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Tutorial

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A SELECTIVE REVIEW OF CURRENT TECHNOLOGY APPLICABLE TO OROFACIAL MYOLOGY RESEARCH

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With advances in technology, measurement techniques have become more precise and accurate. Research instrumentation such as electromyography, kinesiography, cineradiography, videofluoroscopy, nuclear magnetic resonance imaging and computerized axial tomography, ultrasound, dynamic palatography and airway assessment instrumentation may offer avenues for investigation in orofacial myology.

There was an expanding body of literature in orofacial myology prior to the Position Statement (1974) drafted by the Joint Committee on Dentistry and Speech Pathology-Audiology. Following the review of hundreds of publications, the committee concluded that there was insufficient scientific evidence to support the concept of tongue thrust as a clinical entity. Following the publication of this statement, research efforts diminished (Hanson, 1988).

Nelson (1987) stresses that research findings are necessary to support methods and establish credibility, especially in orofacial myology. He states that it is of utmost importance that the profession itself be involved in the research rather than leaving the task to others who seek to disprove rather than clarify theories. Nelson suggests a thorough review of the research literature related to myofunctional therapy, especially since 1975.

In a literature review, Hanson (1976) comments that although scientific experimentation prior to clinical application of a procedure is the ideal, traditionally the clinical approach has had to prove itself worthy of the time that would be invested to conduct the investigation. He also observed that research up to that time had only "provided fuel for the controversies." The problems with the research included inappropriate experimental designs, insufficient control of variables and application of results to a population based upon limited sampling.

Hanson (1988) reports that much of the research to date suffers from lack of adequate controls, but support for the validity of orofacial myofunctional therapy is evident. He urges that more objective criteria are needed for selection of patients who may benefit from myofunctional therapy. Hanson believes that the refinement of diagnostic procedures is imperative, and treatment procedures require further study and clarification.

With advances in technology, measurement techniques have become more precise and accurate. Bronzino (1986) concludes that technology has caused more growth in medical knowledge in the last 50 years than in the previous 2,000. Biomedical engineering is emerging as an integral part of health care and medical research systems. This branch of applied science can assist in understanding and solving problems utilizing approaches drawn from engineering and technology. In a culture oriented to scientific development, this trend can be expected to continue.

Recent advances in technology offer a range of instrumentation to consider in planning research in orofacial myology. Improved tracking devices, intraoral force transducers, imaging devices and the capacity to analyze data with computer technology have quantified variables present in the functioning of the stomatognathic system (Wood, 1987). The following is a survey of selected measurement techniques potentially applicable to orofacial myology research.

INSTRUMENTATION

Electromyography

EMG apparatus consists of an amplifier, a stimulator, a display unit, a loudspeaker and a camera or other recording device (Ludin, 1980). EMGs employ high impedance amplifiers with a frequency response from 10 Hz to 2000 Hz. The results are recorded on FM electromagnetic tape. Multitrack tape recorders can store signals, particularly useful for computer analysis (Basmajian, Clifford, McLeod and Nunnaly, 1975).

Wood (1987) describes four common methods of recording muscle activity: Surface electrodes, usually bipolar, adhered or hooked to the skin; fine wire electrodes inserted into a muscle belly; concentric needle electrodes; and bipolar needle electrodes. The chief advantages of surface electrodes are that they are readily obtained, need little training to apply and give little discomfort to the patient. They are applied as adhesive strips with electrode jelly to improve contact. The disadvantages of these electrodes are that they may be used only with superficial muscles, and that their pickup is widespread. However, they can measure simultaneous activity in a fairly large group of muscles where palpation is almost impossible. Cudahy (1988) suggests the use of needle electrodes to increase specificity of response. The needle is placed close to the nerve, and in some cases is embedded in muscle tissue, making it less sensitive to extraneous sources. In this technique fine wire electrodes are inserted through the skin with a hypodermic needle. Fine wire electrodes reveal discrete activity eliminating interference from surrounding muscles. Although fine wire electrodes demonstrate more accuracy, they are invasive. However, Basmajian, et al, (1975) assert that, "electrodes inserted through the skin are no longer as forbidding as they once were."

Physical transducers are also used in some electromyographic studies. Basmajian, et al. (1975) describe the types of physical transducers utilized in measurement. One type of sensor, the strain gauge, can measure force, acceleration or pressure when incorporated into systems that convert these physical variables into a displacement.

Lear, Flanagan, and Moorrees (1965) studied swallowing incidence over 24 hour periods in 20 subjects in satisfactory health and with normal dental occlusion. Frequency was greatest during eating, and least during sleep. They reported a mean deglutition frequency of 585 per day, with a range of 203-1008. Lear and Moorrees (cited in Subtelny, 1973) used strain gauges to measure labial, buccal, and lingual forces. Daily oral activity of seven adolescent and young adults with normal occlusion was examined. The average pressure during deglutition was 6.9 grams over a two second period. Continuous resting pressure was recorded as two to four grams. They concluded that constant resting pressure was more significant than the intermittent force of deglutition.

Electromyography has also been used as a biofeedback technique (Bronzino, 1977). Processed information (output) is returned (feedback) to the individual to modify muscle behavior. Biofeedback is not a new phenomenon, as it has always existed in the physiological systems of the body: Regulation of muscular movements, body temperature and metabolism. With technology, an individual can monitor physiologic processes through observation of light, sound or a needle on a dial.

Basmajian, et al. (1975) divide kinesiologic studies employing EMG into three areas: Studies to determine how a muscle or group of muscles are active or inactive during a specific moment or posture (this can include both normal ranges and ranges in disease); studies to rank order beginning and end of activity from channels of EMG; studies to derive a profile of rise and fall of EMG in one or more muscles during specified movements within specific time frames.

O'Dwyer, Quinn, Guitar, Andrews and Neilson (1981) performed a comprehensive EMG study of 18 orofacial and mandibular muscles. EMG signals were recorded simultaneously in 14 muscles of the lips, jaw and tongue to investigate action tonic stretch reflexes. Subjects were asked to perform a series of gestures including facial and tongue movements, biting and saliva swallowing. Results indicated that functional verification of electrode placement in these muscles was a difficult process. Participation of adjacent muscles in the same gestures limited the ability to verify results for a specific muscle. This was a particular problem true for single muscle recordings.

Van Mens and de Vries (1984) compared the use of biofeedback with conventional methods to find the clinical rest position of the mandible. Clinical rest position is the ideal relationship between the maxilla and the mandible. They found that use of self-control through biofeedback produced larger variations and incorrect interocclusal distances for the edentulous patients studied. They concluded that conventional methods for determining rest position, that is, saying the letter [m], or licking the lips and then swallowing were more constant and reliable. Watkinson (1987) utilized biofeedback with ten subjects to study clinical rest position and masseter activity. He found that clinical rest position does not correspond with the position of minimal activity of the masseter muscle.

Cornellier, Keenan and Wisser (1982) studied four adult subjects with nocturnal bruxism. EMG activity of the right masseter muscle was monitored at each session for three weeks prior to biofeedback training. Subjects then underwent biofeedback training. Bruxscore devices were worn at night during this phase to provide continuous index of bruxism throughout the study. Biofeedback training resulted in a reduction of muscle activity. Change of symptoms seemed to be related to a reduction in diurnal clenching activity. Long term follow-up was not reported.

McGlone and Proffit (1974) took impressions of the maxillary dental arch and palate of three age groups of children in order to construct intraoral appliances containing pressure transducers. The age categories were further divided into 12 normal speakers, six children with interdental lisps, and five children with lateral lisps. Each child was asked to imitate pre-recorded stimulus syllables containing /s/, /z/, voiced and voiceless /th/. They concluded that pressure patterns for /th/ and those for /s/ and /z/ were almost identical and patterns for a lisped /s/ were different from normal /s/, but were similar to the normal /th/. They also concluded that a lateral lisp was a unique articulatory gesture, in that no tongue grooving occurred.

Ruggieri, Milizia, Sabatini, and Tosi (1983) studied 35 female undergraduates from 20 to 30 years of age. Muscle tone at rest, and tickle sensitivity were measured. Tickle was defined as the superficial skimming of the skin involving the following sequence: Latency, tickle perception and adaptation. All myographic scores were statistically significantly negatively correlated with body-perception scores. This means that when muscle tone increases, body-perception scores decrease, indicating that high muscle tone corresponds to a low body awareness, and low muscle tone corresponds to a high body awareness.

Reflex responses in jaw, lip and tongue muscles of ten adult subjects were elicited with brief mechanical stimuli in a study by Weber and Smith (1987). The results indicated that stimulation of lip and tongue produced responses in masseter muscles. In contrast, stimulation of jaw muscles had no effect on activity of genioglossus or orbicularis oris inferior muscles.

Devlin and Wastell (1986) studied eight dentulous subjects, ages 28 to 54 years, using a calibrated strain gauge transducer inserted between two platforms, just separating the teeth. Subjects monitored their bite force on an oscilloscope screen. The transducer was placed in two positions, anteriorly on the palatal midline opposite the premolar teeth and posteriorly, also on the midline, 5 mm posterior to the first position. When the activity of the elevator muscles was compared on each side of the jaw, no significant differences were found between right and left for masseter and temporalis activity. However, a small but significant reduction of 10% in EMG activity was observed for the posterior position. This supports the theory that greater masticatory activity is required to produce an occlusal load in an anterior as compared to posterior position.

Rastatter and DeJarnette (1984) measured EMG activity for the orbicularis oris superior, orbicularis oris inferior and masseter muscles for eight normal speaking children, eight children with speech articulation disorders and eight adults. The children with articulation disorders exhibited less variability of performance for the inferior muscle, while the variability of superior and masseter muscles were similar to the normal speakers. In a similar study, Rastatter, McGuire, Bushony and Loposky (1987) compared the same muscles in three geriatric women in good health, in four year old and eight year old children and in young adults. The authors suggested that speech-motor equivalence returns to an earlier level of operation upon aging.

Gay and Piecuch (1986) studied ten male adults with normal dentition, ranging from 22 to 41 years. They used hooked wire electrodes in the superior and inferior heads of the lateral pterygoid, superficial and deep layers of the masseter, anterior and posterior temporalis, medial pterygoid and anterior belly of the digastric muscles. They concluded that coordination of muscle activity in both simple and comprehensive oral functions was complex and variable across different subjects.

Electromyography was widely used by researchers in the 1960s and the 1970s to measure tongue pressure at rest, during swallowing and in speech. The lack of universal baselines is a significant limitation to EMG research. Each study establishes its own baseline, and its accuracy depends upon the calibration of the instruments, the researcher's experience in placing electrodes and skill in operating the instrumentation.

Kinesiometric Instrumentation

The kinesiograph consists of a set of magnetometers which sense vertical, lateral and anteroposterior jaw movements (Hannam, DeCou and Wood (1980). The instrument is limited to measuring at the incisor point. Advantages include: It is non-invasive, easy to use and widely applicable.

Many dental specialties are concerned with the vertical rest position of the mandible and maxilla. For dentulous patients, altering the vertical dimension of occlusion may result in traumatic occlusion, possibly contributing to the progress of periodontal disease. Intrusion upon the interocclusal distance may also result in continuous hyperactivity of the masticatory muscles. The vertical rest position of the jaw, and jaw muscle activity were observed in ten normal adults (Rugh and Drago, 1981). The authors describe several phonetic procedures for establishing clinical rest position. These include having the subject produce the letter [m]; lick the lips, say "Mississippi" and hold that position; or follow production of the letter [m] with a saliva swallow. Subjects were given biofeedback training to relax their masticatory and facial muscles; then, vertical jaw opening was measured by the kinesiograph. Subjects were instructed to maintain the lowest possible reading on the digital display while maintaining a determined jaw opening. Specific points of vertical jaw opening were observed where jaw and facial muscle activity was minimal, but these points did not coincide with the rest position. The authors concluded that in an upright position, certain jaw muscles must be in slight contraction to maintain the jaw in the clinical rest position.

George (1983) conducted a pilot study with ten adults from 23 to 31 years of age to determine a method of measuring mandibular movement during speech. The kinesiograph was used to measure mandibular movement in three dimensions. He found that production of the /s/ sound can occur in varying positions depending upon the initial, medial or final placement of /s/ in a word or phrase; the distance between upper and lower incisors during speech was consistent and less than 1 mm; and that the mean rest position was located 0.3 mm posterior to centric occlusion.

RADIOGRAPHIC AND MAGNETIC RESONANCE IMAGING

Cineradiography and Videofluoroscopy

Almost a century ago, Wilhelm Roentgen discovered x-rays, which eventually led to the specialty of radiology and medical imaging. In the last 20 years, changes in imaging techniques and particularly the advent of the computer, have accelerated the use of these techniques in medical diagnosis (Bronzino, 1986).

The image is produced by a point source tube that generates a beam of x-rays when stimulated by a high-voltage power supply. This image is detected by x-ray film, an image intensifier or a set of x-ray detectors (Bronzino, 1986).

In projection (conventional) radiography systems, the detector is photographic film which offers high-resolution, high-contrast images with small dosage to the patient and generates a permanent record. The disadvantages are that it has significant geometric distortion, and lacks the ability to display depth information. Conventional radiography is the appropriate imaging method for dental, chest and bone imaging, since bone strongly absorbs x-rays (Bronzino, 1986).

Cephalometric radiographs are used to identify specific landmarks of the head. Location of these points on tracings of cephalometric radiographs facilitate measurements that define the relationships of the teeth, the maxilla, the mandible and the other cranial structures to each other. "Cephalometric analysis" is based upon averaged data of craniofacial growth and development. The method is useful to the orthodontist in assessing growth and development patterns (Graber, 1972), and to the surgeon planning to correct abnormalities of the facial skeleton.

Shelton, Furr, Johnson, and Arndt (1975) screened 835 third, fourth, and fifth grade children in seven schools for errors in /s/ articulation. Twelve children made five or fewer correct responses on a thirty-item /s/ production task. From this group, ten subjects were administered the Peabody Picture Vocabulary Test and the Mcdonald Articulation Screening Deep Test. A single cephalometric x-ray film was made of each subject for the analysis of seven measurements. Findings included an association between open-bite and poor /s/ articulation. The authors report clinical relationships between occlusion and speech articulation. They suggest that these relationships might be influenced by tongue posture.

Lowe, et al. (1985) documented the relationship between tongue muscle parameters at rest and craniofacial morphology in adults with both normal and anterior open-bite malocclusions. This cephalometric study involved a sample of 60 adult females with Class I skeletal relationships. The procedure during the cephalometric films was to swallow saliva on command. At count 5 of 15, the subject was instructed to swallow and relax. This procedure allowed the reseachers to make a number of soft-tissue measurements such as tongue length and height, tongue tip relative to lower occlusal plane, tongue tip relative to lower incisor tip, total tongue area, upper tongue area, total oral area, anterior oral area, hyoid angle and upper, middle and lower pharyngeal wall. They identified the following correlations: 1) Subjects with short face characteristics and overbite positioned tongue tips below the lower occlusal plane; 2) skeletal open-bite subjects demonstrated tongue tips ahead of and above lower incisor teeth with the mandible in the rest position; 3) undererupted mandibular teeth were associated with reduced tongue height and an inferior epiglottis; 4) short tongue length correlated with a combination of upright central incisors, a small overjet, undererupted maxillary and mandibular teeth, a low ANB angle, and a steep occlusal plane. These researchers concluded that tongue posture at rest appeared to be related to incisor position in skeletal open-bite subjects. They stressed the importance of confirming earlier reports identifying the rest position of the mandible as an important determinant of muscle activity and tooth position.

In fluoroscopic radiographic systems, the detector is a fluorescent screen or an image intensifier-television camera combination. It is particularly useful in examinations in which a contrast medium is injected into the body. The disadvantages of the system are that geometric distortion is still evident, depth discrimination is not possible, and it involves the invasive injection of contrast medium.

Cineradiography, the use of motion pictures, was the first method generally used for recording motion during fluoroscopy. It was useful in examining the pharynx and the esophagus, where peristalsis is rapid. The method created a permanent record (Gelfand, 1984). With the recent advent of television recorders, videotape recording during fluoroscopy is the method of choice.

Cuozzo and Bowman (1975) studied ten females from 19 to 30 years of age to determine the amount of change in positioning of the hyoid bone during forced distal positioning of the tongue by a tongue crib. They took the following records: Myometric analysis of tongue pressure during deglutition and cinefluorographic sequences of normal deglutition. Each subject was fitted with a tongue crib for 24 hours. They concluded that any procedure that encourages forced inferior and/or posterior displacement of the tongue will be readily tolerated in persons whose hyoids are held relatively close to the mandibular plane. In individuals whose hyoids are held distant from the mandibular plane, there would be difficulty in tongue accomodation.

Gobeille and Bowman (1976) agree that tongue position and adaptability of the tongue are related to hyoid position. They studied ten subjects from 11 to 15 years of age to determine to what extent the hyoid bone readapts its position during the swallowing pattern in patients with anterior open bite and tongue thrust when the tongue is forced into a new distal position. A myometric analysis of tongue pressure during delutition, and a cinefluorographic sequence of normal deglutition was taken. Patients wore an orthodontic crib for 24 hours. They concluded that in those whose hyoid bones were located near the mandibular plane, there was good physiological adaptation to the tongue crib, but persons in whom the hyoid was located more distant from the mandibular plane did not achieve a posterior and inferior shifting of the hyoid.

Eckberg and Hillarp (1986) evaluated 19 patients with swallowing difficulties using radiologic examination to determine function during the oral stage of swallowing. Eight patients had surgical resection and reconstruction due to tumors of the tongue, floor of the mouth or mandible. Eleven had suffered from cerebrovascular disease. All patients had incoordination of tongue movements, including problems with initiation of the pharyngeal swallow. In patients who had surgery, muscular derangement due to surgery on the floor of the mouth affected elevation of the hyoid bone, larynx and pharynx. The study analyzed the oral stage of the swallow in terms of tongue movement during chewing and ability to close the lips; preparation, gathering and transportation of the bolus; and initiation of the pharyngeal swallow. The authors agreed with previous research that intact sensori-motor control of the mouth is necessary for proper regulation of oral function when preparing the bolus, and initiating the pharyngeal swallow. They stressed that motor function is difficult to evaluate solely by physical examination of the oral cavity and pharynx. Cineradiography is recommended for evaluation of this function. Swallowing is described as a complicated sequence of muscular activity within the lips, cheeks, tongue, floor of the mouth and soft palate.

Donner (1986) states that while the act of swallowing appears simple, its successful execution requires the coordination of several cranial nerves and 26 muscles of the mouth, pharnyx and esophagus. Logemann (1986) relates that the sensory portion of the swallowing reflex is carried by cranial nerves IX (glossopharyngeal), X (vagus) and XI (accesory). The VII (facial) nerve may contribute to the sensory portion. The motor portion is carried by IX and X. Possible contributers to the afferent portion are V (trigeminal), VII and XII (hypoglossal).

Recently, Logemann (1986) formulated a technique called the modified barium swallow for examining the anatomy and physiology of the oral cavity and pharynx during deglutition. Logemann's technique is mainly concerned with manipulation of the bolus prior to the esophageal stage of the swallow, since disorders occur-ring in the esophageal stage are not amenable to techniques of swallowing therapy. This technique permits the trained observer to identify disorders in speed, in movement patterns controlling the bolus and aspiration, so as to identify the potentially life threatening entry of food or liquids into the lungs. She recognizes the need to examine the preparatory phase of the swallow where the bolus might be held more anteriorly than normal, suggesting a tongue thrust swallowing pattern. Also noted is the competency of the labial musculature to form an oral seal, the intact lingual movement to propel the bolus posteriorly and a firm buccal musculature to prevent food from filling the lateral sulci (Logemann, 1983).

MRI and CAT Scanning

In the 1970s, development of the computerized axial tomography (CAT) scan produced a cross-sectional view of a patient, thus providing the ability to image a single body plane without interference by other body planes. A computer reconstructs the data into high-resolution and high-contrast images of any body plane. Since only the body section to be studied is irradiated, x-ray dosage is reduced. The data can also be used to reconstruct three-dimensional images.

The most promising development appears to be nuclear magnetic resonance imaging, more recently termed magnetic resonance imaging (MRI). This provides a noninvasive method for obtaining organ images without ionizing radiation. The system relies on alteration of magnetic moments of atoms to produce an image. The system utilizes hydrogen nuclei that are essentially arrays of tiny magnets, placed into an external magnetic field that define differences in water content and the relaxation parameters of water molecules of different tissues to create an image. The nuclear magnetic moments tend to become aligned parallel with the external field (Bronzino, 1986).

Radiographic and imaging instruments are further described in the following sections. Magnetic resonance imaging (MRI) has several advantages over computed tomography (CAT) in the evaluation of the head and neck (Dillon, cited in Goldberg, Higgins and Ring, 1985). MRI allows greater contrast detail among soft tissues because of dependence on mobile hydrogen density, unlike CAT which depends upon differences in electron attenuation. MRI has the ability to depict cross-sectional anatomy in multiple planes (axial, sagittal, coronal) without intraveneous contrast, manipulation of the patient or radiation. Dental fillings do not distort the image produced by MRI, which is a distinct advantage for use in the oropharynx. The nasopharynx is easily visualized by MRI because of its soft tissue structure. The superficial mucosa and adenoidal tissue of the nasopharynx are usually indistinguishable from the underlying musculature on CAT, but they have a high-intensity signal on MRI because of an increase in water content. Muscle margins can be seen well on MRI. The lingual, soft palate and palatine tonsillar tissue are also clearly depicted. The intrinsic muscles of the tongue have a mixed intensity due to their mixture with fat.

Seltzer and Wang (1987) obtained CAT and MRI images of the normal masseter muscle from patients who were evaluated for intracranial lesions but who showed no clinical or radiologic evidence of masseter muscle abnormalities. CAT scanning is currently the most widely used imaging method to display masseter muscle abnormalities. The advantage of CAT is that it can depict soft tissue as well as bony tissue on the same scan, therefore showing the extent of tumor masses or infections in and around the masseter muscle and neighboring structures. The disadvantages of the CAT scan are its ionizing radiation, and the distortion of the CAT image by dental fillings and metallic appliances.

Lufkin, et al. (1986) used MRI to study ten healthy subjects and 44 patients with diseases of the tongue and oropharynx. Nineteen patients were also studied with CAT. Both CAT and MRI imaging were excellent aids in planning treatment because they demonstrated deep soft tissue anatomy and allowed assessment of the extent of disease.

Exposure to radiation must be considered when utilizing the CAT scan as a research technique. MRI, however, is non-invasive, but currently is more expensive and technologists in this field are scarce. Patient motion is less of a problem in CAT scanning, unlike MRI where image blurring occurs if the patient moves. Some patients become claustrophobic from being confined inside the MRI gantry (Bronzino, 1986).

Ultrasound

Ultrasound utilizes high-frequency sound waves in the megahertz range that cannot be heard by the human ear. Sound waves, like light waves, can be reflected, refracted and absorbed by a medium. Therefore, ultrasonic waves can image body organs and relate information about the structure and function of body tissues. The clinical advantage is that the technique is completely noninvasive, using nonionizing radiation without reported adverse side effects. Interestingly, ultrasound was discovered by Strutt in 1877, 12 years prior to x-rays, but application did not begin until the 1920s because the appropriate technology was not available to generate the desired ultrasonic field, detect the attenuated signal, and process the information to show meaningful results (Bronzino, 1986).

Ultrasound is not only used in medicine, it has been tested in phonetics. Stone, Sonies, Shawker, Weiss and Nadel (1982) tested five normal adults sustaining production of the vowels /i/, /a/, /u/ and "rest" position for five seconds. Testing was accomplished by holding the ultrasound transducer beneath the chin of each subject during production of the sound. Ultrasound images were recorded on videotape for analysis, and segments of the videotape were transferred onto a 20 second video disc to select the single frame most representative of tongue configuration for each utterance. Instant photographs were taken of all the selected frames and measurements were made from the photographs using a radius grid and a digitizing tablet. Through this method they were able to visualize the tongue surface, internal soft tissue structures including the genioglossus and the floor intermuscular septum (which separates the tongue and jaw muscles), the geniohyoid and the mylohyoid. They found two problems with the method: The transducer had to be placed manually allowing for variability in positioning; also, unlike x-ray, measurement and analysis of the ultrasound data was difficult because there were no visible hard structures in the image against which to reference tongue position.

Since the tongue is soft tissue, and basically a liquid structure, Shawker, Stone and Sonies (1985) were able to simulate the tongue by constructing a water bath phantom. It was a thin rubber bag filled with degassed water which was scanned from below with the transducer directed upwards, in similar orientation as actual scanning of the tongue and oral cavity. The researchers sought to develop a method to demonstrate function in ultrasound imaging, through the use of a stainless steel pellet which would create a reverberation, or echo. The reverberation artifact (stainless steel pellet) was also visible when placed on the tongue surface of a normal volunteer. Using the reverberation artifact as a point indicator the researchers were able to track the excursions during speech of two pellets placed on the tongue surface and one pellet placed on the anterior floor of the mouth. The researchers concluded that it is now possible, using ultrasound imaging of the tongue during speech to display simultaneously in real-time (that is, to process information as it is received), rather than storing it for future use. It is also a technique to observe changes in configuration of the tongue surface, the alteration in position of the oral cavity musculature, and movement of selected points on the tongue.

Stone and Shawker (1986) were able to measure tongue length of six normal adult females between 20 and 40 years. This was accomplished by affixing a pellet to the tongue at the junction between the anterior third and posterior two-thirds of the tongue surface, and imaging with ultrasound. The surface distance from the pellet to the hyoid was measured while the tongue was at rest. Posterior tongue length was added to determine total tongue surface length. A 5 mm stainless steel pellet was attached to the tongue with dental impression material. As each subject swallowed ten boluses of water, the tongue was scanned in the midsagittal plane and videotaped in real time. Each frame of the videotape was marked, while pellet movement was tracked. Analysis in detail of tongue movements during swallow revealed that there are four stages of movement of the tongue blade during the swallow, which include both longitudinal and transverse components. The tongue blade was most active during the first two stages of swallowing. Initial bolus manipulation required precise tongue activity. As the bolus was propelled in a posterior direction, and the tongue moved anteriorly, inferior tongue movement took place. Once the bolus passed, the tongue moved rapidly in a superior and anterior direction to contact the palate. The researchers concluded that the normal swallowing gesture involves a complex timing relationship between hyoid movement, bolus propulsion, and tongue-palate approximation.

Dynamic Palatography

Fujimura, Tatsumi and Kagaya (1972) developed the technique of dynamic palatography. Dynamic palatography is an electrical apparatus that generates a visual display of constantly changing palatolingual contact as a function of time. In this study a thin artificial palate of average thickness of about 1 mm with 64 small silver electrodes was custom made for a subject. The subject uttered nine sentences, 25 times in succession with a short pause between each repetition. A set of palato-lingual contact patterns was derived which elicited information on the dynamic characteristics of lingual articulations. The method was practical for computer-assisted processing of data, for quantifying characteristics of consonants and variability of observable measures.

Michi, Suzuki, Yamashita and Imai (1986) incorporated dynamic palatography for a six year old female cleft palate patient with a repaired unilateral cleft lip and palate. Prior to therapy with the dynamic palatograph, she had excessive posterior movement of the tongue. After therapy, she demonstrated normal palatolingual contact.

Dynamic palatography has distinct possibilities for research. It demonstrates palato-lingual contact patterns, and appears to be an efficient instrument to compare tongue resting posture patterns and speech. This technique, however, is not approved as yet for use in the United States (Charlene Clark, personal communication, June 25, 1988).

Airway Assessment Instrumentation

Warren (1984) expressed concern about the radiographic diagnosis of nasal airway impairment by orthodontists. Radiographs are two dimensional and do not give a clear indication of true airway patency. Superimposition of shadows may lead to misleading conclusions. He demonstrated a noninvasive technique for determining significant nasal obstruction. Nasal airflow was measured with a heated pneumotachograph connected to a nasal mask. Each subject had to inhale as normally as possible through the mouth, close the lips, and then exhale through the nose. Pressure and airflow patterns were transmitted to the computer for analysis. An impaired airway can be determined by this technique since the size of a constriction has a geometric relationship to airflow. The cross-sectional area of the airway is related to the degree of obstruction present, and it can be measured pre- and postoperatively in patients undergoing nasal surgery, maxillary osteotomies and maxillary expansion, to reliably assess the effects of treatment on the nasal airway. The disadvantage of the technique is that it does not provide any information on the location of the obstructed area.

Warren (1986) reported the use of the inductive plethysmograph. This device consists of two transducers that record the relative movement of the abdomen and thoracic cage during respiration. Two teflon-coated wires are sewn into a lightweight washable material and are fastened with Velcro around the upper chest and lower abdomen. A net retainer holds the transducers in place. They are also attached to the frequency oscillators that connect to a calibrator system. The transducer measures change in inductance, proportional to changes in thoracic cage and abdominal volumes. The rib cage and abdominal signals are then calibrated against a known volume by having the subjects breathe into a spirometer. Reliability studies demonstrate that values generated by inductive plethysmography agree with values obtained by integrated pneumotachography, where a patient must be placed in an air-tight enclosure.

In an extensive literature review of nasal airway interference, Riski (1988) notes that the study of nasal airway interference includes literature from many fields, including allergy, otorhinolaryngology, growth and development, medicine, orthodontics and orofacial myology. Presently, complex interactions based upon objective measures should be evaluated by a team of specialists from these fields.

Miscellaneous Instrumentation

REFLECTED LIGHT SENSING

Chuang and Wang (1978) designed a device that used a reflected-light-sensing technique to monitor tongue movement in the frontal oral cavity. The unit was composed of a LED light source and a phototransistor mounted onto an artifical palate and attached to the hard palate. Chinese consonants and vowels were produced. The authors concluded that with some improvement in the method of output-function linearization, this method offered temporal and spatial resolution comparable to that of the then available magnetic, ultrasonic and x-ray techniques.

POSTURE ASSESSMENT DEVICE

To measure posture, Forsberg, Hellsing, Linder-Aronson and Sheikholeslam (1985) devised a tripod equipped with a lamp and a protractor scaled in half degrees which was put up one meter to the left of a subject standing with head extended five degrees, in front of a vertical mirror. The narrow flat beam emerging through the slit of the lamp was adjusted to be horizontal and perpendicular to the median plane of the subject. The postural technique measured quantitatively the assumed flexion and extension postures of the postcervical, supra- and infrahyoid muscles, sternocleidomastoid muscle, temporal and masseter muscles in relation to tonic activity (which was measured by electromyography). They found that contraction activity increased in the postcervical muscles during flexion; postural activity increased in the sternocleidomastoid muscle during extension; supra- and infrahyoid muscles increased activity during both extension and flexion and masseter activity increased during head extension. However, no significant association was found between head posture and activity in the anterior temporal muscle.

In 1986, Hellsing, Forsberg, Linder-Aronson and Sheikholeslam, utilized the above device to record changes in head posture and compare tonic activity of the postcervical, supra- and infrahoid, anterior temporal, masseter and sternocleidomastoid muscles during oral respiration. They studied 30 adults during normal breathing and posture, at intervals following nasal airway obstruction and after normal nasal respiration had resumed. They found that obstruction of nasal airways resulted in head extension and lowered mandibular posture. Postural activity increased in the suprahyoid muscles, but there was no change in the infrahyoid, masseter and sternocleidomastoid muscles. When nasal respiration resumed, activity was similar to that recorded before the nasal obstruction.

Hellsing and L'Estrange (1987) studied changes in upper and lower lip resting pressures following extension and flexion of the head, and at changed mode of breathing in 15 adults with Class I molar relationships. They measured seven different head postures using the light beam technique already described. Lip pressure on upper and lower incisors was measured with a transducer which had been developed earlier by Proffit. During flexion, lip pressure on upper central incisors decreased. During induced mouth breathing, lip pressure decreased significantly in both upper and lower jaws. However, when the head was extended five degrees during mouth breathing, lip pressure increased significantly. This substantiated earlier reports of children with retroclined incisors who experience long periods of nasal obstruction.

ORAL STEREOGNOSTIC PATTERN TESTING

Graubard, Carrel, and Chialastri (1979) define oral stereognosis as ability to perceive and identify three dimensional qualities or shape of objects placed orally. They studied 63 children, from six to nine years of age, who were selected randomly from the Oral Pediatrics Clinic at Temple University School of Dentistry. The children had no history of oral or facial trauma, and no visual or auditory sensory disturbance. All had a normal range of tongue motion. The researchers found no perceptual deficit in tongue thrusting children. Colletti, Geffner, and Schlanger (1976) had earlier used 10 geometric forms varying in shape to test 30 second grade children ranging in age from 7.2 to 8.2 years. They were divided into 3 groups: A group with a tongue thrust swallowing pattern, open bite and an interdental lisp; a group with only a tongue thrust pattern and no lisp and normal occlusion; and a normal control group. Each subject was trained to recognize similarities and differences in geometric shapes. A total of 47 pairs were presented to each subject. A significant difference in oral stereognostic ability was found between children with tongue thrust who had a malocclusion and interdental lisp, and children with normal swallow, speech and occlusal patterns.

Falk, Wells, and Toth (1976) maintain that neuromuscular facilitiation is one means of subcortically affecting muscle function. They selected 11 subjects from six years to thirteen years. Dental models and cephalograms of each patient were made by the referring orthodontist at three months, six months and one year following initiation of the program. Facilitation techniques such as positioning, brushing, icing, pressure, and resistance were used with each patient for six months. Comparison of the serial dental models revealed that there was a reduction in the distortion of anterior relationships after the application of neuromuscular faciliation principles to new swallow patterns. The nature of the training precluded the need to intellectualize the learning of the normal swallowing process. Nine of the 11 subjects showed no regression during the six month period that followed therapy. The authors contend that with the use of neuromuscular facilitation techniques, patients may be younger than those normally enrolled in a swallow therapy program, and that cooperation is less critical.

Falk, Delaney and Litt (1979) compared neuromuscular techniques and the traditional conscious-level methodology of Garliner. A total of 20 children, ages eight to twelve years, with deviant anterior dental relationships and tongue thrust were evaluated by a pediatric dentist and two speech pathologists experienced in tongue thrust treatment. The speech clinicians, equally skilled in both methods, were each assigned five subjects for treatment with each approach. Serial dental models were made as in the former study at the initiation of therapy, and three and six months later. Models were evaluated by 14 orthodontists who served as judges. Changes in swallow patterns were inferred from alterations in dental relationships observed in the models. With this criterion, the neuromuscular facilitation group showed significantly greater improvement in bite relationships after three months of training, which continued three months following cessation of therapy.

MYOSCANNER

This instrumentation was developed by Garliners' Institute of Myofunctional Therapy to test the strength of orbicularis oris, tongue, mentalis and masseter muscles. Mean values for 275 subjects, 125 males and 150 females, from 4 to 67 years were compiled. The myoscanner consists of an electronic probe which records on an electronic scale, and measures in pounds of force. The following clinical trends were noted in the testing: Unequal masseter readings in patients with myofacial pain and in crossbite; strong masseter readings in myofacial pain patients, bruxing patients and patients with Class III tendency; weak masseter readings in habitual mouth breathers; generally weak profile in thumbsucking patients and weak retention and compression of orbicularis oris in patients with imprecise speech (Garliner, 1985).

PAYNE TECHNIQUE

Garliner (1974) described an early technique for detecting tongue position in swallowing. It utilizes a fluorescent substance on the tip of the tongue. The patient is asked to swallow, and the opaque substance clings to the area that is touched by the tongue. Black light is then reflected into the oral cavity, and the focal point of tongue force is revealed.

DISCUSSION

Due to the present cost of technology, as well as the invasiveness of some of the procedures, one must consider carefully the benefits and liabilities of each research tool. Bronzino (1986) describes the use of human experimentation as the manipulation of the clinical situation to gather information regarding new technology, treatments or diagnostic procedures. He classifies studies as either therapeutic or nontherapeutic. In a therapeutic study (such as the use of a new device or procedure) direct benefit may be derived by the patient. Nontherapeutic research, however, is generally without direct benefit to the patient. There is an element of concern especially when children are involved. Informed consent must be received from each subject in a study, and the subject must be capable of giving consent.

The research of the past 30 years does not allow orofacial myologists to revert to dogmatic statments or exaggerated claims, nor should there be a willingness to submit to their temptations. Objectivity in diagnosis and treatment are of primary concern. However, once objective data are available, clinical judgments, based upon knowledge and experience, must still be made. Once a diagnosis has been made the physician employs clinical judgement to decide when to order medical tests, or to make referrals to specialists. The dentist properly refers a patient to an orthodontist, oral and maxillofacial surgeon, otolaryngologist, periodontist, prosthodontist, speech pathologist or orofacial myologist based upon an accurate diagnosis of clinical findings. As John Mew (1981) has said: "Although scientific evidence in the field of myotherapy may be decades away, it is still necessary for the orthodontist to observe, assess and treat according to clinical experience." For the orofacial myologist, the challenge is to develop a fund of knowledge based on carefully controlled clinical and laboratory research. From this, the most effective clinical treatment can be devised. The day of anecdotal "clinical experience," as a valid basis for a profession's clinical practice has long passed.

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