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Kinesiometric instrumentation:

a new technology

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A method of monitoring mandibular movements in three dimensions is described whereby a permanent magnet is secured to the mandible, and magnetometers are located relative to the permanent magnet so as to sense changes in the magnetic field which result from mandibular movement. The outputs of the magnetometers are processed electronically to obtain three discrete analog voltages, each directly proportional to a specific distance—vertical, anteroposterior, or lateral—from the magnet to the particular magnetometer. The vertical distance output is differentiated electronically to provide a measurement of acceleration. The Mandibular Kinesiograph provides new capabilities for diagnosis and research in dentistry.

Kinesiometric instrumentation: a new technology

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The study of mandibular kinesiology is essential to analysis of the muscular, ligamentous, bony, and occlusal components of masticatory function. The information is needed for both research and diagnostic purposes. Dysfunction or incoordination of the various components of the stomatognathic system will have a deleterious effect on the overall functional capacity of the system.

Progress in the field of mandibular kinesiology has been limited by the capability of instrumentation available to trace mandibular movement and to identify tooth contact while patients engage in functions such as eating, swallowing, and speaking and in parafunctional acts such as bruxing and clenching. Instrumentation for the investigation of stomatognathic physiology has by and large reflected the status of contemporary technology. Techniques progressed from cinematography of a moving reflective point in 1931[1] to cinefluorography in 1940,[2] stroboscopic photography in 1942,[3] and mechanical tracing of chewing strokes in 1951.[4] Electronic recording techniques were first reported in 1953[5] to record the occurrence and duration of occlusal contacts while masticatory movements were being monitored. In this system, tooth contact was recorded on an oscillograph as opposing metallic tooth surfaces formed "make-or-break" switches.

The concept of recording contacts with make-or-break switches was pursued in subsequent years. The utilization of occlusal telemetry in 1961[6] and the introduction of simultaneous electromyography in 1964[7] provided additional refinements to the original concept. Instrumentation to trace the actual movement pattern of the mandible during the wide variety of functional and parafunctional excursions followed.[8,9]

Limitations inherent in the available systems became apparent as the need for more refined data crystallized. Clearly, the implantation of switches on the occlusal plane gave only infor-

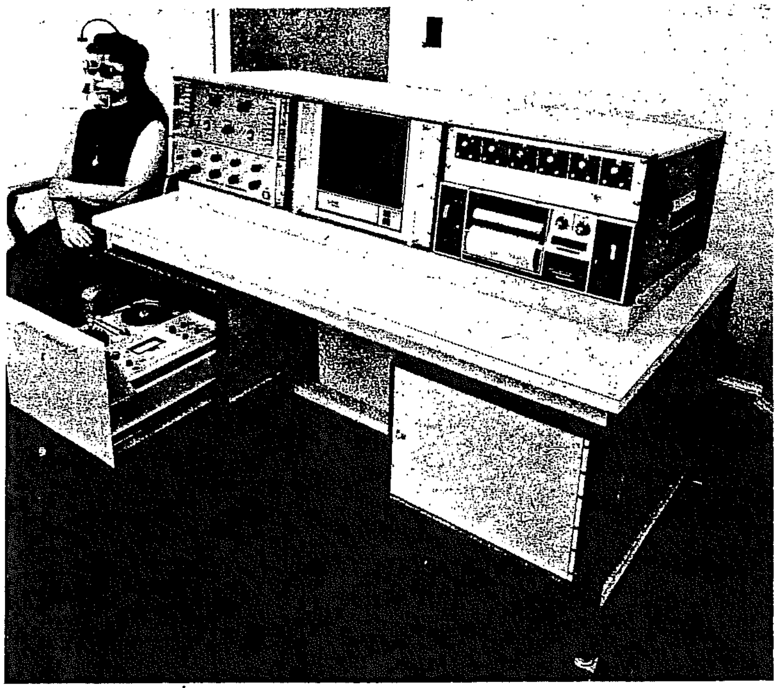


Fig 1 ■ Mandibular Kinesiograph.

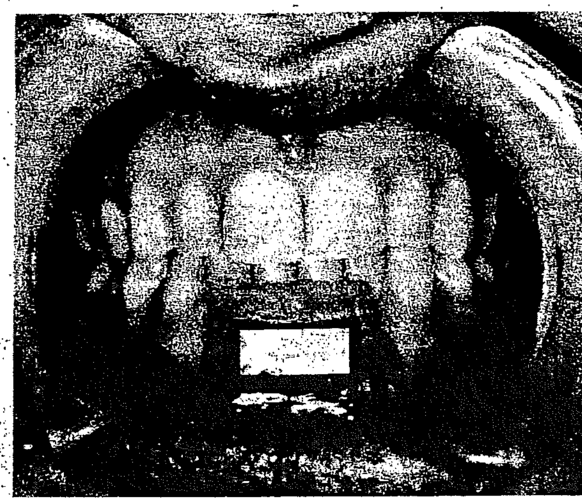


Fig 2 ■ Correct placement of the oral magnet.

mation on maxillomandibular contact, with system accuracy defined principally by the geometry of the contacts. The elaborate transmitter systems required large expenditures of time and money and were limited to patients having a sufficiently large edentulous space to house the transmitter. In other instrumentation designed to track mandibular movement as well as tooth contact, photoelectric transducers were mounted on clutches affixed to the maxillary and mandibular arches. The interference of these protruding elements and the mechanical oscillations of the supported assemblies introduced the possibility of an altered proprioceptive response by the musculature.

A further limitation to progress in the study of mandibular kinesiology has been the use of custom circuitry for each person. Thus, data produced by these studies have not been subjected to critical analyses by other competent investigators using the same instrumentation techniques.

■ *Functional requirements of the mandibular tracking system:* On the basis of the pioneering work of prior investigators and the rigid requirements of a total systems approach to stomatognathic analysis, these criteria were defined as essential for an acceptable system.

—The relationship of the mandible to the maxilla must be determined in three dimensions.

—Data output must be continuous to permit analysis of the dynamic components of mandibular function.

—The system cannot encroach on the occlusal plane so as to alter proprioception.

—To avoid unnatural proprioceptive input and minimize mechanical limitations on mandibular movement, no supporting structure or wires should protrude from the mouth.

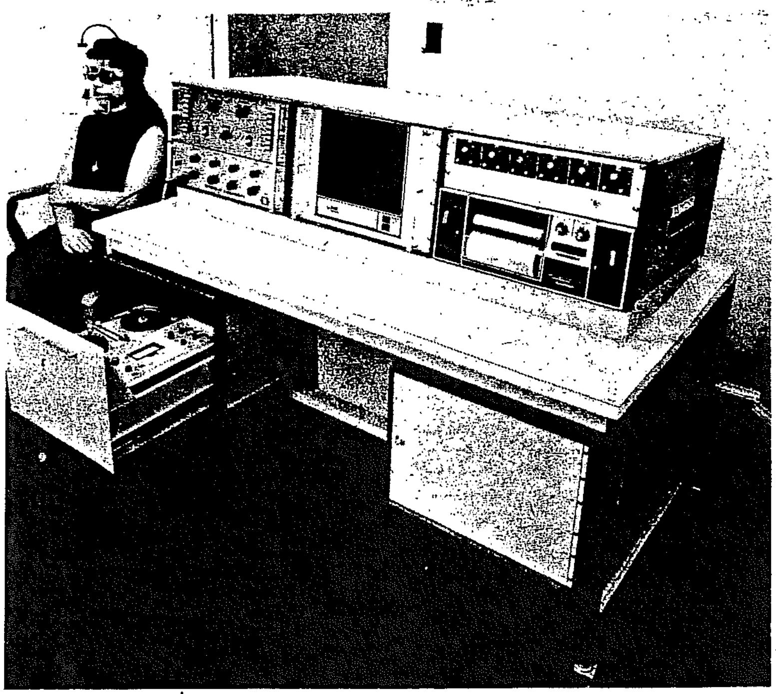
—The practical use of the system requires that setup time be minimal and that the system be self-contained, that is, compatible with, but independent of, any computers or highly sophisticated ancillary equipment.

—Measurement in the vicinity of the occlusal plane should be accurate within ±0.1 mm.

—The system should be widely available and operable by dental personnel without special electronic training.

System description and theory of operation

The Mandibular Kinesiograph* pictured in Figure 1 is the result of system evolution over several years. The system senses the spatial location of a permanent magnet that is mounted on the mandibular incisors with a dental plastic as shown in Figure 2. (Setup time for each patient is about three minutes.) The system does not alter proprioceptive input either by interfering with the occlusal plane or by limiting the normal range of mandibular function.



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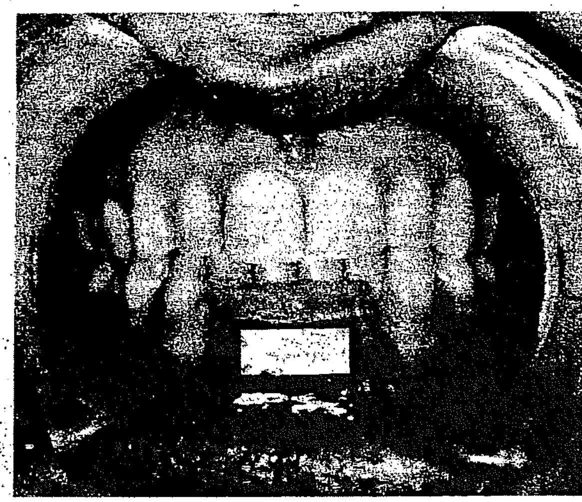

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by the use of magnetically shielded rooms or other special low noise areas, but our experience has shown that such increased accuracy is of limited value in a diagnostic or clinical situation.

The Mandibular Kinesiograph provides an accuracy of 0.1 mm for resolution of mandibular positions in the vicinity of occlusion. At a vertical opening of 20 mm, the geometric error is approximately −3% in the vertical channel, +5.7% in the anteroposterior channel, and, of course, 0% in the lateral channel because of its differential nature. There is, however, a corresponding gain-loss error in the lateral channel of about −6% when the mandible is deviated 10 mm left or right at a 20-mm vertical opening; (that is, if the jaw is positioned 10 mm to the left of center at a 20 mm vertical opening, the Kinesiograph will read out a 9.4 mm change in lateral position to the left).

For increased accuracy with large motions away from occlusion, a computer program has been written and is in use, according to an oral report by A. Hannam, department of oral biology, University of British Columbia, that corrects the system errors to a maximum of 0.5 mm anywhere within a 40-mm vertical opening, for ±10 mm of anteroposterior motion, and 10 mm left or right; this more than covers the range of function.

Kinesiograph data samples

Figures 4 through 15 are examples of data routinely collected with the Kinesiograph. The diagnostic significance includes parameters such as restriction and extent of movement, deviation on opening and closing, evaluation of interocclusal vertical dimension, deflection of the mandible from premature contacts to complete intercuspation, the spatial relationship of rest position to the intercuspal position and the pathway of closure, evaluation of muscle relaxation (resting length is a prerequisite to registration of a muscularly oriented occlusion), evaluation of muscle coordination and the position at which muscle incoordination occurs as indicated by velocity analysis, and the skid of denture bases in response to occlusal force showing direction and extent. In addition, an objective evaluation of clinical treatment progress is now possible through successive recordings that document the changes in the aforementioned parameters. The broad possibilities for research are shown

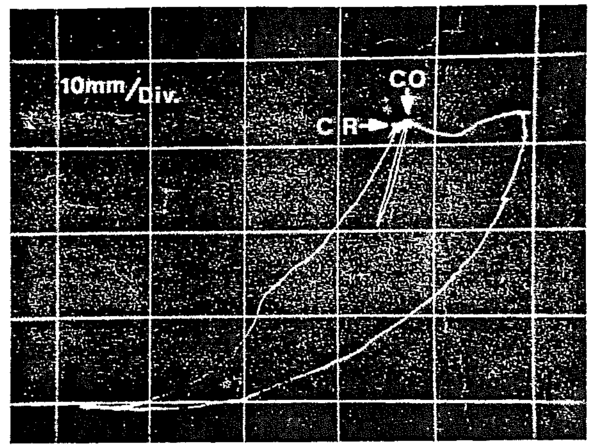

Fig 4 ■ Kinesiograph recording of envelope of movement on sagittal plane showing one opening and closing stroke that began and ended at centric occlusion (CO). (Notice angle and position of "hingelike" swing of mandible when mandible is manipulated or instructed to centric relation (CR). Then notice different angle and terminal position of voluntary tap.)

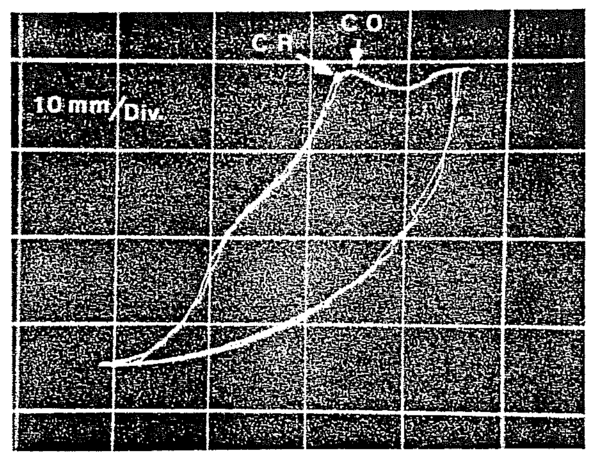

Fig 5 ■ Two consecutive envelopes of movement showing muscle strain on opening and closing. (Notice inability of patient to retrace pattern.)

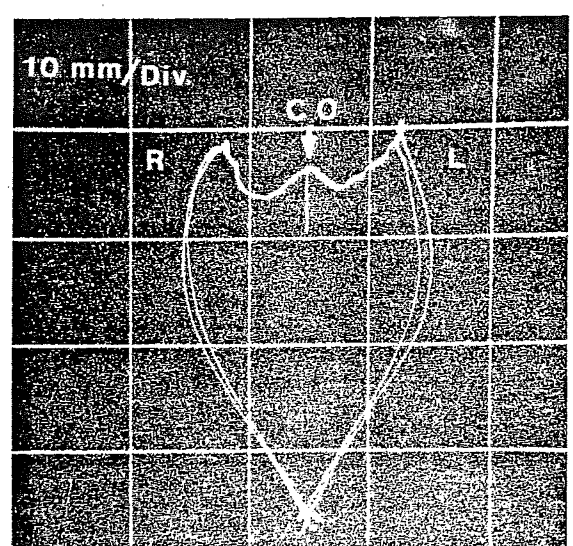

Fig 6 ■ Frontal plane. Two consecutive envelopes of movement plus a single closure to intercuspation at centric occlusion. (L, left; R, right.)

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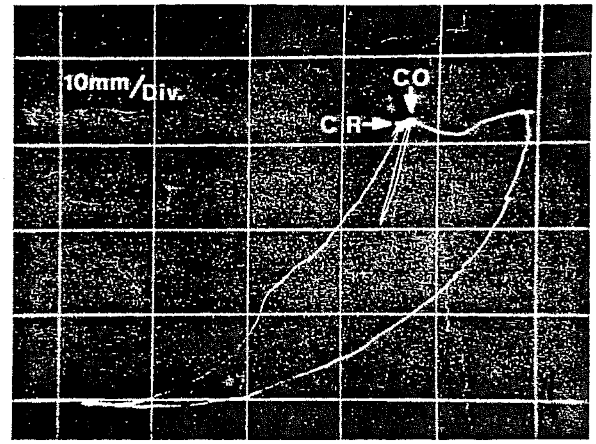

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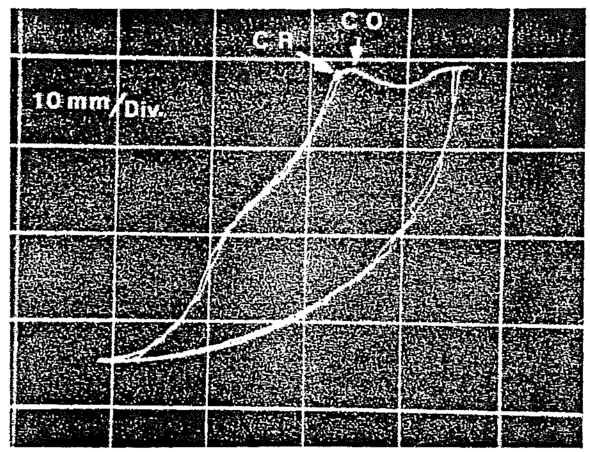

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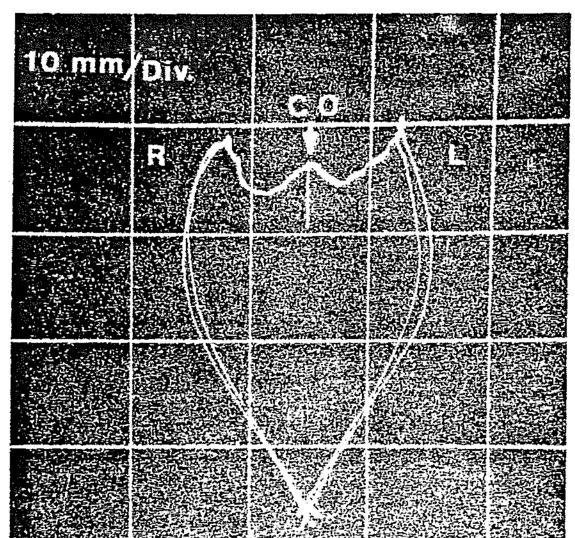

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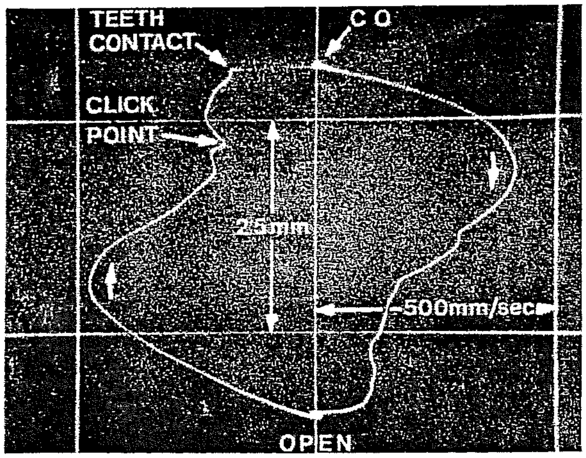


Fig 13 ■ Velocity trace of opening and closing movement of same individual as in Figure 12. Note irregular change in velocity and recording of "click point" (point at which an audible click occurs).

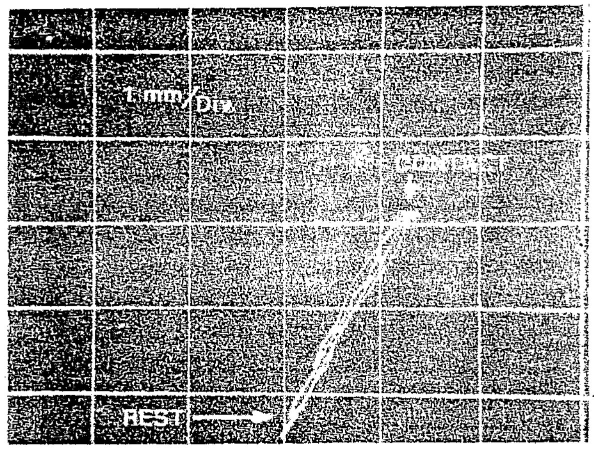


Fig 14 ■ Sagittal plane. Myo-monitor-induced mandibular closure, over which is superimposed voluntary closure. Muscles were first pulsed for 15 minutes, to remove influence of proprioception, until rest position, as shown by Kinesiograph recording, was stable. Single Myo-monitor-induced closure and return to rest position was recorded. Myo-monitor was then deactivated and patient asked to close mouth until teeth came lightly together. Recording shows that after muscles had been relaxed, voluntary closure closely followed pathway of externally induced contraction.

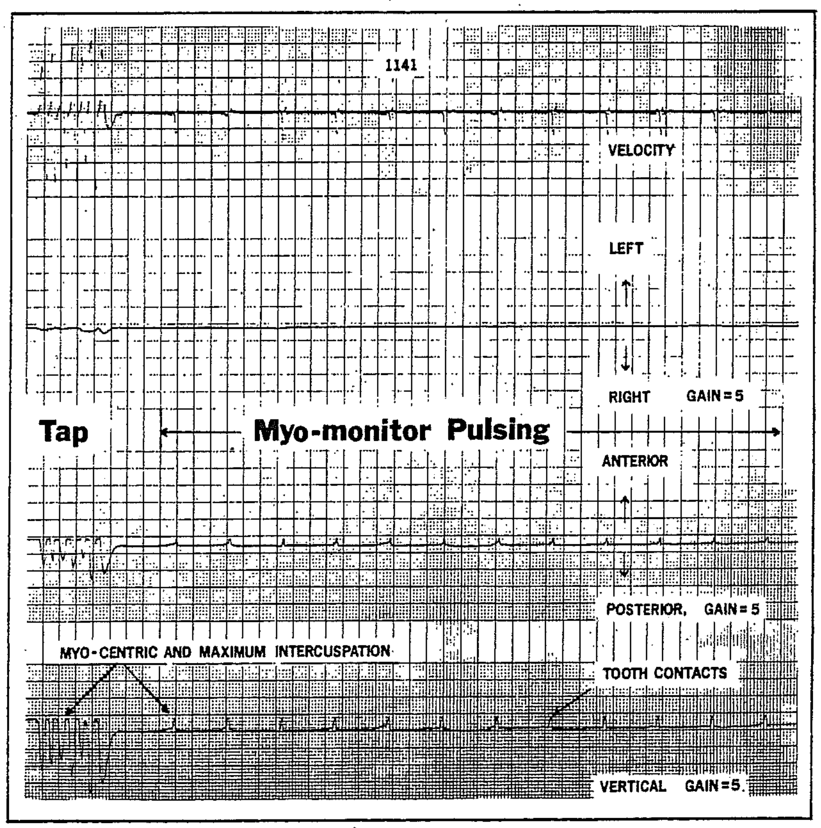
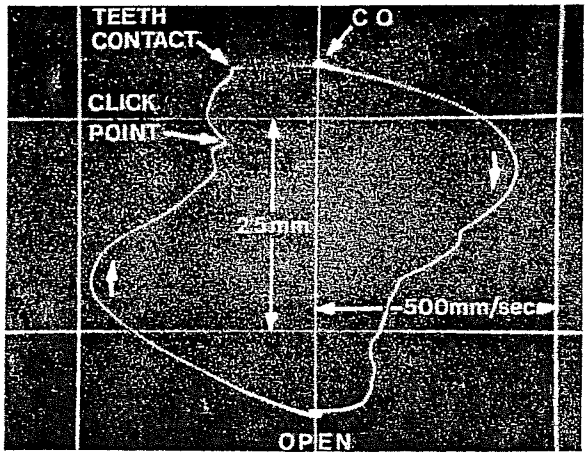


Fig 15 ■ Four-channel strip chart recording of vertical position, anteroposterior position, lateral position, and vertical velocity with respect to time (10 mm/sec) showing Myo-monitor stimulation relative to voluntary tapping. Notice stability of rest position of mandible between pulses and that position of Myo-monitor occlusion in this patient coincides with position of voluntary closures.



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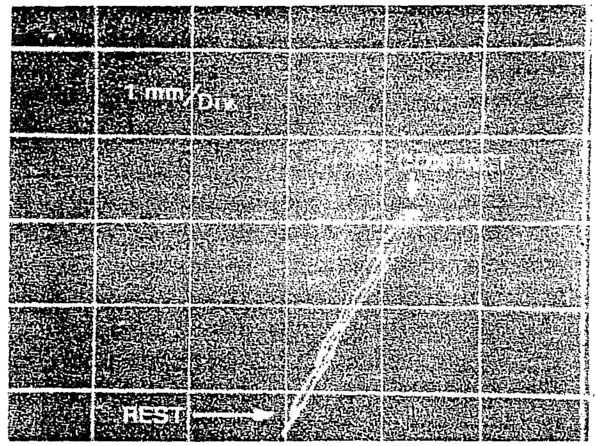

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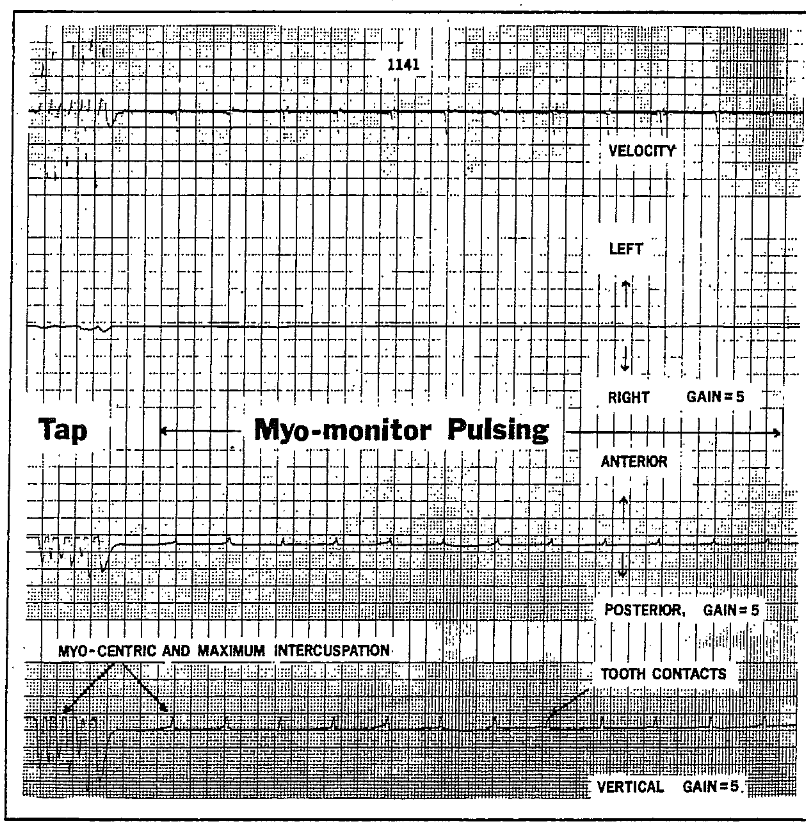

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