

**CONDYLAR MOVEMENT  
PATTERNS ENGRAVED IN  
PLASTIC BLOCKS**

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## Condylar movement patterns engraved in plastic blocks

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The interest of dentists in recording mandibular movements has increased in recent years following attempts to simplify the recording equipment and methods.<sup>1-5</sup> A secondary benefit of the newer recording devices is their use in research. Since research involves collecting data for measurement and comparison, certain types of recorders are more suitable than others for these purposes.

This article reports the findings of an investigation designed to test the reliability and reproducibility of a method of three-dimensional tracing of mandibular movements in plastic blocks. The variations in condylar movements of a group of subjects were determined by an analysis of the tracings.

### TECHNIQUE

*Recording equipment and its use.* The recording equipment is developed by Lee<sup>†</sup> was selected for this study, because it possessed many desirable features amenable to the techniques of research. This equipment permits condylar movement patterns to be recorded as three-dimensional engravings in clear plastic blocks using turbine air drills. The drills cut a pathway in the plastic block that corresponds to movements of the mandible. The plastic recording blocks are manufactured to precise external dimensions. Accurately drilled holes in the blocks key them to the recording and to standardized jigs for measurement of recordings.

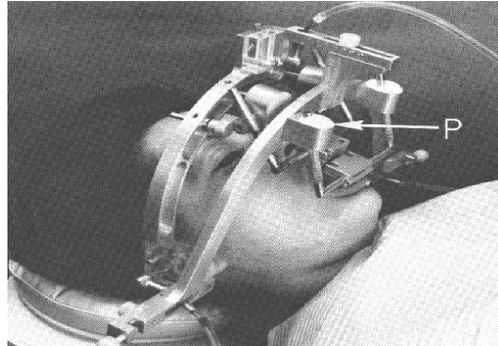
The blocks are attached to the upper bow of the recorder which is aligned to the patient using the transverse hinge axis and the axis-orbital plane. The recorder is assembled on the patient using a unique system of locking the bows to the clutches with attachment tubes filled with plaster.<sup>5</sup> Subsequent recordings of the same subject

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**Fig. 1** The bows of the recorder are locked to the clutches by filling attachment tubes (P) with quick-setting plaster from a plaster syringe. Subsequent recordings of the same subject can be made because of this feature.

are feasible, because the recorder can be reattached with ease and accuracy. The drill is also aligned with the transverse hinge axis of the patient by means of special orientating blocks attached to the upper bow of the recorder (Fig. 1). Multiple recordings of the same patient can be easily accomplished by simply exchanging new blocks and repeating the recording technique.

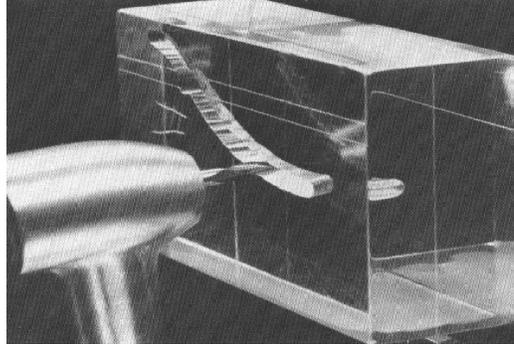
*Comparison of engraving by photographic enlargements.* The engravings of the condylar movement patterns made by the turbine air drills in the plastic blocks were photographically enlarged to permit comparisons between patients (Figs 2 to 4). Standardized mounting jigs were constructed to support the blocks and the camera<sup>\*\*\*\*</sup> at a fixed distance from the plastic blocks. The engravings of the lateral and protrusive movements were photographed with the camera lens perpendicular to the surface of the block (Fig. 5).

Superior views of the blocks were required to compare the engravings of the immediate side view of the mandible during a lateral movement. (Bennett movement). To obtain greater clarity of this view, metal Positives were made by pouring low-fusing metal into the engravings. The metal positives were photographed in a manner similar to that for the plastic blocks (Fig. 6 and 7).

Photographic 2" x 2" slides of the engravings in the plastic blocks were projected onto a 4' x 6' board (Fig. 8). The distance between the board and the projector\* remained fixed. The board was designed to be adjusted in the vertical plane only. Superimposition of slides of different subjects was obtained by first adjusting the board to the projected point of penetration of the drill into the block at the location of the transverse hinge axis. Next, adjustment was made to the axis-orbital plane,

\*\*\*\* Nikkormat camera, 55 mm Micro-Nikkor lens with M ring

\* Nikkormat camera, 55 mm. Micro-Nikkorlens with M ring.



**Fig. 2.** A record of a lateral mandibular movement has been made by the turbine air drill. Part of the top of the block containing the alignment holes has been removed for photographic purposes.

which had been previously scribed on each block. When this alignment of the board to the slide was achieved, the character of the projected pattern of drill movement was drawn on the board. A millimeter scale was obtained by projection of a slide made from millimeter graph paper photographed in the same film to subject distance as the standardized jig.

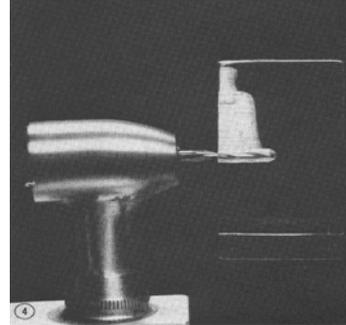
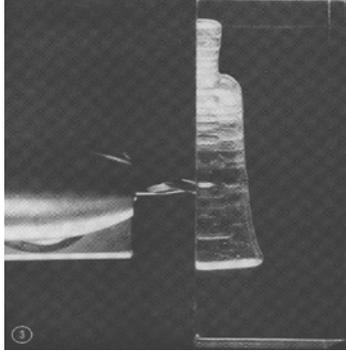
*Controls for reliability of the engraving procedure.* In each recording, all movements were rechecked by reinserting the cutter drills into the original Locigraph slot at one or more sites along the trace. The accuracy of the seating of the drill was measured with a 0.0005 inch feeler gauge. The drill followed the same pathway with a maximum measured discrepancy of 0.0015 inch, which also attested to the rigidity of the instrument system.

The consistency of orientation of the attached upper and lower recorder bows was also tested. The bows were initially oriented to the patient using the hinge-axis orienting blocks. The orienting blocks were replaced with Locigraph or recording blocks. Recordings were made, and the blocks were again placed with the orienting blocks. The cutter drills were now found to be concentric with their original positions and firm in their turbine attachments, indicating no important change in the orientation of the recorder bows.

Each of these consistency checks related both to the recording instrument and to the care exercised by the dentists in affixing the equipment to the patient.

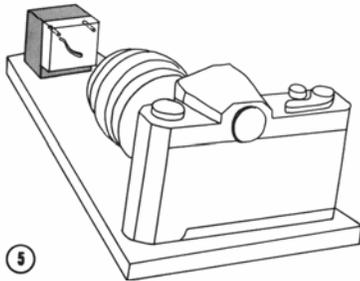
## RESULTS

*Reproducibility in the engraving procedure.* The same dentist and assistant obtained recordings on the same subject at time 0, 1 week and 3 weeks to determine the variation for the operator. Measured on a photographic enlargement of 10x, the maximum separation at any point along the lateral pathways of different engravings



**Fig. 3.** A superior view of the recording block depicts the character of the immediate side shift on the balancing side of the mandible during a lateral movement.

**Fig. 4.** The drill is at a position representing the end of a left lateral movement in a frontal view of the recording block.

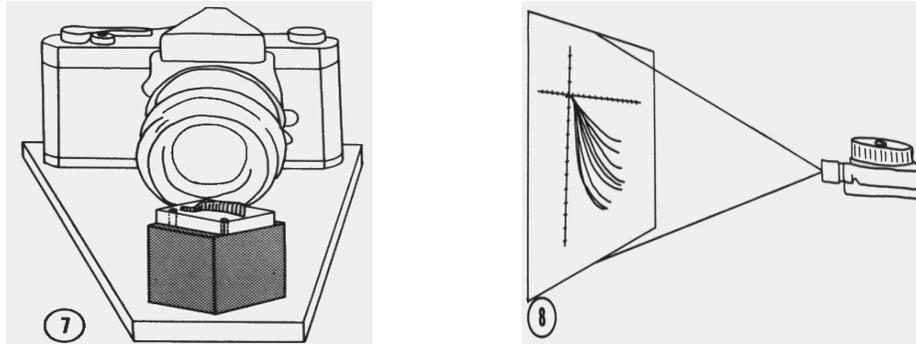


**Fig. 5.** Photographs were made at a standardized distance for each block using a fixed mounting jig.

**Fig. 6.** A photograph of a metal positive shows a superior view of a recording made by the turbine drill.

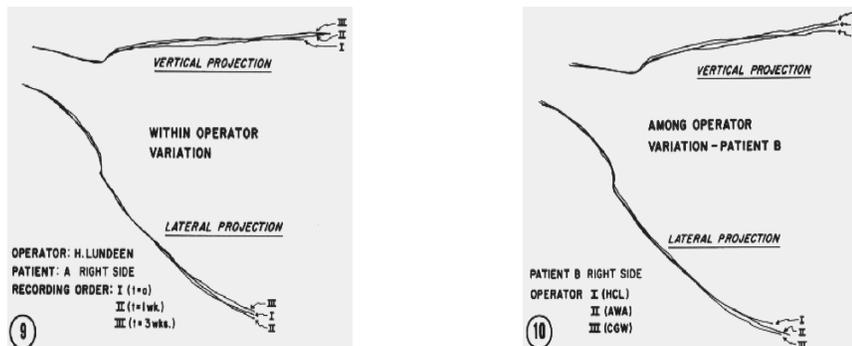
was 0.150 inch. For projection of the superior view, the maximum separation of the lines was 0.0140 inch. The width of the tracing lines varied from 0.008 to 0.015 inch (Fig. 9).

Three dentist-assistant teams recorded the movements of three patients to determine the variation *between operators* in the engraving procedure. The maximum separation of the lines among the teams was 0.10 inch for the lateral pathways on a 10x projection. The projection of the superior view showed a maximum separation of 0.17 inch. Similar variation in the width of the lines was observed (Fig. 10).



**Fig. 7.** A camera arrangement permits the making of standardized photographs of the metal positives.

**Fig. 8.** The slide (transparency) of a mandibular engraving is projected onto a board that was adjustable only in the vertical plane. A tracing of the engraving of each subject was made on the board, thus giving a composite of the group.

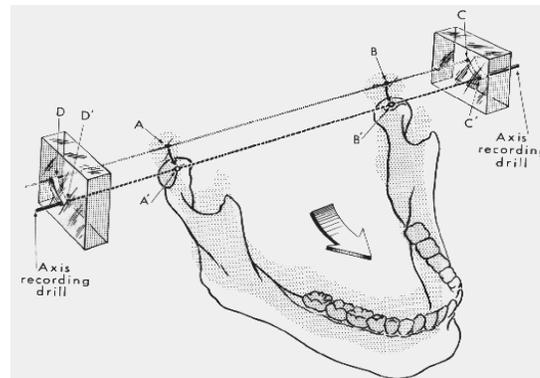


**Fig. 9.** Mandibular movements from the same patient were recorded at 0, 1, and 3 week intervals by the same dentist. Tracings are superimposed using a standardized photographic method.

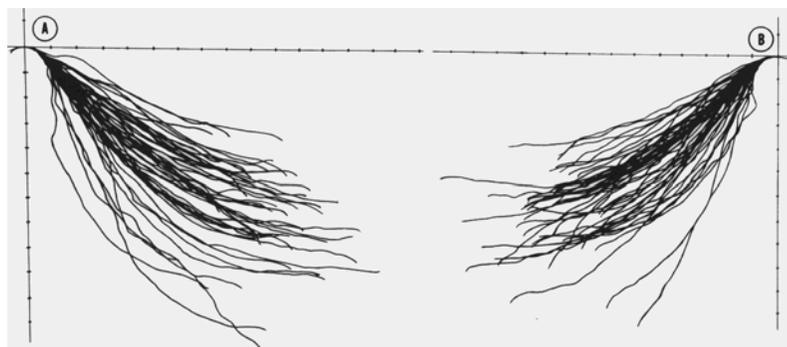
**Fig. 10.** Tracings of the recordings of one patient made by three different dentists are superimposed.

*Comparisons of condylar movements of 50 human subjects.* The condylar movements of 50 subjects, 20 to 55 years of age, were recorded and compared using the methods described. No special method for patient selection was used. Several subjects reported previous muscle and joint pain and indicated that they had received treatment by a variety of methods, including occlusal splints, adjustments, and reconstruction. One patient had an obvious click in the temporomandibular joint that showed up as a consistent sharp deviation in the tracings of the condylar pathway. Patients were not accepted for the recording procedures if they had pain or limited mandibular movement. All patients received intravenous medication just prior to the recording session. The premedication consisted of 0.4 mg. Atropine sulfate, 150 mg. Sodium pentobarbital, and 50 mg. Meperidine.

The protrusive pathways of 50 superimposed tracings of the recordings showed similarity of the right and left sides (Fig. 11). At a point corresponding to 5 mm. of



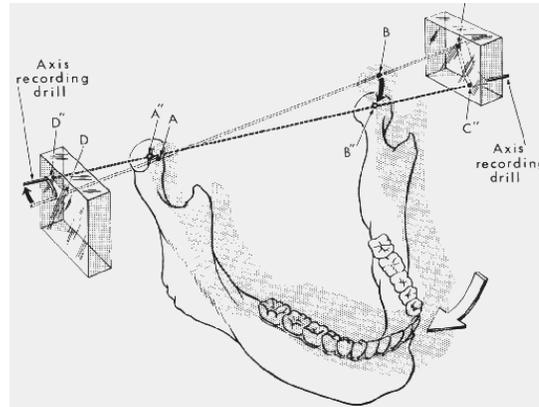
**Fig. 11.** The engraved pathways were created by the turbine drill as the patient's mandible moved in a straight protrusive direction. (Courtesy of Dr. Robert L. Lee).



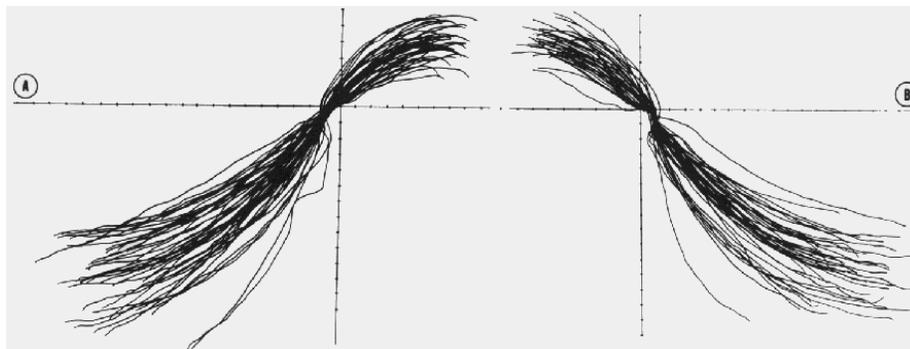
**Fig. 12.** (A) The superimposed tracings of the recordings from the right side of 50 subjects making the protrusive mandibular movement. The broken lines represent a millimeter scale. The horizontal line parallels the axis-orbital plane used to orient the blocks to the patients. The vertical line was drawn perpendicular to the horizontal line that intersects the top point of penetration of the drill into the plastic block at the site of the transverse hinge axis. (B) Tracings of the protrusive recordings from the left side.

protrusive movement, the angle formed with the axis-orbital plane was a minimum of 25 degrees, a maximum of 65 to 75 degrees, with a median of approximately 40 degrees (Fig. 12).

The tracings of the lateral pathways were also similar in the pictures of the right and left sides (Fig. 13). At a point corresponding to 5 mm. of lateral movement of the translating (balancing) condyle, the angle formed with the axis-orbital plane was



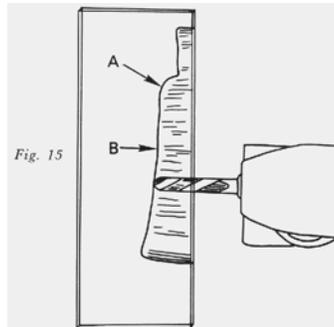
**Fig. 13.** The lateral movements produce a "backlash" (D to D') which is the magnified effect of the rotating condyle recorded at a distance outside the condyle. (Courtesy of Dr. Robert L. Lee.)



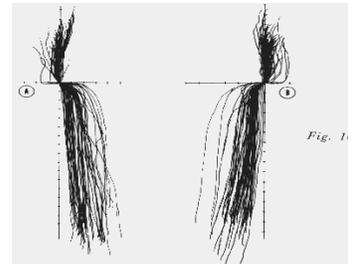
**Fig. 14.** (A) The recordings on the left sides of 50 subjects making a right lateral mandibular movement. The horizontal line is parallel to the axis-orbital plane, and the perpendicular line intersects the top point of penetration of the drill into the plastic block at the site of the transverse hinge axis. (B) Tracing of the recordings made on the right side.

a minimum of 25 degrees, a maximum of 75 degrees, with a median of 45 to 50 degrees (Fig. 14).

The projections of the superior view showed the immediate side shift (Bennett movement) and the Bennett angle as two identifiable portions of the lateral movement (Fig. 15). The immediate side shift occurred during the first few millimeters of the movement as the drill tip moved inward, forward, and downward. The inward curved portion varied from 0 to 3.0 mm, with a median of approximately 1.0 mm. The Bennett angle was the remainder of the pathway shown as arcs of



**Fig. 15.** A superior view of the recording from the left side clearly shows two distinct portions of the lateral movement. The immediate side shift (A) occurs close to the terminal hinge axis. The progressive side shift, or Bennett angle, (B) is the remaining portion of the total lateral movement which closely resembles an arc of a circle.



**Fig. 16.** (A) Fifty superimposed projections of the superior view of the recording blocks on the right side produced by left lateral mandibular movements. (B) Projections of the superior view of the recording blocks on the left side produced by right lateral mandibular movements.

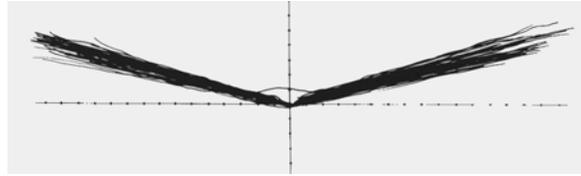
circles which were very nearly parallel to each other. Once the immediate side shift had occurred, very little variation was seen in the rest of the movement for different subjects. Five different operators could duplicate this movement when instructed to guide their patients' mandibles along the border pathways (Fig. 16).

Gothic arch projections were made with this mandibular recording system by a third drill located in front of the mandibular incisors. The superimposed lines for each subject were related to the apex of the Gothic arch recordings and represent the posterior border pathways for the right and left lateral mandibular movements (Fig. 17).

## DISCUSSION

In the reproducibility studies of variations among dentists, the maximum separation between the tracings was significant only when compared with estimates of corresponding tooth contacts, e.g., the mandibular first molar region. The length of the lateral pathway made by the drill was approximately eight times greater than the travel of a distobuccal cusp of a lower molar on the same side.

The projection of the superior view of the immediate side shift of the lateral movement compared with the travel of the distobuccal cusp of the lower first molar on the same side shows a movement ratio that approached 1:1. When reasoning by ratios is used to assess the importance of errors, the immediate side shift component is of particular importance when compared to the total lateral pathway.



**Fig. 17.** The Gothic arch type of projections were made by the third vertical drill located anteriorly in the front and center of the recorder.

The effect of the central-bearing mechanism on the pathways of condylar movement was also measured with the feeler ribbon during reinsertion of the drill. The length of the central-bearing screw was increased as much as 20 mm with no appreciable changes in pathways of the drill, confirming the findings reported by Lee<sup>5</sup>. Recordings of condyle movement made when the drill was not oriented to the hinge axis were affected by the central-bearing mechanism of the clutches.

All lateral projections represent the most attainable superior pathways of the condyles. The mandible was rigidly supported at the angle and guided along the posterior borders with the central-bearing screw of the clutches maintaining contact with the central-bearing plate. Without this precaution, the drills would often drop vertically as much as 1 mm at the terminal hinge position.

The projections of the superior views showed that the lateral border pathways were reproducible when the recordings were made with firm lateral guidance of the body of the mandible. The maximum attainable immediate side shift could be repeated by this method. A mere passive guidance with the hand at the chin point would register less immediate side shift and was not repeatable by various dentists with the same patient.

This study was designed to compare the shapes of the lateral boundaries of condylar movement. No attempt was made to relate these characteristics to the occlusal relations of the teeth.

This recording system was developed to utilize the primary recording information to generate analogue or play-back blocks by means of a transfer machine. The analogue blocks are then used as the posterior controls (condylar guidances) of the articulator. In this manner, further studies can be made relating the recorded information to the teeth.

No measurements of the movements of the rotating or working-side condyle drills were made in the frontal plane. In the horizontal plane, the sagittal displacement of the working-side condyle drill was outward and backward in all but two instances. With these two exceptions, the direction was outward and very slightly forward.

## SUMMARY AND CONCLUSIONS

A three-dimensional recording of mandibular movements in plastic blocks<sup>5</sup> was found to be a valid source of research information on condylar movements. Tests showed that a given point in space relative to a specific jaw movement could be

relocated, and the path of a specific point attached to the jaws could be traced at another time. The recordings engraved in plastic blocks represented permanent records of jaw movement that could be measured, compared, and stored indefinitely.

Variations in mandibular recordings made by different dentists on the same patient occurred when the mandible was not guided along the border pathways. These discrepancies were seen in enlarged projections of the superior view of the pathways created during mandibular movements.

The results of recordings of condylar movements of 50 subjects were superimposed and compared in three views showing the protrusive and lateral pathways as well as the superior view of the immediate side shift. Similarities in the tracings were noted in all three views for the 50 subject tested.

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