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13. THE ACCESS ARTICULATOR AND THE CAD/CAM

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It is still difficult to put the knowledge of occlusion into actual practice. Many articles, incredible theories, and ingenious machines have filled the past 70 years of the post-Gysi period, yet, the question remains: Is it logical to study mandibular movements in the same way they were studied 50 years ago with more or less the same instruments, whether mechanical or electronic? Is it possible that the new technologies will lead to progress beyond the previously established limits?

Certainly, the new electronic instrumentation should not return to the original technology. The technology of occlusion is already different, and no one can anticipate what will be the ultimate result of computer-aided studies. After all, who could have anticipated what the electron microscope was going to allow scientists to observe before first turning it on and seeing the wonders that it presented?

Before philosophizing on occlusion and its computerized and electronically assisted results, it was important to know how reliable and precise a dynamic articulator analysis of occlusion can be. I designed such an articulator between 1985 and 1989, and is called the "Access Articulator."

I will report on an initial study of the reliability of the Access Articulator and the extent to which it fulfills my expectations of 1984, while meeting the requirements of the more sophisticated techniques such as CAD/CAM. The purposes of this study were (1) to evaluate the precision of the angles obtained with the Access Articulator display compared to calibrated guides and (2) to evaluate the efficacy of integration of the values of cusp angles and lateral movement vectors into a CAD/CAM crown.

Presented at the Conference by Dr Duret.

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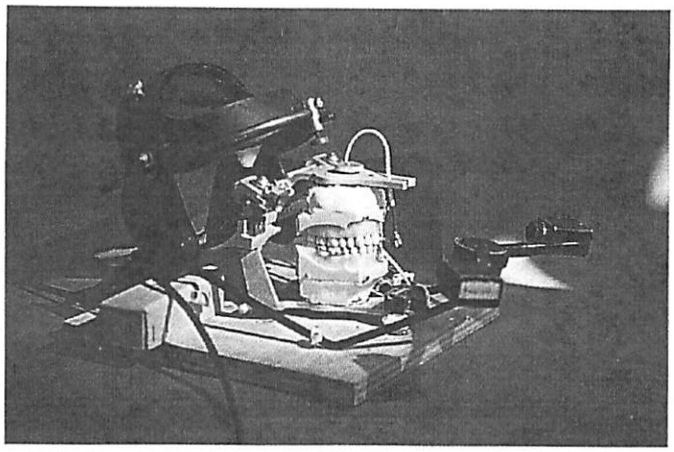

Fig 13-1 Apparatus fixed to a mounting board for recording.

MATERIALS AND METHODS

The Access Articulator is a device for measuring the mandibular movements and is composed of the following (Fig 13-1):

1. Two photo diode type cameras, fixed on the maxillae using a stable headgear
2. Three interdependent diodes (LED) attached to the mandible through anchorage on the central incisors
3. A computer board for signal conversation and digitization, using a clock installed in a Commodore PC 30 III typed computer
4. Basic MS-DOS software and software specific for the application
5. A CM 1401 color monitor

To facilitate this study the headgear holding the recording cameras was mounted on a flat surface to ensure stability. A Denar D5A articulator (Denar Corp, Anaheim, CA) was positioned within this device and the three LEDs were mounted on the incisal pin. These were properly oriented to the two cameras on the headgear to allow recording incisal pin movement, analogous to mandibular movement recordings.

Four lucite guides of different angles, 60°, 90°, 120°, and 180°, were fabricated. Each of the guides consisted of a patrix and matrix portion; the former represented the cusp and the latter represented the fossa. The guides were located in the region of the canine, premolar, and second molar (Figs 13-2a and 13-2b).

The first part of the experiment sought to evaluate the precision of the angles obtained with the Access Articulator compared to the calibrated guides.

The recording cameras were referenced to the three LED's using the occlusal plane. The articulator movements tracked the guides and were analyzed by the Access Articulator software in the frontal, horizontal, and sagittal planes.

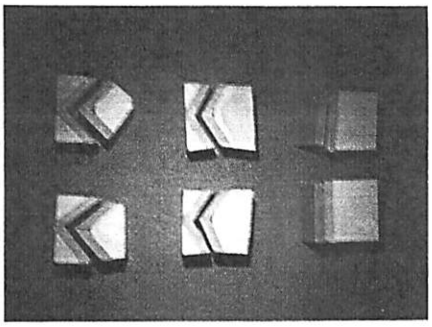

Fig 13-2a Occlusal guides used.

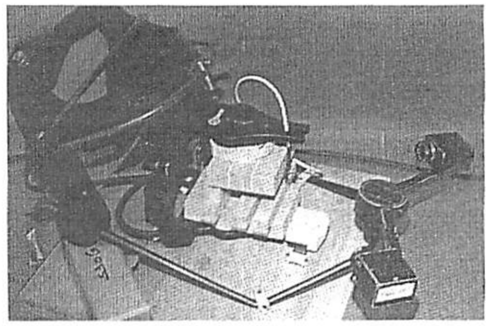

Fig 13-2b Occlusal guides placed for recording.

The clock rate was 2 Khz, but after making the needed corrections, a frequency of 600 points analyzed per second was used, which corresponds to 12,000 points over 20 seconds of recording time. To facilitate the display in real time, only 200 points of analysis per second (4000 points over 20 seconds) are shown on the monitor and not more than fifty are shown on the graph.

The second part of the experiment was to fabricate a Dicor (Dentsply Inc, York, PA) crown using data from a set of mounted casts. The casts with a die of a complete crown preparation were arbitrarily mounted in the articulator and the maxillary cast moved over the mandibular cast (guided by the other teeth) while the cameras recorded diode movement in the same manner as above. These data were then input into a CAD/CAM system (Sopha Bioconcepts, Los Angeles, CA) and a Dicor crown was fabricated.

RESULTS

For every test performed with the gauges, the values of 60°, 90°, 120°, and 180° were reproduced with a drift of 2°.

The tests made by this electronic articulator on the work model whose impression had been used for the design of a crown by CAD/CAM (Sopha Dental CAD/CAM) provide us with the following results: cusp angle (projected at the frontal plane based on the spatial analysis), 39°; angle of left lateral movement, 22°; and angle of right lateral movement, 42°. The crown fabricated using these data displayed no interferences in lateral excursion. The cusp height and ridge-groove direction appeared appropriate for the movements tested.

DISCUSSION

A certain number of questions arise after a qualitative and quantitative analysis of the results. Answers to such questions are subjective and speculative, based on past experience as well as the data acquired.

In our opinion the movement detector provides sufficient information to be precise and to produce data that can be interpreted by the computer. The system uses more than 600 points per second with the current prototype. An analysis of the dynamics of mandibular movement indicates that the mandible moves at a maximum speed of 2 cm/s during recording, resulting in one point every 4 μm being analyzed.

The deviation of the measured angles from the actual values of the guides used for the instrument tracking seems to have resulted from manually tracing the line obtained on the graph rather than from the information provided by the device itself.

The drift of the results does not seem to arise from an error in the device because all the tests of linearity a value that never exceeded 1.4% for a noise level of less than 0.2%. It seems more logical to look for this error in the manual method used for measuring the angles. This method consists of drawing lines on the graphs of the printer and measuring the angle obtained using a protractor. This manual method has the advantage of using human intelligence, but has the disadvantage of being a purely empirical sketching. Moreover, working on a graph of a low resolution, providing less than 10% of that recorded and displayed, makes the task much more difficult. Furthermore, the data from crown fabrication were drawn from a sample of one. Repetition of the project using significant numbers is essential for validation of the initial observations.

The only improvement that could be desirable for the hardware would be to increase the frequency of sampling to allow averaging of the data, permitting better approximation of absolute spatial precision of between 2 and 5 μm.

It is our opinion that the accuracy of this device is within the reasonable limit of the human movement and not less than 98% per angle, which is more than satisfactory.

Data transfer from the Access Articulator has not made use of the three-dimensional recording, but the display is only in the different planes. This incorporates some error as one dimension is superimposed on another and has unquestionably reduced the power of this analysis and the quality of its use. However, the procedure was simple and logical.

We feel that the achievement of recording data to be translated by the computer for the machining of an occlusal surface that is in harmony with mandibular movement is as decisive for the dental CAD/CAM as that of producing the first crown in Paris in 1985. Indeed, for the first time this work merged the information issued from the analysis of the mandibular movements with the design of a crown within a single experiment in real time.

CONCLUSIONS

These studies, performed at the University of Southern California School of Dentistry in the Department of Oral and Maxillofacial Imaging have allowed us to demonstrate the following:

1. The apparent precision of the prototype of the Access Articulator is ± 2°.
2. The analysis of this precision is made difficult by the fact that the test is done on the graphs of low resolution.

3. The transfer of the information to the Sopha Dental CAD/CAM has allowed the correction of the occlusal design of the crown on the monitor prior to fabrication by milling.

Dr François Duret is presently a Research Professor and Chairman of the Section of Restorative Imaging in the Department of Oral and Maxillofacial Imaging at the University of Southern California. He is internationally known as the premier developer and researcher in dental CAD/CAM. He holds multiple degrees, including a PhD in Human Physiology, a PhD in Biochemistry, his Doctoral degree in Dentistry and has completed post doctoral studies in periodontics. He is the holder of numerous innovative patents and has published extensively.