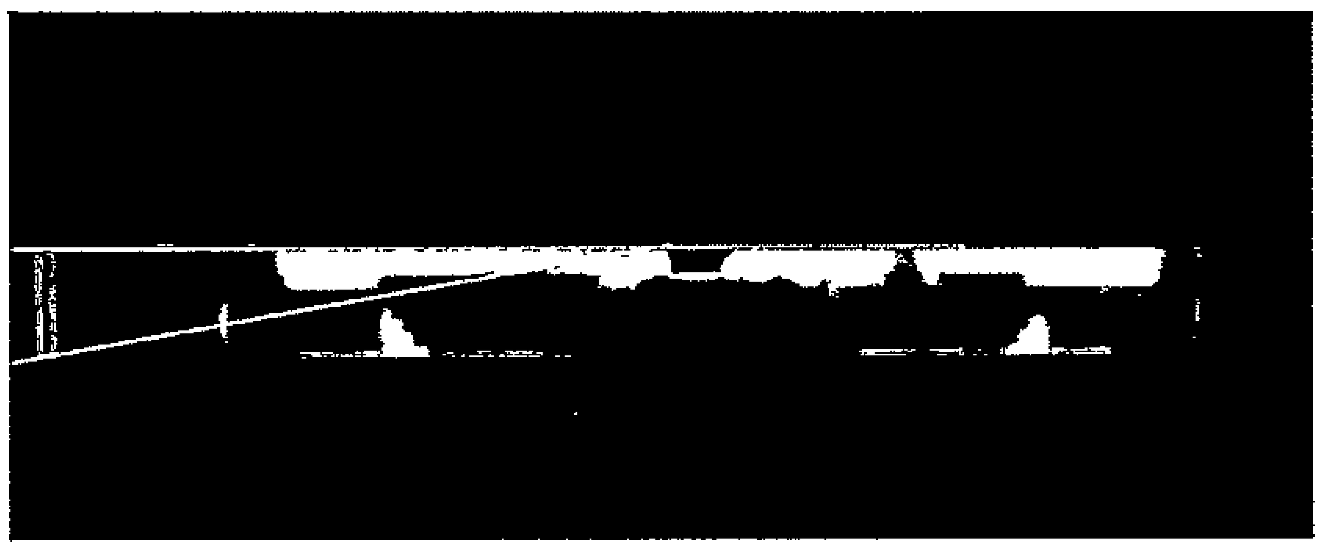


Fig 4a and b. Measurements were taken of the trajectory of electrode into the approximate mediolateral and arnteroposterior centre of the superior head of the lateral pterygoid. θ° = angle to the mid-sagittal plane ϕ°=upward angulation from the FHP

A sterilized (A-M Systems, Inc., Washington, USA; 75 mm dia. with Teflon coating, 110 mm) fine wire electrode through a disposable spinal needle (50 mm long, 25 G; Becton-Dickinson, USA) was directed along a sterilized carrier. The needle contained two fine Teflon coated stainless-steel wires, which were bared at the tip. The wires were bent 2-3 mm from their ends over the bevel of the needle, following the technique described by Basmijan and Steko (1962).

For electrode placement in the SHLP, the area around the insertion point was vigorously swabbed with alcohol and an EMLA (EMLA 5% patch, Astra Pharmaceutical Pty Ltd, Ryde, NSW, Australia) patch placed 45 minutes prior to insertion, to provide surface anesthesia.

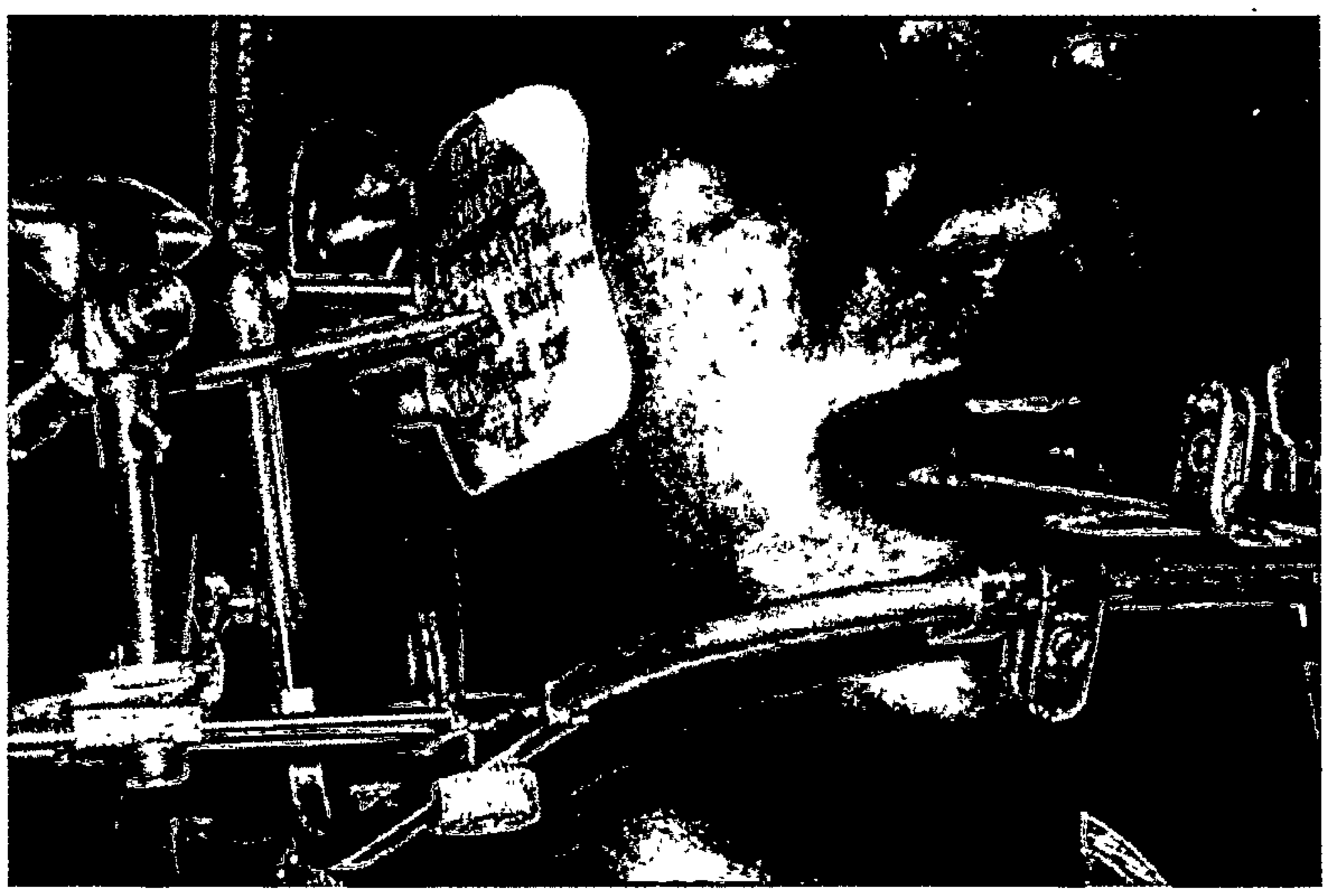


Fig 5. Emla EMLA 5% patch, Astra Pharmaceutical Pty Ltd, Ryde, NSW, Australia patch placed over the insertion point.

The spinal needle was directed along a sterilised needle carrier, oriented according to the predetermined measurements, to the skin surface and then carefully and slowly through the skin and subcutaneous tissues to reach the

SHLP muscle. Once the prescribed depth was reached, usually confirmed as a result of bone contact (inferior surface of petrous part of the sphenoid bone), the needle was carefully retracted, leaving the fine-wire electrodes within the muscle.

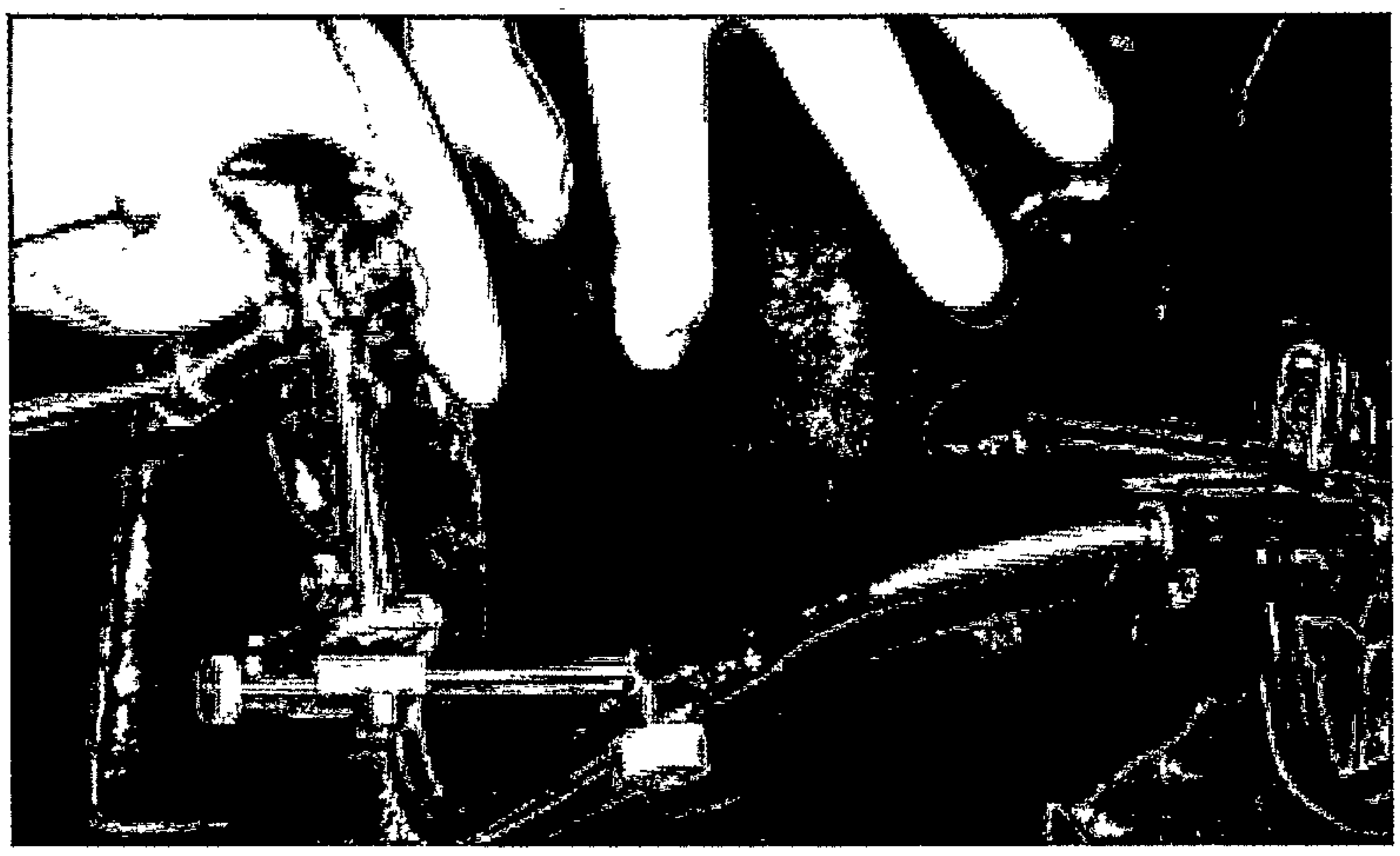


Fig 6. Insertion of the needle carrier.

INFERIOR HEAD OF THE LATERAL PTERYGOID

The technique for electrode placement in the inferior head of the lateral pterygoid (IHLP) involved inserting a sterilized, pre-curved spinal needle, containing two fine Teflon-coated stainless-steel wires (bared at the tip) through the oral mucosa above the level of the upper second molar, as described by Wood et al (1987). The needle was advanced, to contact the middle third of the lateral surface of the lateral pterygoid plate, and was then withdrawn, leaving the wires within the inferior head. The wires were secured to the buccal surface of the upper first molar with Stomadhesive (Convatec, Squibb and Sons Inc Victoria, Australia) and led out through the angle of the mouth.

A second CT session was used to verify the fine-wire placement in the SHLP and IHLP at the conclusion of the recording (See Murray et al 1999)

Superficial jaw muscles

Bipolar recordings were made with (a) Surface patch electrodes (Duo-Trode, Myo Tronics, Seattle, USA) placed over the lower one-third of the Mas muscle, approximately 10 mm from the anterior border; and over the midbody of the Dig muscle. (b) Hook electrodes were placed through the skin overlying the AT and PT muscles. Signals from the muscles were digitised (sampling rate: 1000 samples/sec; bandwidth: 10-30 to 500 Hz).

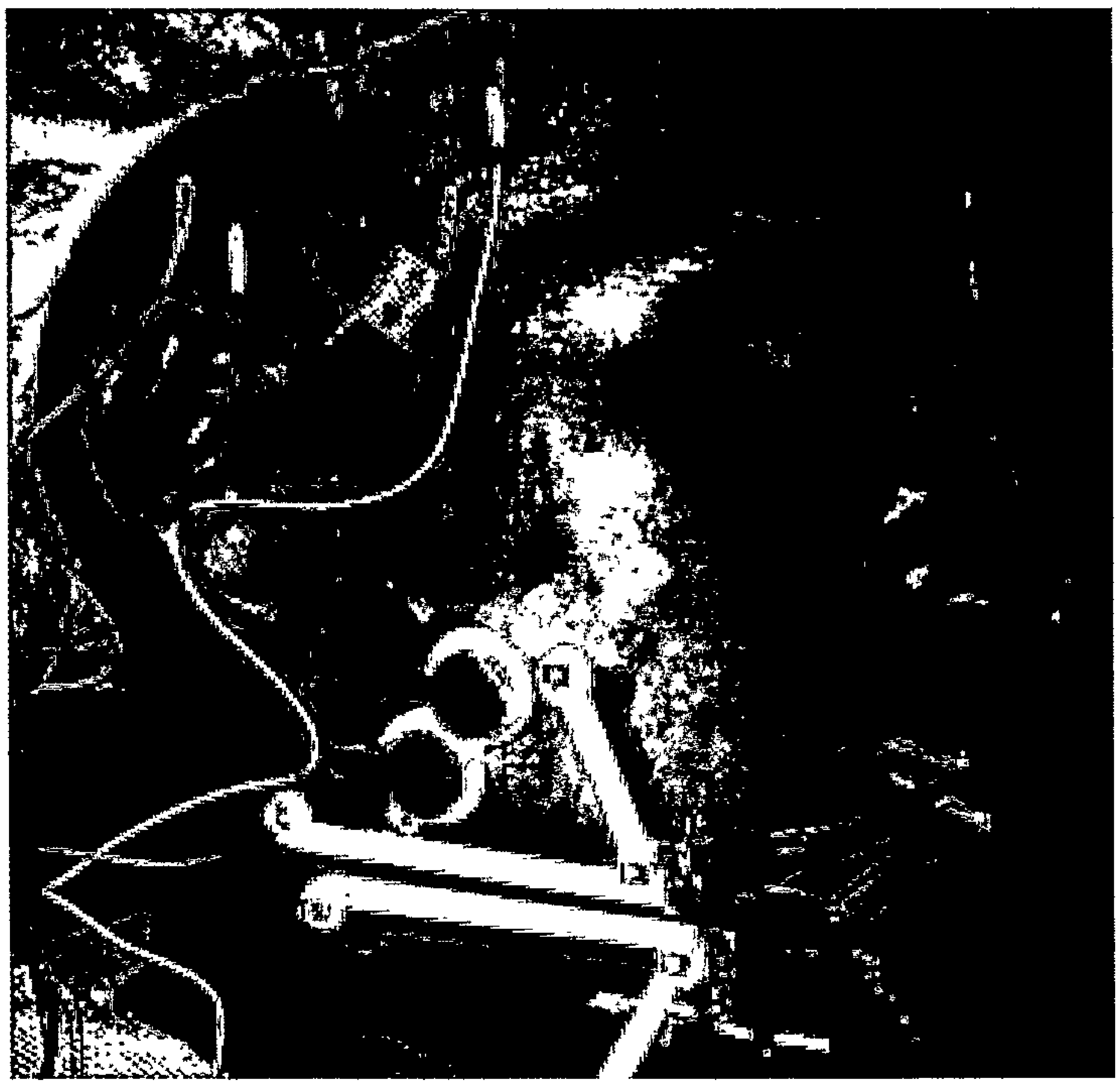


Fig 8. Complete experimental set up. The pictures shows hook electrodes for anterior and posterior temporalis muscles, surface electrode for the masseter muscles; and target frames attached to the clutches

2.5 Tasks

All participants were asked to perform a series of clenching tasks. At the beginning of the trial, the subject had 5 seconds at postural rest position. A red LED light, located at the subjects' eye level, was the signal for the subject to clench for 5 seconds; a second red light signal instructed the subject to relax. Total recording time was approximately 20 seconds. Each subject performed different clenching tasks as follows:

1. Clenching from rest position to an intercuspal position (IP clench) at maximum bite force;
2. Clenching with the AJ at maximum bite force;
3. Clenching with the AJ at half maximum bite force;
4. Clenching with the LG at half maximum bite force; and
5. Clenching with the LG at maximum bite force.

A series of 5 trials were recorded for each of the tasks, with 2 minutes rest between. Maximum bite force was recorded form each subject and visual feedback was used to confirm the consistency of the maximum bite force level. Half maximum bite force was taken as 50% of the maximum and visual feedback was also used as a guide.

EMG recording of SHLP and IHLP, Mas, AT, PT and Dig muscles were made. All recordings were taken from the right side of each subject.

2.6 Data Analysis

The EMG activity from each of the recorded muscles was rectified and smoothed with a digital filter [Butterworth filter (Vaughan, 1982); cut-off: 2 Hz]. A computer script was written to calculate the area underneath the curve for comparison. The values for each dependent variable were averaged, such than each subject had one value from each trials with a standard deviation. The value was then averaged over 5 trials and compared with control (IP clench).

Table 1 lists the results. The data were normalised, with the control set at 100%. The data was then presented as a percentage of the normalised EMG value of the control. A value over 100% indicates an increase in EMG; and a value less than 100% indicates a decrease in EMG.

A two- tailed Mann- Whitney non- parametric test was performed on maximum bite force with AJ and LG against control, to determine the significance ($p<0.05$) of each trial. Significant changes are shown as a shaded area in Table 1. Statistical analyses were not performed for half maximum bite force data, because the control was set at maximum bite force.

3. Results

Data from subjects RS, MA, SP, and SF were complete for both condylar movement and EMG activity of IHLP, SHLP, AT, PT, Mas and Dig muscles. In the recording with subject SP, a haematoma developed and may have interfered with the EMG recording. It was noted on withdrawal that the SHLP fine wire electrodes were twisted. In Subject RS, data from the IHLP muscle were not recorded.

3. 1 VERIFICATION OF PLACEMENT OF ELECTRODES INTO THE SHLP MUSCLE.

A second CT scan was performed after the trial to verify electrode placement. Electrodes were accurately placed and verified in the SHLP in all subjects. In subject SP, however the fine wire tips were found on removal of the electrodes to have been twisted, and it was suspected that the tips may have been in contact with each other during the recording.

(9a)

(9b)

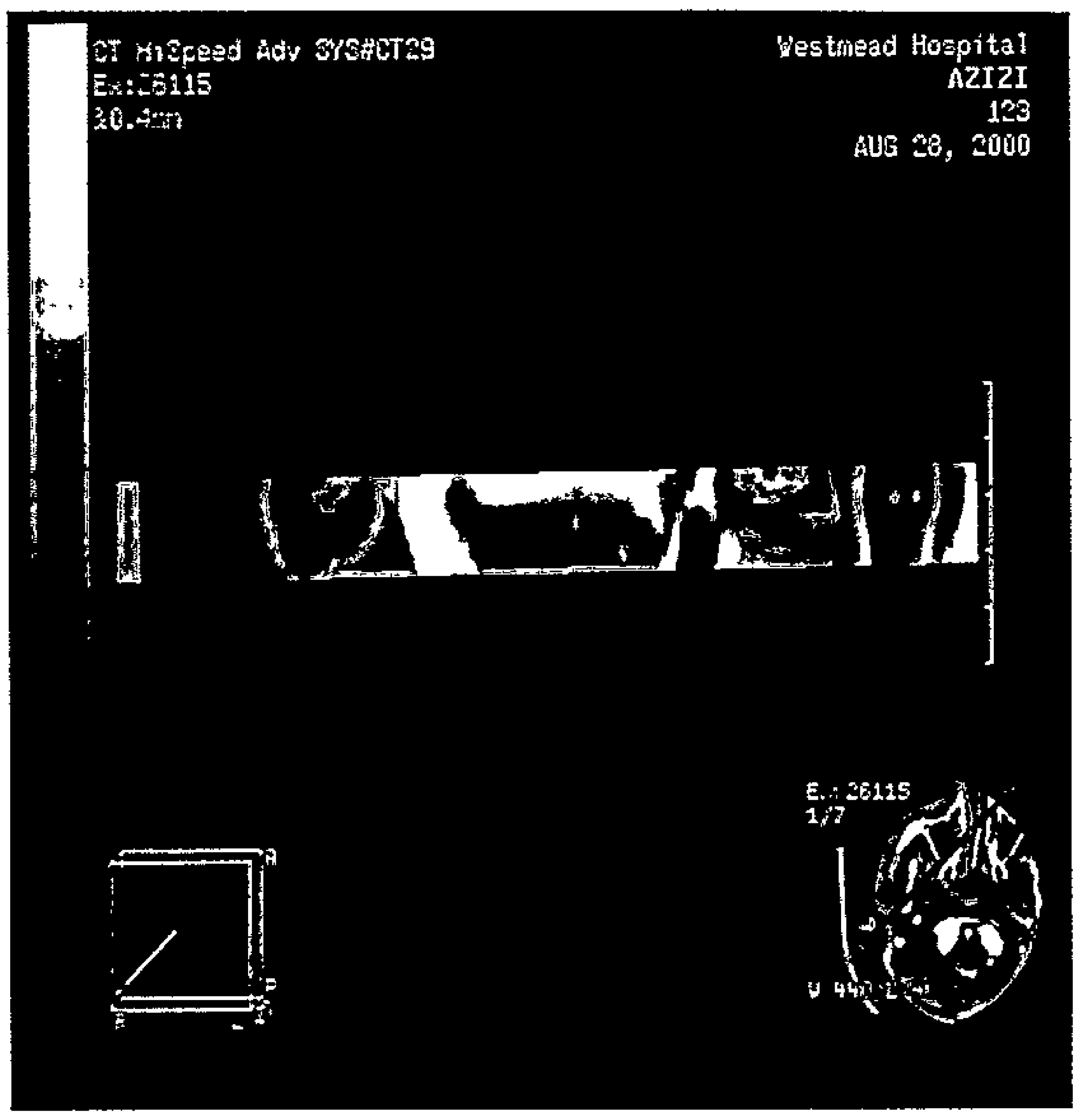


Fig 9a. Verification coronal CT scan showing the fine wire electrode sitting in the superior head of Lateral Pterygoid muscle.
Fig 9b. Coronal scans showing electrodes in the both superior and inferior head of the Lateral Pterygoid muscle.

3.2 General description

There were intra - and inter - subject variation of EMG activity during each trial. Half maximum bite force did not correspond to half maximum EMG activity. There was low-level EMG activity observed with Dig and IHLP muscles in all trials. Static IP clench (control) resulted in the highest EMG activity in Mas, AT and PT muscles compared with trials using LG and AJ. Subject PA showed no significant changes in both AJ and LG trials, compared with control.
High standard deviation of averaged EMG data was observed with half maximum bite force trials.

3.3 Anterior Jig

The placement of the AJ produced little change in EMG activity of IHLP, and Dig in all subjects with different bite force, except subject MA. There was significant reduction of EMG activity of AT and PT with subjects RS, SF, and SP. Subject MA had a significant reduction in AT EMG levels, but not PT. There was a significant decrease of Mas EMG in subjects RS and MA.

SHLP activity significantly increased with subjects MA (790% increase compared with control) and SP, whereas subject RS showed a significant decrease. In subject SP there was high EMG activity of IHLP using the AJ at both maximum and half maximum bite forces. In these subjects, however, the position of the fine needle electrode into the IHLP could not be verified after the trials.

3.3 Leaf Gauge

Half maximum bite force resulted in a reduction in EMG activity with Mas and AT in all subjects. Subjects MA and PA had an increased (although not significant) EMG activity of PT with maximum bite force. With the SHLP at maximum bite force, activity was increased with all subjects except subject RS and SP. In subjects MA and PA, EMG activity of SHLP was higher with half maximum bite force than maximum.

Maximum bite force showed a significant reduction in EMG activity with AT and PT with subjects RS and SP only. No significant changes were observed with subjects RS and PA.

3.4 Bite Force

Half maximum bite force from the transducer was not necessarily the same as half maximum EMG values. The bite force recording using LG was the subject's subjective interpretation of the bite force from the initial training.

Fig 10 shows an example of data from subject SF. The jaw displacement graph shows a superior- posterior displacement, and a reduction in EMG activity of PT, AT and increased SHLP activity.

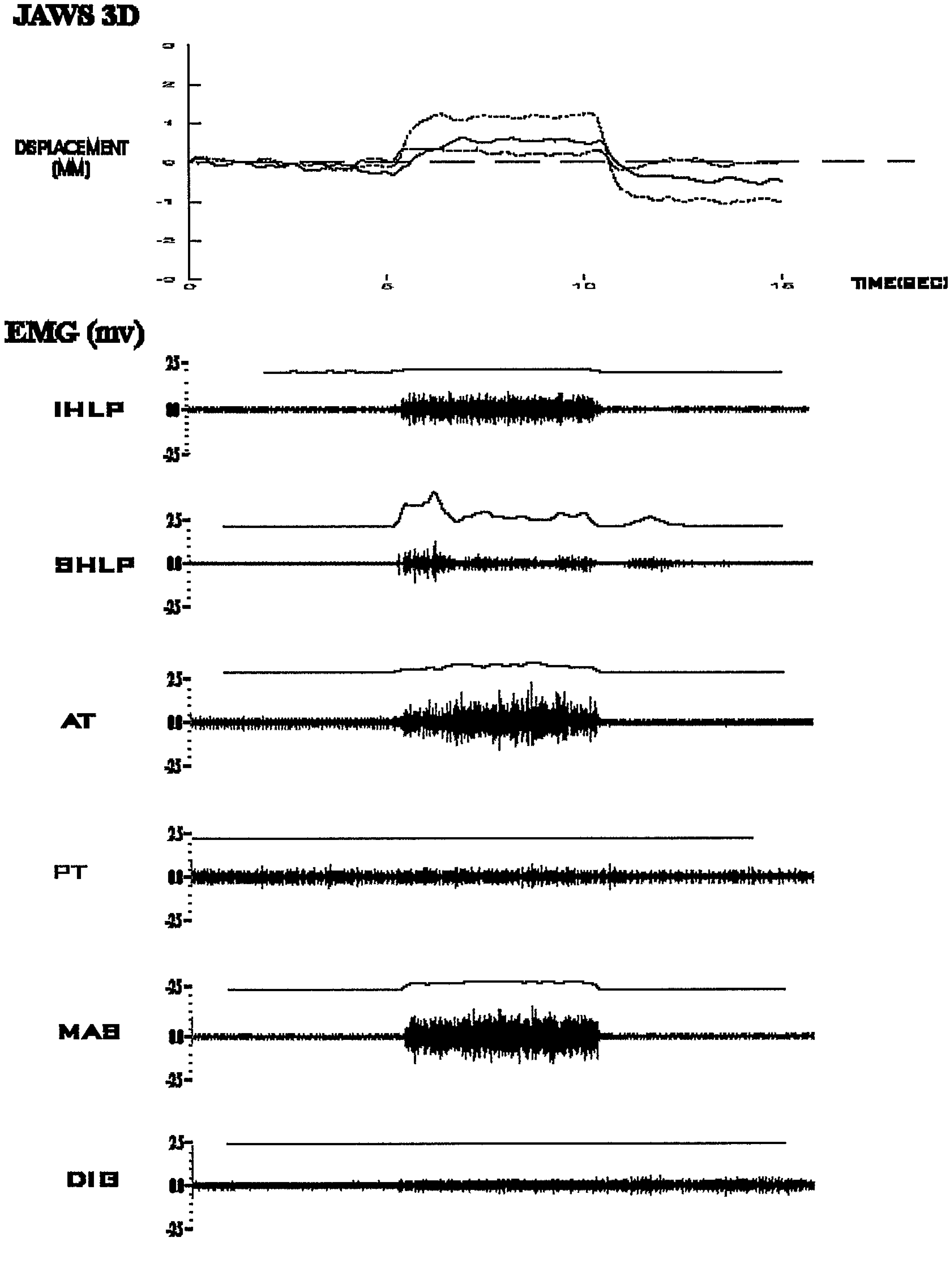


Fig 10. An example of condylar displacements, smoothed and rectified EMG, and raw EMG of subject SF during clenching with LG at maximum bite force (trial 30). Condylar displacements shown as 3 axes: X – axis (dots...) for supero-inferior direction; Y-axis (dash---) for postero-anterior direction; and Z- axis (solid___) for latero-medial direction. The upper EMG graph in each muscle panel indicates the smoothed and rectified EMG data, and the lower graph in each panel indicate the raw EMG. The data from SHLP, IHLP, AT, PT, Mas, and Dig are time matched with the jaw displacement.

SUBJECTS	TRIAL	BITE FORCE	EMG											
			IHLP		SHLP		MASS		AT		PT		DIG	
			mv2	%	mv2	%	mv2	%	mv2	%	mv2	%	mv2	%
RS	control	max	N/A	N/A	0.07	100.0	0.56	100.0	2.54	100.0	0.83	100.0	0.03	100.0
		sd			0.01		0.34		2.59		1.02		0.01	
	jig	half	N/A	N/A	0.04	57.1	0.05	8.9	0.03	1.2	0.02	2.4	0.01	33.3
		sd			0.01		0.01		0.01		0.00		0.00	
		max	N/A	N/A	0.05	71.4	0.12	21.4	0.09	3.5	0.02	2.4	0.02	66.7
		sd			0.01		0.03		0.06		0.01		0.00	
	leaf gauge	half	N/A	N/A	0.04	57.1	0.16	28.6	0.45	17.7	0.16	19.3	0.01	33.3
		sd			0.01		0.10		0.29		0.12		0.00	
		max	N/A	N/A	0.06	85.7	0.15	26.8	0.78	30.7	0.43	51.8	0.02	66.7
		sd			0.00		0.05		0.40		0.04		0.01	
MA	control	max	0.02	100.0	0.10	100.0	1.30	100.0	0.13	100.0	0.03	100.0	0.03	100.0
		sd	0.00		0.04		1.21		0.03		0.01		0.00	
	jig	half	0.02	100.0	0.43	430.0	0.18	13.8	0.02	15.4	0.03	100.0	0.03	100.0
		sd	0.00		0.08		0.02		0.01		0.01		0.00	
		max	0.03	150.0	0.79	790.0	0.29	22.3	0.02	15.4	0.02	66.7	0.03	100.0
		sd	0.00		0.27		0.02		0.00		0.01		0.00	
	leaf gauge	half	0.02	100.0	0.35	350.0	0.25	19.2	0.02	15.4	0.03	100.0	0.02	66.7
		sd	0.00		0.21		0.05		0.00		0.01		0.00	
		max	0.02	100.0	0.16	160.0	0.61	46.9	0.09	69.2	0.04	133.3	0.04	133.3
		sd	0.00		0.06		0.12		0.06		0.03		0.00	
SF	control	max	0.03	100.0	0.32	100.0	0.24	100.0	0.60	100.0	0.21	100.0	0.04	100.0
		sd	0.03		0.30		0.03		0.17		0.07		0.01	
	jig	half	0.04	133.33	0.22	68.8	0.11	45.8	0.07	12.3	0.03	14.4	0.02	50.00
		sd	0.00		0.09		0.01		0.01		0.01		0.00	
		max	0.04	133.33	0.27	84.4	0.16	66.7	0.14	23.2	0.03	14.3	0.02	50.00
		sd	0.02		0.08		0.00		0.02		0.00		0.00	
	leaf gauge	half	0.06	200.00	0.53	165.6	0.21	87.5	0.17	28.3	0.05	23.8	0.02	50.00
		sd	0.00		0.47		0.01		0.14		0.02		0.00	
		max	0.07	233.33	0.92	287.5	0.23	95.8	0.09	15.0	0.03	14.3	0.03	75.00
		sd	0.01		0.58		0.02		0.08		0.01		0.00	

Table 1 continued next page

SUBJECTS	TRIAL	BITE FORCE	EMG											
			IHLP		SHLP		MASS		AT		PT		DIG	
			mv2	%	mv2	%	mv2	%	mv2	%	mv2	%	mv2	%
SP	control	max	0.01	100.0	0.01	100.0	0.38	100.0	0.69	100.0	0.28	100.0	0.03	100.0
		sd	0.00		0.00		0.07		0.08		0.05		0.00	
	jig	half	0.16	1040.3	0.01	117.5	0.29	75.26	0.02	3.58	0.02	6.33	0.02	61.88
		sd	0.03		0.00		0.03		0.00		0.00		0.00	
		max	0.23	1510.1	0.01	155.9	0.39	102.37	0.03	4.10	0.02	7.30	0.03	79.06
		sd	0.06		0.00		0.12		0.00		0.00		0.00	
	leaf gauge	half	0.01	97.3	0.01	101.8	0.07	19.26	0.24	35.12	0.13	45.32	0.02	63.13
		sd	0.00		0.00		0.04		0.10		0.06		0.00	
		max	0.02	102.7	0.01	91.8	0.46	121.58	0.37	53.76	0.12	44.60	0.03	95.31
		sd	0.00		0.00		0.21		0.04		0.03		0.00	
PA	control	max	0.16	100.0	0.02	100.0	0.27	100.0	0.53	100.0	0.07	100.0	0.03	100.0
		sd	0.11		0.00		0.00		0.04		0.06		0.00	
	jig	half	0.02	12.5	0.04	200	0.08	29.62	0.06	11.32	0.02	28.5	0.03	100
		sd	0.01		0.01		0.00		0.01		0.00		0.01	
		max	0.02	12.5	0.02	100	0.12	44.44	0.19	35.85	0.05	71.45	0.02	66.67
		sd	0.00		0.01		0.01		0.04		0.01		0.00	
	leaf gauge	half	0.09	56.25	0.08	400.00	0.15	55.56	0.18	33.96	0.07	100.00	0.05	166.67
		sd	0.06		0.07		0.04		0.16		0.07		0.00	
		max	0.06	37.50	0.02	100.00	0.24	88.89	0.39	73.58	0.13	185.71	0.06	200.00
		sd	0.00		0.00		0.05		0.02		0.02		0.01	

Table 1. Result Table. The average area underneath the EMG curved(mv2) are shown for each jaw muscle with the standard deviation. Normalised data are shown in the second colum of each muscle data, and expressed in term of percentage of the control nomalised value.

4. Discussion

4.1 Bite force

This study examined the EMG activity of jaw muscles produced by an AJ and an LG. The AJ used in this experiment was used to train the subjects to bite at maximum and half maximum bite force. Assuming that EMG activity is related to bite force and has a linear relationship (Hickman et al 1993) under isometric conditions and at small openings of vertical dimension (MacDonald and Hannam, 1984), the method used in this study can be justified.

Muscle fatigue may occur with time, however the 2-minute rest time between tasks was used to minimise this possibility. Biting comfort on the soft LG or hard AJ, may affect subjects' ability to exert their true maximum and half maximum bite forces during the experiment. Maximum bite force however may produce a more consistent result.

Other studies (Williamson, 1980, Golsen, 1984) used the patient's own subjective judgement of "half maximum" and "half hard" bite force. The results of our study showed that half maximum bite force as determined by the transducer does not correlate with the half maximum at clench as given by the EMG activity of MAS or AT and PT.

There were no statistical tests performed for the half maximum bite force data. Subjects MA, SF and PA had higher EMG activity when biting with the LG with half maximum, than maximum bite force. This indicates the difficulty of some subjects in determining bite force levels under the experimental conditions. Subjects may also alter the direction of the muscle vector, to maintain their perception of a half maximum bite force.

The observed differences in maximum EMG levels in our study may have been due to several factors:

(a) The subjects reported some discomfort towards the end of the recording session with the hook electrodes.

(b) This may cause subjects to exert sub-maximal bite force and possibly inconsistently, changing the jaw muscle force vector during clenching.

4.2 ANTERIOR JIG

The AJ used in this study was positioned at an *increased* occlusal vertical dimension to that of the LG. This would affect the bite force produced by the subject. Hence, we cannot extrapolate the half bite force used with the jig, to the half bite force used with the LG. However, the jig was used to train the subject's perception of a "half maximum" bite force. Future studies may use an LG and AJ fitted with a strain gauge that is smaller and thinner to allow minimal separation of posterior teeth. This would allow the possibility of comparing AJ and LG data with more comparable levels of bite force.

The flat plane jig allows incisal clenching, without retrusion of the mandible, as may occur with the LG and Lucia jig. This may account for the different results with tasks using LG and the jig in this study.

Results of tasks using the jig show similarities to studies using a *flat plane* AJ (Becker et al 1999) and acrylic incisor stops (MacDonald and Hannam, 1984). Becker et al (1999) used a pre-fabricated anterior bite stop and measured the activity of AT, PT, Mas, and anterior Dig during clenching and grinding. The anterior bite stop had a significant effect in decreasing electromyographic activity for both clenching and grinding for all muscles tested, except the anterior Dig.

MacDonald and Hannam, (1984), in a 2- part article described the relationships between electromyographic activity in the jaw closing muscles and the location, area and direction of effort (vertical and eccentrically) applied to specific tooth contact points. They found that an incisal stop with vertical clench had the least muscle activity, especially the PT muscle.

In our study, the introduction of the jig showed a general decrease of EMG. This was indicated by the normalized data, with a significant decrease of Mas, AT, and PT of subjects RS, SF, MA, and SP.

Posterior disclusion shifted the periodontal mechanoreceptor contributions to bite force to the anterior teeth exclusively. The lowered feedback from anterior biting only, may not recruit the maximum number of motor units in the jaw closing muscles, reducing the EMG activity compared to maximum clench in IP (Kikuchi et al 1997).

4.3 Leaf Gauge

Higher activity of the AT and PT compared to that of Mas was reported by Williamson et al (1980). Whilst Hickman et al (1992) showed a decrease in Mas and temporalis muscles using a LG compared to different jaw relation techniques. There was no indication in these articles whether AT and/or PT were used for recordings. Donegan et al (1990) used an activity index to determine the result of LG on AT and Mas EMG activity. They showed no effect on normalised postural muscle activity, on the duration of clenching after using a LG for 15 minutes.

Our study showed varied results with EMG activity of AT, PT and Mas. Introduction of the LG decreased EMG activity of these muscles. Significant decreases of EMG activity were observed in subjects MA, SF, and SP.

With the exception of subject RS, there was an increase EMG activity of SHLP with LG. The variations between our study and that of the authors mentioned may be due to the location and the type of electrodes used, and the subjects' ability to maintain biting force and jaw position.

4.4 Lateral pterygoid muscle activity

Lateral pterygoid muscle EMG activity was recorded in this study. This is the first study to measure and verify EMG activity of SHLP and IHLP muscles with a LG.

We would expect a higher EMG activity of SHLP with the LG, especially when maximum bite force was used. Retrusion of the mandible may increase the activity of SHLP. However, in our study no significant changes were observed with SHLP in all subjects when LG was used in maximum bite force.

High activity of SHLP was observed with subject MA. This may be due to the deep overbite and acute functional angle of occlusion, when the LG was introduced. Subject RS showed a consistent (but not statistically significant) decrease in SHLP EMG using AJ and LG, compared with control. The decrease in SHLP activity may possibly be associated with the heterogeneicity of this muscle as described by Murray (in press, J Orofac Pain, 2001). The response of components of this muscle, which are not activated, may result in less overall EMG.

Minimal IHLP activity was observed in all subjects and tasks, except subject SP during clenching tasks using the AJ. Different activities of both IHLP and SHLP supported the study by Phanachet et al (2000), where both heads of the lateral pterygoid had different activities in the return phase of protrusive and contralateral jaw movements. The flat, smooth surface of the jig may have allowed some anterior movement of the mandible during clenching, which may explain the increased EMG activity of the IHLP.

4.5 Anterior tooth relationship

Different anterior tooth relationships would change the vector of muscle force during maximum clench. The palatal surface of the upper anterior teeth allows retrusion of the mandible with the LG, and may alter jaw muscle EMG activity, especially PT and SHLP.

Two out of three subjects with Class I occlusion showed a reduction in EMG activity of Mas, AT and PT. Class II div II subject had a significant decrease in Mas and AT only.

There were intra - and inter - group variations between subjects with Class I anterior tooth overbite and overjet relationships, to that of Angle Cl II div 2 and Class III edge-to-edge relationship.

Due to the small sample size this pilot data is suggestive only and is not conclusive of the effects of the anterior tooth relationship on EMG activity of jaw muscles when a LG and AJ are used.

5. Conclusion

The data suggest that introduction of a LG has the following effects on jaw muscle EMG:

1. There was a general reduction of EMG activity in the MAS, AT and PT muscles.
2. Minimal EMG activity of the DIG and IHLP muscles occured with half maximum and maximum bite force levels.
3. No significant changes with SHLP were observed in all subjects when LG was used in maximum bite force.

Further studies are needed to more clearly clarify the significance of anterior tooth relationships on jaw muscle EMG.

References:

Barghi N, Rugh JD and Drago CJ. Experimentally induced occlusal disharmonies. J Dent Res 1979; 58: 317

Basmijan JV and Stecko GA. A new bipolar indwelling electrode for electromyography. J App. Physiology 1962; 17: 849-851

Becker I, Tarantola G, Zambrano J, Spitzer and Oquendo D. Effect of a prefabricated anterior bite stop on electromyographic activity of masticatory muscles. J Prosthet Dent 1999; 82: 22-26

Braun S, Marcotte MR, Freudenthaler JW and Honigle K. An evaluation of condyle position in centric relation obtained by manipulation of the mandible with and without leaf gauge deprogramming. Am J Ortho Dentofac Orthop 1997; 111: 34-37

Carroll WJ, Woelfel JB and Huffman RW. Simple application of anterior jig or leaf gauge in routine clinical practice. J Prosthet Dent 1988; 59: 611-616

Carr AB, Donegan SJ, Christensen LV and Ziebert GJ. An electrognathographic study of aspects of deprogramming of human jaw muscles. J Oral Rehabil 1991; 18: 143-148

Donegan SJ, Carr AB, Christensen LV and Ziebert GJ. An electromyographic study of aspects of deprogramming of human jaw muscles. J Oral Rehabil; 1990; 17: 509 – 518

Golsen LF, and Shaw AF. Use of leaf gauge in occlusal diagnosis and therapy. Quintess Internat 1984; 6: 611-621

Hellsing G and McWilliam S. Repeatability of the mandibular retruded position. J Oral Rehabil 1985; 12: 1-8

Hickman DM, Cramer R and Stauber WT. The effect of four jaw relations on electromyographic activity in human masticatory muscles. Archs Oral Biol 1993; 38: 261-264

Kikuchi M Korioth TWP and Hannam AG. The association among occlusal contacts, clenching effort and bite force distribution in man. J Dent Res 1997; 76: 1316-1325

Klineberg I. Occlusion: Principles and assessment. Oxford Butterworth-Heinemann 1991:p 13, 70

Long JH. Locating centric relation with a leaf gauge. J Prosthet Dent 1973; 29: 208-210

Lundeen HC. Centric relation records: The effect of muscle action. J Prosthet Dent 1974; 31: 245-251

MacDonald JWC and Hannam AG. Relationship between occlusal contacts and jaw-closing muscle activity during tooth clenching: Part I. J Prosthet Dent 1984; 52: 718-729

MacDonald JWC and Hannam AG. Relationship between occlusal contacts and jaw-closing muscle activity during tooth clenching: Part II. J Prosthet Dent 1984; 52: 862-867

Murray GM, Orfanos T, Chan JY, Wanigaratne K and Klineberg IJ. Electromyographic activity of the human lateral pterygoid muscle during contralateral and protrusive jaw movements. Archs Oral Biol 1999; 44: 269-285

Orfanos T, Sarinnaphakorn L, Murray GM and Klineberg IJ. Placement and verification of recording electrodes in the superior head of the human lateral pterygoid muscle. Archs of Oral Biol 1996; 41: 493-503

Phanachet I and Murray GM. Human lateral pterygoid muscle activity on the return phase of contralateral and protrusive jaw movements. Archs Oral Biol 2000; 45: 517- 529

Pullinger AG, Selligman DA and Gornbein JA. A multiple logistic regression analysis of the risk and relative odds of temporomandibular disorders as a function of common occlusal features. J Dent Res 1993; 72: 968-979

Vaughan, C.L.,. Smoothing and differentiation of displacement data: an application of splines and digital filtering. International Journal of Biomedical Computing 1982; 13: 375-386.

Williamson EH, Steinke RM, Morse PK and Swift TR. Centric relation: A comparison of muscle-determined position and operator guidance. Am J Orthod. 1980; 77: 133-145

Woefel JB. New device for accurately recording centric relation. J Prosthet Dent 1986; 56: 716-727

Wood WW. A review of masticatory function. J Prosthet Dent 1987; 57: 222-232