ELECTROPALATOGRAPHY AND THE LINGUAGRAPH SYSTEM

Steve Kelly*, Alison Main†, Graham Manley‡ and Calum McLean*.

* Medical Electronics Research Group, Electronic Engineering Laboratory, University of Kent, Canterbury, Kent, CT2 7NT, UK; † Speech and Language Therapy Department, William Harvey Hospital, Ashford, Kent, TN24 0LZ, UK; ‡ Dental Department, Canterbury Health Centre, 26 Old Dover Road, Canterbury, Kent, CT1 3JH, UK.

ABSTRACT
This paper describes the technique of electropalatography and the development of Linguagraph, which is a user-friendly, clinical instrument, for measurement of tongue/palate contact, during speech. Linguagraph allows objective assessment of tongue function; appropriate targeting of therapy is therefore possible. Visual feedback is also provided, for therapy, and an objective measurement of outcome is easily obtained. Linguagraph was used, for both therapy and assessment, in a clinical trial. Technical aspects of Linguagraph and of the trial results are presented here. These suggest that the instrument will prove useful in the assessment and management of many speech disorders. Full clinical details of the trial are reported elsewhere.

Keywords: Linguagraph, electropalatography, instrumentation, speech disorders, dysarthria

INTRODUCTION

SPEECH
Normal speech relies on a highly complex and versatile system of co-ordinated muscular movements. The involved structures are known as the articulators, whose movements are controlled neurologically. Speech sounds are air pressure waves, which, in the majority of cases, are powered by the expiratory phase of respiration. During speech, a great deal of control is required.

Air passes from the lungs to the larynx. For many of the speech sounds, the vocal folds are used to interrupt the flow of air, causing periodic pulses of air, or phonation. The air pressure waves then pass through the pharynx. Its role in speech is that of a resonating cavity, the dimensions of which can be altered. During the production of nasal consonants, the pharynx is coupled to the nasal cavity. However, for the vast majority of the consonants of English, the nasal cavity is closed by the velum. The lips are also involved in the creation of sounds, for example as a source of air friction.

The tongue, which is the most versatile of the articulators, is involved in the production of all vowels and the vast majority of consonants. The versatility of the tongue allows different sounds to be produced; these require different tongue configurations. By altering tongue position and shape, the size of the oral cavity, and therefore its resonating characteristics, are changed. The tongue can also act as a place of closure, in the production of plosive sounds, where a build up of intra-oral air pressure is required. Furthermore, by using the tongue to create a narrowing against the hard palate or teeth, fricative sounds are produced.

SPEECH DISORDERS
A number of problems can result in impaired speech. These factors can be either developmental or acquired, and may be neurological or physical.

In early childhood, the development of speech may be affected by a number of factors, e.g. structural abnormalities, such as cleft palate, neurological conditions affecting the articulators, or sensory impairment such as deafness. In cases where auditory feedback is not available (i.e. with hearing
impairment), and where there is some interruption to the articulatory system (e.g. cleft palate), tongue coordination and placement may be affected, for example, resulting in poorly intelligible speech.

In adulthood, those who have developed normal speech may experience trauma or disease, which affect its use. Dysarthria, which comprises a group of speech disorders resulting from disturbances in muscular control, is the most common of the acquired disorders of speech and language. Dysarthric speech may be characterised by, for example, imprecise consonants, pitch abnormalities, sound distortions and hypernasality. Perceived speech difficulties may have a variety of causes, each requiring different types of intervention.

**ASSESSMENT OF SPEECH**

Assessment of speech defects is initially subjective, relying on the clinical judgement of the Speech & Language Therapist. This will involve both assessment of the intelligibility and quality of the patient’s speech, and observation of the visible aspects of articulation (e.g. lip and some tongue movement). However, the majority of the articulators are not visible during speech. Additionally, there is a growing need for evidence-based intervention. The best approach is to use perceptual assessment, to highlight potential areas of difficulty, then objective, instrumental assessment of these areas, to confirm the nature and severity of their involvement.

**OUTLINE OF THE PAPER**

This paper provides a brief overview of currently available speech instrumentation, followed by a detailed review of one particular technique – electropalatography. Although electropalatography is a very promising technique, it is not well known and is used mostly for research, rather than clinically. A new system – Linguagraph – is then described. Linguagraph is designed specifically for clinical use and is intended to extend availability of this potentially valuable technique. The clinical usefulness and technical limitations of Linguagraph are illustrated, by reference to a clinical trial using the device, and implications for future practice are discussed.

**SPEECH INSTRUMENTATION**

The measurement of tongue movement during speech is not easy, for the simple reason that, for the majority of sounds, the tongue is obscured by the lips or teeth. Several methods of accurately determining the nature of movement have been used.

Tongue strength can be measured by tongue force transducers: a flexible rubber bulb, connected to a pressure transducer. The amount of pressure put on the bulb gives a measure of strength of movement. This gives no indication of mobility and movement patterns, however.

Both Computerised Tomography (CT) and Magnetic Resonance Imaging (MRI) scans allow tongue placement for speech sounds to be accurately visualised. However, due to the time required to obtain an image, these cannot record dynamic tongue movement, but rely on the subject holding a gesture for some time. The subject is also required to lie prone, and still. MRI, since it uses a magnetic field and radio waves, and gives a clearer view of soft tissue, may be the more useful of the two. CT uses ionising radiation, exposure to which may be damaging.

X-ray microbeams use a narrow beam of radiation to track the movement of small gold pellets attached to various articulators, including the midline of the tongue. This technique has been used in the investigation of a number of articulation disorders, including dysarthria. The disadvantages of this system are that it is invasive, the subject is exposed to ionising radiation, and the resulting information is on the movement of the midline of the tongue, in two dimensions. Similar disadvantages restrict the use of videofluoroscopy, which gives a two-dimensional moving image of the articulators, allowing movement of the lips, jaw, tongue and the soft palate to be recorded during speech.
Electromagnetic Articulography (EMA) gives similar information to X-ray microbeams, but without the radiation. Here, pellets are again placed on the midline of the articulators, and their movement tracked. But in this case the pellets are transducers, and the subject is placed within a magnetic field. As the transducers move, a voltage is induced, and recorded. This is very much a research tool, however. The subject must wear a large “helmet” containing the magnetic coils. It is invasive, as transducers are glued to the articulators under investigation. Few subjects can tolerate a pellet attached to the velum. The equipment is also extremely expensive, and the images recorded are again two-dimensional. It has been used therapeutically, in the treatment of dyspraxia.

Electromyography (EMG) is a system that detects and measures the electrical activity in muscle fibres. The more active a muscle is, the greater the signals which will be recorded. Therefore the degree of involvement of different muscles during different articulatory gestures can be measured and compared. However, EMG is invasive, since it involves either surface electrodes or the insertion of needle electrodes into the muscles. It is used diagnostically, for example in verifying Motor Neurone Disease (MND). EMG has been used therapeutically, to provide biofeedback, for example in hyperkinetic dysarthria.

Ultrasound uses the reflection of ultrasonic energy from tissue in its path. It therefore enables the calculation of distance and speed of movement. Images from a transducer, mounted below the chin, allow the movement of the body of the tongue to be visualised and analysed. Ultrasound is non-invasive, and does not use ionising radiation. However, the image provided is not detailed, and skilled transducer placement and image interpretation are required.

Electropalatography is an instrumental technique for determining tongue/palate contact during speech. The subject is provided with an artificial palate, in which electrodes have been embedded. Generally, these palates are custom made, from dental impressions. They are made of thin, but rigid acrylic, with clips to secure them to the subject’s teeth. The palate extends from the front incisors to the junction of the hard palate and velum. Individual wires from each electrode emerge from the palate in two bundles, which leave the subject’s mouth, one on each side.

The palate is connected to a multiplexer, and a further body, or hand-held electrode provides a small current. As the subject’s tongue comes into contact with the electrodes on the palate, a circuit is completed, and the resulting data can be visualised on a computer monitor. Information on tongue/palate contact can be observed in real-time, recorded and analysed. Unlike the above systems, there is no harmful radiation, and no invasive electrodes are attached to the tongue.

While electropalatography measures dynamic movement of the tongue during speech, precise tongue placement, and the part of the tongue which makes contact with the electrodes, can only be inferred. For example, while there may appear to be continuous contact in the lateral areas of the palate, these electrodes may be 2-3 mm apart, and there may be areas of no contact between them. Similarly, correct looking contact patterns may be produced incorrectly, e.g. using the tongue tip to create velar patterns. Speech is the result of co-ordinated movements of the articulators, of which the tongue is only one. It is generally accepted that, to maximise the usefulness of electropalatography, it should be used in conjunction with other instruments.

A number of different electropalatography systems have been developed.

RION DP-01 ELECTROPALATOGRAPH SYSTEM

An electropalatography system was developed in Japan in the 1960s, mainly for phonetic research. From this early research, the Rion system was developed. The original system was not PC based, but instead relied on direct activation of Light Emitting Diodes (LED's), each corresponding to a palate electrode, in a single, one-palate display. The sampling rate was 64 frames per second. Data, one second in duration, could be recorded for immediate replay, or simultaneously with sound onto magnetic tape, enabling later analysis. Replay could be in real-time, or frame by frame. Hard copies of recorded data
could also be printed out, for analysis 16, 17. The Rion system has been combined with feedback on other parameters of speech, for example voicing, in the Multi-Function Speech Training Aid 16.

As in other systems, palates can be made to fit the individual subject. The original palate had up to 63 gold-plated copper electrodes embedded in the tongue-facing surface. These were attached to a film, which was then attached to a custom made palate 17. The electrodes were placed in rows, 5mm apart, along the line of the dental arch. A larger electrode, equivalent to the hand-held or body electrode used in other systems, was also embedded in the palate, but this faced and touched the hard palate 18. For children, smaller palates with fewer electrodes were made. Rion later developed a flexible palate 19, which was intended to avoid the need for customisation. It has 64 electrodes, and comes in several standard sizes 17. While this reduces palate cost, there are several disadvantages 20. These include the lack of repeatability in palate placement, and the possibility that important anatomical landmarks may not be covered by the palate.

KAY PALATOMETER SYSTEM

This is the American system, developed by Fletcher. It is PC based, with a sampling rate of 100 frames per second. Data can be recorded, replayed and analysed 21.

For the Kay Palatometer, several palate configurations have been described. Each utilises a thin, flexible acrylic palate, custom made for each individual. The palate fits over the teeth, to secure it in place. The electrode layout may be:

- a uniform grid covering the entire palate, with the number of electrodes depending on the palate size 21
- a grid of 96 electrodes concentrated in the alveolar region, but extending to the velar region along the line of the dental arch 21
- a grid of 96 electrodes in the alveolar and pre-palatal region 22
- 96 electrodes concentrated in the alveolar region, but extending posteriorly along the dental arch, and the midline 23.

The Palatometer can be linked to Kay's Computerised Speech Lab, allowing comparison of tongue/palate contact patterns with other speech outcome data, for example spectrum analysis.

READING SYSTEM

This system was developed by the Speech Research Laboratory at Reading University, initially as a phonetics research tool, which came to be used in Speech and Language Therapy clinics 24.

EPG2

This was an early version of the Reading system, initially designed to work with a Commodore computer. It provided real-time feedback, which could be used for therapy, and the facility to record and replay data. An acoustic signal from a microphone could also be recorded and replayed, giving additional information on speech outcome 12. Although some EPG2 systems are still in use, this equipment has been superseded by EPG3.

EPG3

This system again uses a PC, and records and displays tongue/palate contact data, plus acoustic data from a microphone. The body electrode is hand held. A multiplexer unit is worn around the neck, and the palate is plugged into it. The body electrode feeds a 300 mV RMS sinusoidal signal at a frequency of
15 kHz, current limited to 50 μA, to the patient. Signals from contacted electrodes are detected, at a scanning rate of 100 frames per second. These signals are then amplified and sent to the main EPG unit, which controls the scanning rate, and houses the signal detection circuitry. To eliminate false contacts, for example from saliva, the detection threshold is adjustable, and set for each individual user. The audio input, from the microphone, is also in the main EPG unit, and the input level is adjustable. Amplified signals are relayed to the computer, via an interface card. The recording time is limited to 10 s or less, and the duration must be selected prior to recording. However, on replay, the acoustic information is also available, allowing tongue/palate contact to be related directly to the speech outcome.

EPG3 can be used for analysis of recorded data. Tongue palate contact patterns, and spectral information can be obtained by moving a cursor along the displayed acoustic waveform. Sections of the data can be zoomed in on for detailed analysis. The entire recording, or selected portions of it, can be replayed, acoustically. Additionally, total contacts and frequency of contact for each electrode, and centre of gravity plots, are available. Hard copies can be printed out.

For feedback and therapy, real-time display of tongue/palate contact is also available. Data from two palates can be displayed on the screen. The palate displayed on the right is static, to provide a target, and the left hand palate is “live”, giving a real-time display.

The Reading system also uses rigid, custom-made palates, this time with 62 electrodes embedded in rows corresponding to phonetically important articulatory landmarks. Consequently, although the number of electrodes is constant, spacing of these varies according to mouth size and shape. There are eight rows: the anterior row containing six electrodes, and all other rows containing eight. The greatest concentration of electrodes is in the alveolar region. Placing the electrodes according to these rules allows comparison of data from different speakers. The palate clips to the upper teeth, using standard dental cribs (see Figure 1). Fine individual wires from each electrode are collected in two bundles, sheathed in flexible sleeving, which leave the palate behind the rear molars, pass along the lateral sulci and exit the mouth at the corners. These bundles terminate into a simple PCB edge connector.

EPG4

This system requires no computer, since only a real-time display is available: the display cannot be frozen, and there is no record facility. A multiplexer similar to that for EPG3 is required, and a standard Reading palate is plugged into this. The display, of one palate only, is an array of LED’s, each corresponding to an electrode on the palate. EPG4 was developed to be used for feedback only, i.e. as a therapy tool, once assessment using EPG3 had taken place.

Linguagraph

With the exception of EPG4, which is limited to therapeutic use, there appears to have been little development in electropalatography in recent years. Existing systems also appear to be more suited to research than clinical use. Their reported clinical use largely relates to case studies on small numbers of patients. Additionally, the Rion system is no longer available in the UK. For the technique to achieve broad clinical acceptance, a new approach is needed.

Linguagraph was developed to meet the need for a clinical, user and patient friendly, portable, low-cost electropalatography system. It was developed by a multidisciplinary team, comprising Engineers, Speech & Language Therapists, Plastic Surgeons and a Dental Surgeon. The system comprises an artificial palate, a small electronics unit, and interfaces to a standard PC. Custom software, running under MS DOS, provides visual displays and analysis.

The clinically important features of Linguagraph are:

- Large bright coloured display, which is easily seen by elderly patients and stimulating to children.
- Simultaneous, two channel display, facilitating patient/clinician interaction.
- Instant replay of data, during therapy.
- Long recording time for assessment (several minutes).
- Easy assessment and analysis of data.
- Designed to be portable – can be used in the clinic, at the bedside, or in the patient’s home.
- Ease of use and portability mean that electropalatography need no longer be confined to specialist clinics.
- Low cost system (less than £1000 for a single-channel system).

**PALATE**

To provide compatibility with the other system in use in Europe, the Palate developed at the University of Reading has been adopted for use with Linguagraph (see Figure 1).

![Figure 1: The Reading Palate](image)

**LINGUAGRAPH UNIT**

The palate connector plugs into the Linguagraph unit, which hangs around the subject’s neck, by means of an adjustable strap. The unit is small and light, with one adjustable control, which is used to vary the sensitivity of the device (See Figure 2).
The Linguagraph unit receives control data from the computer. A low-level AC signal (800 Hz, 50 μA RMS square-wave), the body clock, is sent to the subject via a wrist strap, which houses an electrode. This signal is then present throughout the subject’s body, and when the tongue touches a palate electrode, a circuit is completed, and a data pulse returned to the Linguagraph unit. Such signals are then passed from the Linguagraph unit to the computer.

Housed within the Linguagraph unit are multiplexing, threshold, isolation and limiting circuits. A block diagram of Linguagraph is provided in Figure 3.
Figure 3: Linguagraph Block Diagram
In this figure, patient connections are shown on the left and computer connections are on the right. The opto-isolators, to the right of the circuit, are purely for patient safety and have no effect on the digital signals passing between the Linguagraph and the computer. Isolation is achieved by converting electrical energy into light energy, using an LED, and subsequently converting the light energy back into electrical energy, using a photosensor.

The body clock signal from the computer (bottom right) passes through an opto-isolator to a voltage limiting circuit. This drops the logic-level (5 V) signal to 0.5 V. This circuit also includes protection diodes, which prevent this voltage from exceeding 0.7 V in the event of component failure. A coupling capacitor removes the DC component of the signal, thus an alternating, bipolar signal is passed, via the wrist strap connector, to the patient.

The 62 individual inputs from the palate are grouped into banks of eight, each of which passes through an eight-to-one analogue switch. A three-bit address, from the computer via opto-isolators, is used to control the analogue switches, selecting each of the eight inputs in turn. Thus, the data appears on the analogue switch outputs as eight sequential sets of eight signals. The amplitude of these is less than the 0.5 V level of the body clock, due to attenuation as the signals pass through the subject's body. The amplitude varies from subject to subject due to differences in skin resistance.

The analogue signals are converted into digital form using eight voltage comparators. A threshold is set against which these incoming signals are compared, such that signals exceeding the threshold produce a logic ‘high’ output (5 V), whereas signals which fall below the threshold result in a logic ‘low’ output (0 V). Since the incoming data are analogue, and highly variable, it is not a simple case of differentiating between signal and no signal. Crosstalk between electrode wires, and erroneous resistive connections caused by saliva, result in low level signals at points which should be zero. Also, the return signal contains a significant amount of 50 Hz AC noise, due to pick up. It is therefore important that the threshold is set approximately at the mid-point of the range of incoming signals. As both attenuation and noise vary from subject to subject, the threshold must be variable. This is provided by means of an adjustable potentiometer.

The resulting digital signals from the comparators are passed, via opto-isolators, and transferred as eight consecutive bytes to the computer.

Linguagraph samples at 100 frames per second, and each frame comprises eight bytes. Therefore, the body clock must run at a frequency of 800 Hz. Also present in the input lines is 50 Hz mains pickup noise. To minimise this, while retaining the body clock signal, passive high-pass filters, with a cut off frequency of 200 Hz, are incorporated in the analogue switches. These comprise coupling capacitors on each of the 64 inputs, combined with load resistors on the analogue switch outputs. These are not shown on the block diagram.

INTERFACE CARD

The Linguagraph electronics unit connects to an Amplicon PC14AT digital I/O card housed within the PC. Additionally, a crystal controlled clock on the card ensures accurate sampling at a 100 Hz frame rate, by providing an 800 Hz body clock.

SOFTWARE

Data from the Linguagraph unit is displayed and analysed by custom software running under DOS. The software enables a variety of functions to be used.

In “assessment” mode, electropalatography data on tongue/palate contact, for example during speech, are collected at 100 frames per second and temporarily stored in RAM. A simultaneous real-time display allows the therapist to monitor the quality of the data as it is recorded. Once collected, these data can be saved on hard or floppy disc, together with subject details, which are entered by the therapist. Data can be retrieved for subsequent review and analysis.
For therapy, several facilities are available. In single-channel mode, a real-time display of the subject’s tongue/palate contact can be used to provide biofeedback. This can be “frozen” to allow study of a particular contact pattern. Several minutes worth of data can be collected in RAM, for replay and discussion. If required, these data can be saved to disc.

In two-channel mode (see Figure 4), all of the above facilities are available, with the addition of a second palate display. During therapy, this is generally used to provide demonstration of appropriate tongue/palate contact, and a static target for the subject to attempt to copy. A separate programme is provided for data analysis (see later).

**Figure 4: Linguagraph Two Channel Display**

### ADDITIONAL FACILITIES

The above describes Linguagraph in its simplest form. For therapy, a second Linguagraph channel, comprising an identical unit, can be incorporated, allowing therapist and subject data to be viewed simultaneously.

To relate tongue/palate contact patterns to sounds uttered, an optional speech channel is also available. This provides an on-screen display of the speech envelope, i.e. the amplitude of the acoustic signal, when captured data are reviewed (see Figure 5).
A cursor can be moved along the speech envelope window to produce the corresponding tongue/palate snapshot for the cursor position. The speech channel comprises a variable gain, low noise amplifier, allowing the sensitivity to be adjusted for individual speaker volume. This is followed by an envelope detector, which simplifies and reduces the bandwidth of the acoustic signal. Finally, an eight bit Analogue to Digital (A/D) converter is used to digitise the signal before it is passed to the digital I/O card. The sampling clock of the A/D converter is derived from the crystal controlled clock on the PC14AT interface card. The microphone input is a standard, unbalanced ¼ inch jack, allowing a wide range of domestic microphones to be used. There is a buffered line output provided on a stereo minijack, both channels being commoned.

ASSESSMENT WITH LINGUAGRAPH

For assessment, subjects’ tongue/palate contact patterns and acoustic information are recorded on computer and, optionally, tape. Analysis of these data is then carried out using specially written Linguagraph analysis software. This opens any saved Linguagraph files. Analysis is of accepted important parameters of tongue/palate contact, which are listed below.

---

Figure 5: Linguagraph Display with Acoustic Waveform
PALATAL ZONES

![Diagram of palatal zones and rows]

Figure 6: Palatal zones and rows

PARAMETERS

- **Alveolar contact**: the percentage of electrodes contacted in the alveolar region. Contact in this region is necessary for /l/, /t/ and /s/.

- **Centre of gravity**: the linear centre of gravity of the total contact region, specified as a row number, from front (row 1) to back (row 8) of the palate. This gives an indication of the degree of contact behind the alveolar region. Such contact is required for /t/ and /s/. Centre of gravity provides a measure of where contact occurs.

- **Balance**: lateral symmetry of contact over the entire palate.

- **Groove width**: the number of electrodes, within a row, not contacted. For /s/, there must be a groove and it must be within the alveolar region.

- **Degree of closure**: closure is contact of a complete row of electrodes. Complete closure in the alveolar region is required for /t/.

The custom Linguagraph analysis software enables simple calculation of each of the above parameters. Waveforms representing the parameters are shown against time. A cursor can be moved along the waveforms. A snapshot of tongue/palate contact is displayed at this point. In addition, numerical values of the parameters at this point are calculated (see Figure 7). This numerical data can be saved as a row in a text file table, where further statistical, numerical or graphical analysis can be carried out, using a proprietary software package, e.g. Microsoft Excel.
Linguagraph was used for both therapy and assessment, during a three-year clinical trial. This compared the use of electropalatography with conventional speech and language therapy in the treatment of acquired dysarthria. The project was a randomised crossover trial. Each subject received six weeks of conventional and six weeks of electropalatography therapy, twice weekly, on a domiciliary basis. For this purpose, Linguagraph was used in conjunction with a portable, lunchbox style computer.

**OUTCOME**

All of the assessment data from the trial suggests that both types of therapy were beneficial to the majority of subjects. Subjective assessment of outcome, using the Frenchay Dysarthria Assessment suggested that both techniques were equally effective. However, the objective measure (electropalatography), which proved more sensitive to small changes, revealed that electropalatography therapy was significantly more effective in improving tongue/palate contact (related t-test: $t = 2.72$, df = 23, $p < 0.01$). A questionnaire on “attitudes to communication” showed that 79% of subjects reported that therapy had had a positive effect on confidence in communication skills.

An interesting result was an order of therapy effect, seen in data from the Frenchay Dysarthria Assessment. Those who had electropalatography therapy first did better overall than those who had conventional therapy first. There are a number of possible explanations for this.
Electropalatography provides biofeedback and clear evidence of improvement, since even small changes in performance can be seen. The majority of subjects found this extremely motivating, and this may have affected their attitude to therapy generally.

Electropalatography clearly shows the complexities of speech and why it is necessary to articulate carefully. By providing this insight early in the treatment period, work on the more general aspects of speech may have become easier, and the overall benefits greater. The improved articulatory patterns developed during electropalatography therapy may provide a better basis for subsequent therapy. Therefore, improvements resulting from electropalatography therapy may continue during the following conventional therapy.

**PRACTICAL ASPECTS**

During the above trial, work started with 34 adults with acquired dysarthria. The equipment was transported to subjects’ homes throughout East Kent. Subjects had a wide range of age groups and etiologies. As well as the above trial results, a wealth of knowledge on the technique of electropalatography, and the equipment used, was accrued.

**EQUIPMENT**

This trial was domiciliary, not clinic based. At the time of planning the trial there had been no references to domiciliary-based electropalatography therapy or assessment. This continues to be the case. Recently, stand alone units which give one live display only have been developed, and are in use in more remote speech and language therapy clinics in Scotland, as part of a cleft palate trial; though initial assessment must still be done in a specialist centre.

The use of Linguagraph as a portable system was therefore unique. It was necessary to find a computer that was capable of taking an interface card, gave a clear display, was robust, and affordable. The Colossus 486 is a lunchbox computer, with a full size keyboard, a colour CRT display and the capability of taking the necessary ISA bus interface card. The choice of display was particularly important as, at this time, laptop computers were of limited brightness and resolution. A clear display was necessary due to the client group: generally elderly and unwell, and often with poor visual acuity.

This computer was transported many miles per week in the boot of a car. It was set up and dismantled up to six times per day twice weekly, in subjects’ homes. Inevitably, there was some wear and tear. Cards occasionally worked loose, and were eventually glued in place. The Linguagraph units were also subject to transportation and being plugged in up to six times per day. They were dropped occasionally, and wet on other occasions, with subjects’ saliva, or water, as subjects cleared saliva from their mouths. These too required occasional repair. Despite the considerable rigours of the trial, the equipment survived.

**PALATES**

Prior to the commencement of the study, discussions regarding the requirements of the study were held with a dental laboratory which, at the time, was the only UK manufacturer of electropalatography palates. Despite their commitment to provide a service, there were considerable delays.

Much of the previous electropalatography research has been with children, and the few papers which mention acquired dysarthria make no mention of denture palates. The Rion System handbook suggests using a conventional palate fitted onto the subjects’ normal dentures. Many of the subjects in this trial were elderly, with dentures. An exact replica of the subject’s denture was made. This was forwarded to the specialist laboratory for placement of electrodes (see Figure 8).
Each electropalatography palate was then fitted by the Dental Surgeon. Because of the additional weight of wires and electrodes, and the fact that some of the subjects’ existing dentures were old and ill-fitting, many subjects required denture fixative, to hold their electropalatography palates in place. Interestingly, one of the most frequent complaints at the Second European Symposium on ELG/EPG (1997), was that subjects found palates badly fitting and uncomfortable. This was not experienced during this trial, suggesting that the involvement of a Dental Surgeon on the team was highly beneficial.

SKIN CONDUCTIVITY PROBLEMS

Work with the first group of subjects began, and promptly stopped, due to poor skin conductivity in many of the elderly subjects. This had not been anticipated: there are no references to similar difficulties in the literature, and until the palates were received, it was not possible to try out the equipment on the subjects. Research into how to improve the electropalatography signal in subjects immediately started. Advice was taken from the Cardiology Department at Kent and Canterbury Hospital, then experiments were carried out on BS, the Pilot Subject, with whom we had experienced only minor difficulties.

These experiments showed a skin resistance of about 1 MΩ, compared with typical values of between 10 and 200 kΩ for younger subjects, using our usual wrist connector. However, by using standard “Red Dot” disposable ECG electrodes on the upper arm or neck, the resistance value for BS fell to approximately 100 kΩ, which is well within the normal range.

Following these experiments, each member of the group was visited, and the modified technique showed that the signal had improved significantly, in all cases.

CONCLUSIONS

Linguagraph is a clinical, user-friendly, instrument, which has been developed for measurement of tongue/palate contact, during speech. This affordable system allows visualisation of tongue contact patterns, in real-time, as well as quantitative assessment. It thus enables biofeedback and objective analysis of this important aspect of speech production. Appropriate targeting of therapy is therefore possible. It provides a visual feedback, which assists in therapy and is very motivating for therapist and patient. And it gives an objective measurement of outcome, which is an increasingly important consideration.
The combination of electropalatography and conventional speech and language therapy and assessment is potentially extremely beneficial, in the treatment of moderate to severe acquired dysarthria.

The tongue is the most versatile articulator, and is thus of vital importance in speech. Tongue involvement is common in all types of dysarthria, and many other speech disorders. Nevertheless, there is likely to be involvement of other articulators, which are not directly measured by electropalatography. As a result of the work done on this trial, the multidisciplinary University of Kent Medical Electronics Research Team has developed SNORS+, a modular, multiparameter, clinical system, incorporating Linguagraph. In addition to electropalatography, SNORS+ allows the simultaneous measurement of nasal and oral airflow, from which the function of the velum can be inferred. A Laryngograph® can also be connected, to provide information on vocal fold function. The limited clinical trials carried out with SNORS+ have shown it to be highly beneficial. Further clinical trials with this multiparameter system are necessary, as is further research, for example into the effects of speech mechanism on outcome, and the interaction of the articulators during speech.

ACKNOWLEDGEMENTS

The authors would like to thank South Thames NHS Region Research and Development Directorate (formerly LORS, SE Thames Region), who funded the clinical trial. Grateful thanks to Dr Rosemarie MorganBarry, consultant Speech and Language Therapist on this trial, for her encouragement and support. Thanks are also due to Mr Jean Skoda, for software development, Mr Tim Lewis, for technical support, and the various therapists and subjects who were involved in the trial.

REFERENCES


15) Shibata, S., Ino, A., Yamashita, S., Kiritani, S., and Sawashima, M., A new portable type unit for electropalatography. Annual Bulletin Research Institute of Logopedics and Phoniatrics (Faculty of Medicine, University of Tokyo), 1978, 12, 5-10.


