A digital optoelectronic method for recording mandibular movement in association with oral electromyograms and temporomandibular joint noises*

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Abstract—In order to obtain a better understanding of jaw movement and its relationship to other parameters such as muscle activity or noises from the temporomandibular joint, it is necessary to correlate these activities. A digital optoelectronic method was therefore designed to record these activities simultaneously. It uses a closed-circuit television camera to view the movement of a light source attached to the patient's lower jaw; this is then discriminated and provides an analogue or digital output (x and y axes) based on a matrix of 300 vertical divisions and 400 horizontal divisions covering an area of 60×80 mm in the recording plane. The recording error for static or dynamic movement is ±2.5% and movement in the z axis increases this by an additional 2.0% per cm z axis movement. Electromyograms or temporomandibular joint noises are related using adjacent channels on a recording polygraph.

Keywords—Dentistry, Optoelectronics, Jaw movement, Electromyograms, Temporomandibular joint sounds

Introduction
The interactions between the physiological components of the masticatory apparatus are being increasingly studied. Harmony of interaction is essential if the masticatory apparatus is to function satisfactorily, and included in this system are the muscles of mastication, the temporomandibular joint, the occlusion of the teeth and the relationship between the mandible and the maxilla; until a comprehensive understanding has been reached, treatment of dysfunctions of the system will remain empirical. Mandibular movement reflects the activity of the dynamic components of the masticatory system, and studies of movement therefore allow an estimation to be made of normal or abnormal activity in the system. Additionally, if the study of movement can be correlated with other activity, such as the electromyogram and temporomandibular joint sounds, then a more comprehensive understanding of overall activity can be obtained. This paper describes a method which has been developed for recording mandibular movement and which provides facilities for integration with other relevant data.

Requirements
A device suitable for the recording of mandibular movement must satisfy the following requirements.

- It must be capable of recording the speed and direction of movement in three dimensions: namely, vertical, lateral and horizontal planes. There must be provision for permanent records to be obtained easily and simply and the method should ideally yield data in a form suitable for computer analysis and for synchronisation with, for example, electromyograms, which may be recorded simultaneously.
- Recording should be a simple procedure, without the need for cumbersome attachments to the patient's jaws which could interfere both mechanically and psychologically with occlusion and movement. Further, the time required to record must be short, thus permitting routine clinical use. Finally, the system must be accurate and the method repeatable.

Many methods of recording mandibular movement have been reported in the literature. These include simple mechanical techniques (Kurth, 1942, 1949), electromechanical methods (Beck and Morrison, 1962; MesserMan, 1967), electronic methods (Benersdorff, 1970), photographic methods (Benersdorff, 1970; Bowman, 1947; Söntebö, 1961), photoelectrical systems (Gillings, 1967) and cineradiographic methods (Sheppard, 1959). Previous methods that have been used suffer from certain disadvantages: either the procedure is very complex and prolonged in length, or the method does not provide data in a form suitable for immediate analysis by a computer or for synchronisation with the electromyogram or temporomandibular joint (t.m.j.) sounds.

Method
The system uses an optoelectronic method which records the movement of a small light source attached to the patient's mandible using a closed-circuit television camera. A monitor screen facilitates positioning of the camera, and the relevant outputs from the camera control unit are fed into a digital discriminator unit which gives a digital (binary or b.c.d.) or analogue readout, corresponding to the x and y co-ordinates of the position of the light source.
in space. The system samples the position of the light source 50 times per second. The analogue readouts may be used to drive a storage oscilloscope, x-y recorder or other suitable recording system, which in turn provides a visual plot of the movement of the light source, either as a trace of the actual movement in two planes or as displacement in the x and y co-ordinates. The analogue information may be directly related to electromyograms or sounds from the t.m.j. by feeding such information into adjacent data channels when using a multichannel recording system. The digital output is adaptable for direct computer input. Vectors and resultants for velocity and acceleration patterns are readily obtained by measurement from recorded traces, or computerised analysis.

**Electronics**

The digital discriminator unit uses 5 V t.t.l. integrated circuitry and AIMdac 10 bit d.-a. convertors [Bourns (Trimpot Division)] (Figs. 1 and 2). The record is based on a matrix of 300 vertical divisions and 400 horizontal divisions covering an oblong 60 x 80 mm in the recording plane, resulting in a resolution of 0.2 mm, and an analogue output of 1 V d.c. per cm movement of the x or y axis in the calibrated mode.

The vertical matrix is derived from each frame scan of 312½ lines, minus those lines containing no picture information and ignoring the slight inaccuracy (0.15%) resulting from alternate scans; and the horizontal matrix is obtained by dividing each line into 400 divisions using a 6 MHz oscillator. The position of the light source on this matrix is derived by discriminating the video bright-up pulse information relating to this spot from background illumination, and relating the discriminated pulse to binary counts of the number of lines down the matrix or pulse divisions across the matrix. Only the leading edge of the bright spot is detected in both horizontal and vertical planes. The timing sequences for the above operation are based on the blank period between frame scans and on the discriminated bright-up pulse (Fig. 1). The binary counters are set to