Chewing Patterns in Normal Children

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Chewing patterns are precisely plotted in deciduous, mixed and permanent dentitions. These show a progression from a large lateral component in the opening movement with a more medial closing path in the deciduous dentition, to a more vertical overall pattern with the closing path lateral to the opening path in the early permanent dentition.

The human mandible has long been a focus of much attention from dental investigators, and most aspects of this unique bone are fairly well understood. Remarkably, the role of the mandible in mastication still stands out for the lack of research and comprehension, and knowledge of the development of chewing patterns in children is even more deficient.

Thurow[1] states that "the deciduous occlusion exists in a continuous state of rapid change as it adapts to growth and developing functional patterns. Basic functional occlusal patterns are well established prior to eruption of the permanent teeth, making these first stages of occlusal development extremely important."

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Hannam[2] makes the point even more strongly in his review of human mastication with the statement that "longitudinal studies, especially of mastication in the infant and growing child, are virtually nonexistent. This is particularly galling because it is here that profound learning changes occur—the conversion from suckling to masticatory behavior and the transition of the latter through the deciduous, mixed and permanent dentitions. . . . Clearly we need to observe early attempts at mastication in the true sense, and the changes which occur as various teeth emerge and establish functional contact."

Perhaps the most formidable obstacle faced by investigators of this area is the design of a satisfactory means for the study of mastication. Cinematography and electromyography have been most commonly employed for the study of mandibular movements, but each presents its own limitations. A third method has now been developed and is utilized in the present study. This is the "Replicator System" developed at Case Western Reserve University by Cannon, Reswick, Messerman and Gibbs.[2,3,4] Such a system is currently located at the College of Dentistry, University of Florida.[5]

This paper reports on a study of chewing patterns in a large group of normal growing children. Groups of children in the deciduous, mixed, and early permanent dentition were studied. The cross-sectional picture of their evolving chewing patterns presents a panoramic view of the development of normal jaw function and occlusion and serves as a basis both for comparison to adult chewing patterns and for more accurately assessing effects of malocclusion on jaw function.

Methods and Materials

In order to permit subconscious chewing, the instrumentation of the replicator system was designed to be non-interfering in function.[3,4,5,6] The patient's head is unrestrained while jaw motions are recorded on magnetic tape. The extent of jaw movement is measured with six incremental photo-optical transducers mounted between maxillary and mandibular reference face bows.

The total weight of the patient-supported components is 100 grams. The weight transmitted to the mandible is only 60 grams. The design of the attachment clutches and light weight of the recording instrument permit normal chewing activity (Fig. 1).

The incremental transducers provide a measuring precision of 0.0625 (1/16) mm. The system accuracy for increments of jaw movement has been determine to be 0.125 (1/8) mm. There are several distinctive and important advantages in the use of incremental transducers. One of these is the lack of electrical drift which is a common occurrence with analogue transducers. In addition, incremental transducers facilitate the recording of the data on magnetic tape in a digital format, which is most efficient for computer entry and maintains the accuracy of the tape-recorded data over long storage periods. These are important advantages over analogue data which usually require analogue-to-digital conversion for computer entry.

Computer processing facilitates data analysis and allows points of interest on the jaw to be plotted in a number of views. Data for this study have been processed and plotted by a Hewlett Packard 21MX computing system at the rate of 100 points per

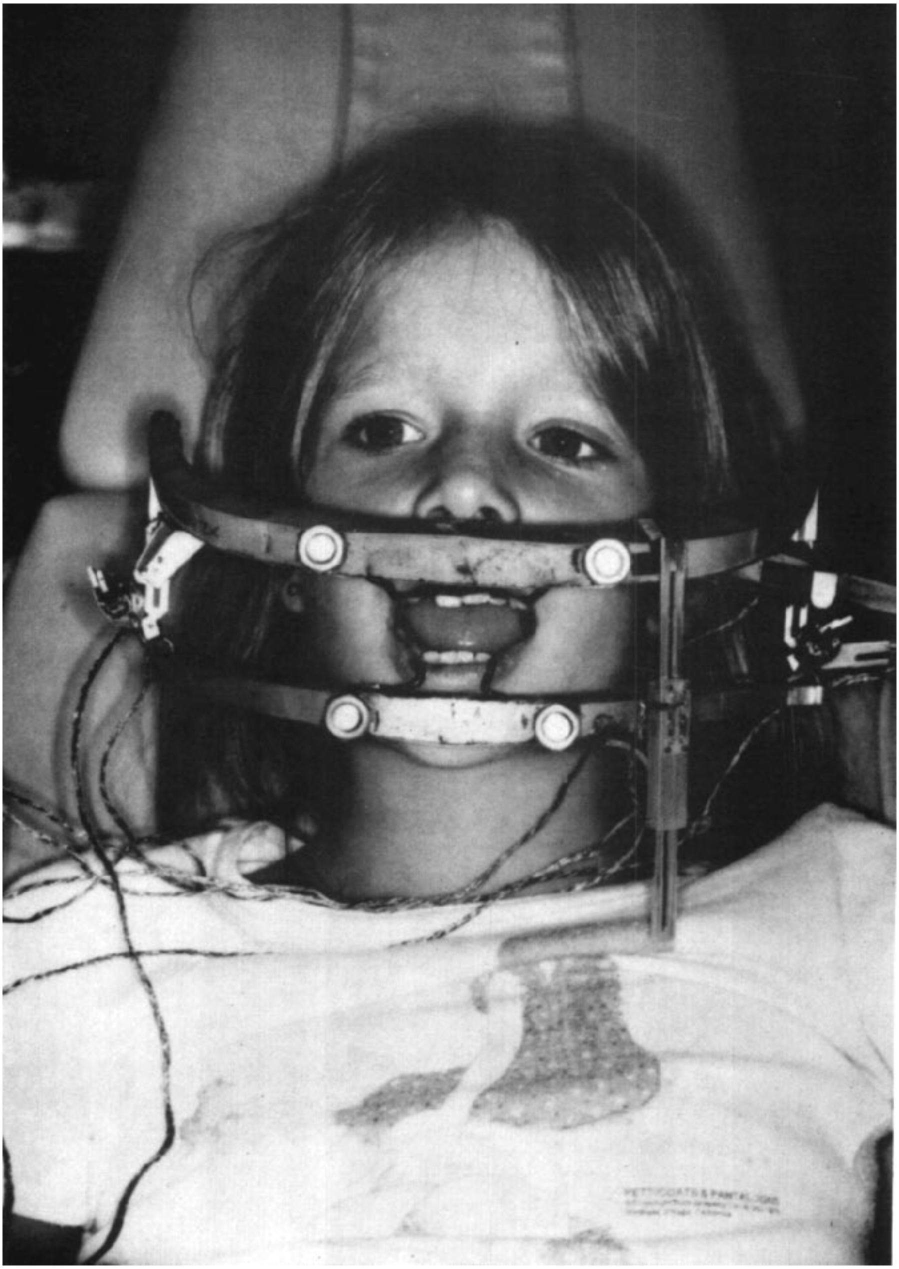

Fig. 1 Subject with intraoral clutches and face bows attached to mixed dentition, demonstrating unrestrained mandibular movements. Six incremental photo-optical transducers mounted between the face bows measure jaw motions in all three dimensions.

second. The program calculates and plots jaw position for each 0.01 second increment of time (Fig. 2).

A playback jaw motion replicator device has been constructed to move the subject's mandibular cast with six stepping motors responding to the transducer signals previously recorded on magnetic tape. Stepping motors are highly accurate and easy to control. In operation, the mandibular cast moves in precisely the same manner as the original movements of the subject's jaw, but at one-tenth the speed. The maximum error for reproducing jaw motion in the area of the intercuspation of the teeth is 0.25 mm. The mounted casts are visible from nearly all angles, so information on cuspal contact relationships can be gained by direct observation of their motion (Fig. 3).

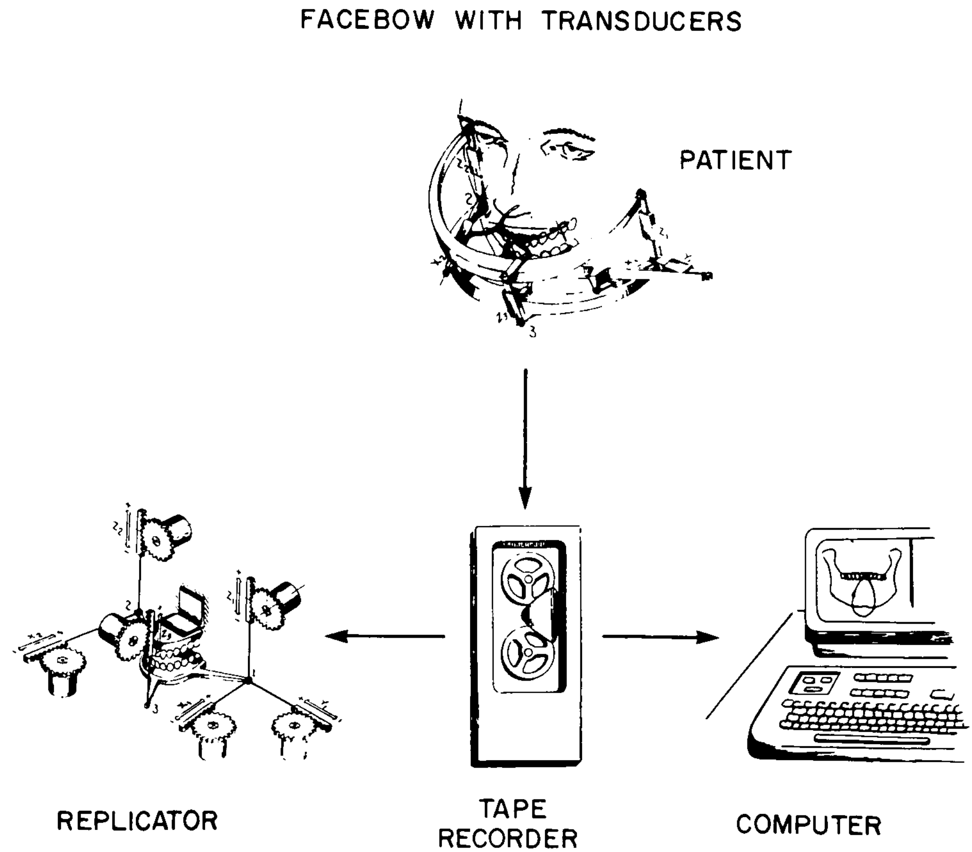

Fig. 2 System Schematic.

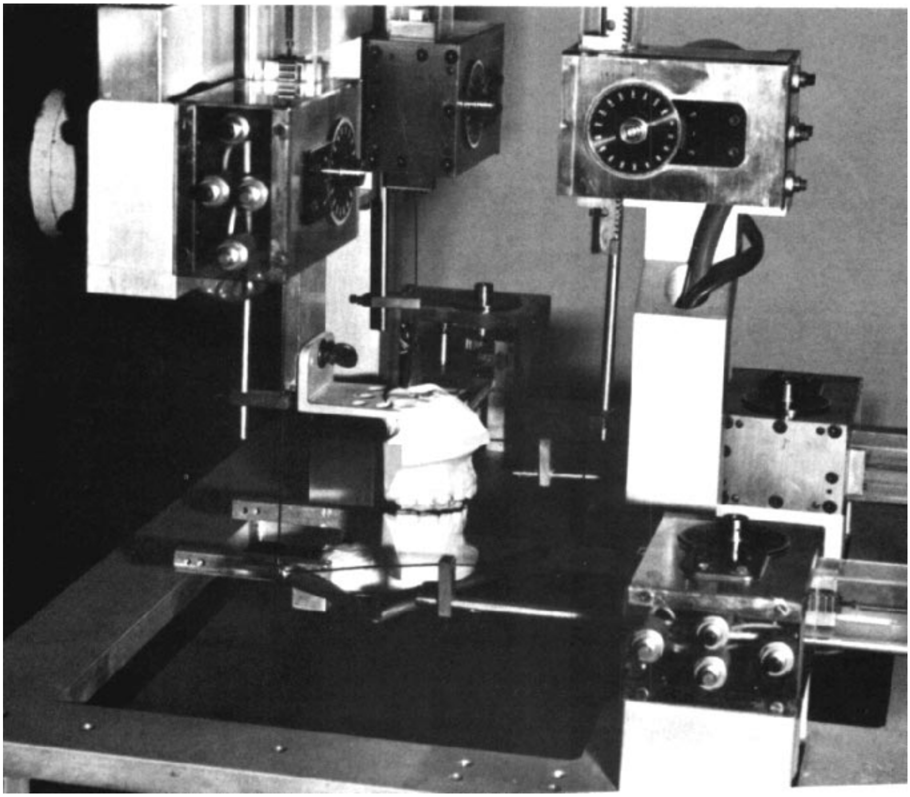

Fig. 3 Replicator System: Subject's casts can be viewed from all aspects while the mandibular cast is moved by six stepping motors, permitting unique occlusal relationships to be observed.

The motion plots are referenced to the occlusal and mid-sagittal planes. The condyle plotting points are selected on the hinge-axis line at a point 12 mm medial from the skin surface for children. This represents the average distance as measured from the P-A cephalogram. The hinge-axis line for each patient is calculated from a recorded hinge movement, using a three-dimensional "screw axis" method.[5,7] The border movements are recorded from the "incisor point," which is a selected site between the mandibular central incisors at their edge. The replicator system also has the capability of assessing complex movements of the mandible recorded from molar and condylar points.

The subjects for this portion of the study were normal developing children with no history of orthodontic treatment. They were separated into three dentition groups of deciduous, mixed, and permanent rather than calendric ages.

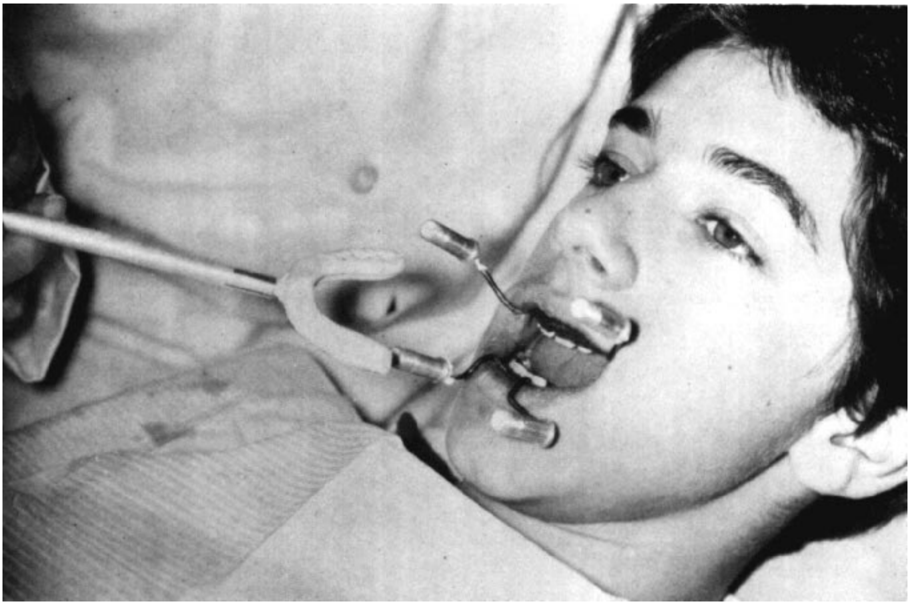

Fig. 4 Subject wearing intraoral clutches rehearses bite-fork placement prior to recording session.

The findings in this study are illustrated with actual data represented by computer drawn plots. Individual or multiple chews are used rather than composite chews or statistical summaries of the total subject pool.

The scales on the illustrations refer to the jaw motion plots only. The drawings of the jaws and teeth are shown only for orientation purposes and are drawn to a smaller scale.

The main criteria for inclusion in the study are a Class I occlusion, a normal growth pattern and no previous orthodontic therapy. Children selected for participation are given two appointments. The initial appointment is used to gather base-line diagnostic data. This data consists of the following:

1. Medical and dental health history
2. Orthodontic casts
3. Informed consent
4. Centric wax registration
5. Panoramic dental radiograph
6. Lateral cephalogram
8. Complete intraoral and extraoral photographs
9. A face-bow transfer
10. Measurement of maximum opening and lateral mandibular movements
11. Measurement of head width
12. Fabrication of an acrylic bite-fork
13. Fabrication of maxillary and mandibular clutches

The initial group of data is familiar to any orthodontist and indispensable in a longitudinal growth study such as this one. The face-bow transfer is required to properly relate the maxillary dentition to the condyles for mounting on the articulator. A bite fork comprised of quick-cure acrylic adapted to a metal framework is carefully constructed for each patient in centric relation.

The bite fork serves several important functions. It provides a stable reference point during testing, ensuring that each starting and stopping point will be the same. The patient inserts and removes the bite fork during each portion of the chewing test (Fig. 4). Since the computer records these starting and stopping points, the data is automatically partitioned for easier accessability and study. The bite fork provides an accurate check on clutch and computer integrity. Finally, the bite fork is used to mount the patient's dental casts into the jaw motion duplicator.

The maxillary and mandibular clutches are fabricated from mounted casts of the patient utilizing a wire framework covered with a self-curing methyl methacrylate resin. The wire framework is carefully adapted to the casts to allow the patient normal lip sealing on closure and swallowing. The resin material is then added to the wire framework to provide maximum surface area for retention without any interference with the occlusal contacts of the teeth (Fig. 5).

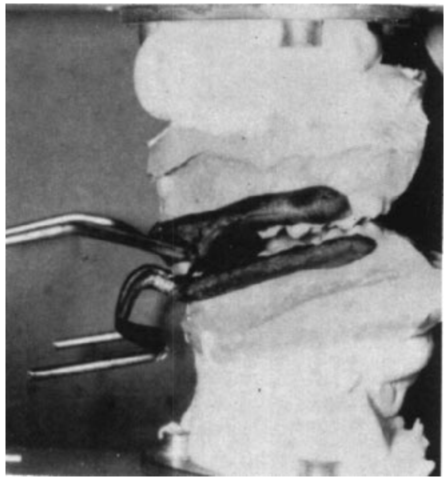

Fig. 5 Intraoral clutches are fabricated on mounted casts to preclude occlusal interferences.

At the second visit, which is spaced no more than two weeks after the first, the patient is prepared for clutch cementation. The labial and buccal surfaces of all teeth are pumiced thoroughly to remove any surface accumulation. All deciduous teeth are dried and etched for one minute with a phosphoric acid etching agent. To avoid any possible damage to the enamel, permanent teeth are not etched. Following etching, the teeth in one arch are carefully dried and one clutch is cemented with an orthodontic bonding adhesive which has been found to produce good clutch retention under the forces of mastication. The other clutch is cemented in a similar manner. Care is taken to remove any adhesive material which can possibly interfere with the occlusion (Fig. 6). The measuring instrumentation is then attached to the dental clutches.

For non-chewing recordings, the subject is seated in a reclining dental chair with headrest.

The first activity to be recorded, if present, is the shift from centric relation to centric occlusion. This is a manipulated activity which requires the investigator to direct the subject to the most retruded condylar position and initial cuspal contact. The

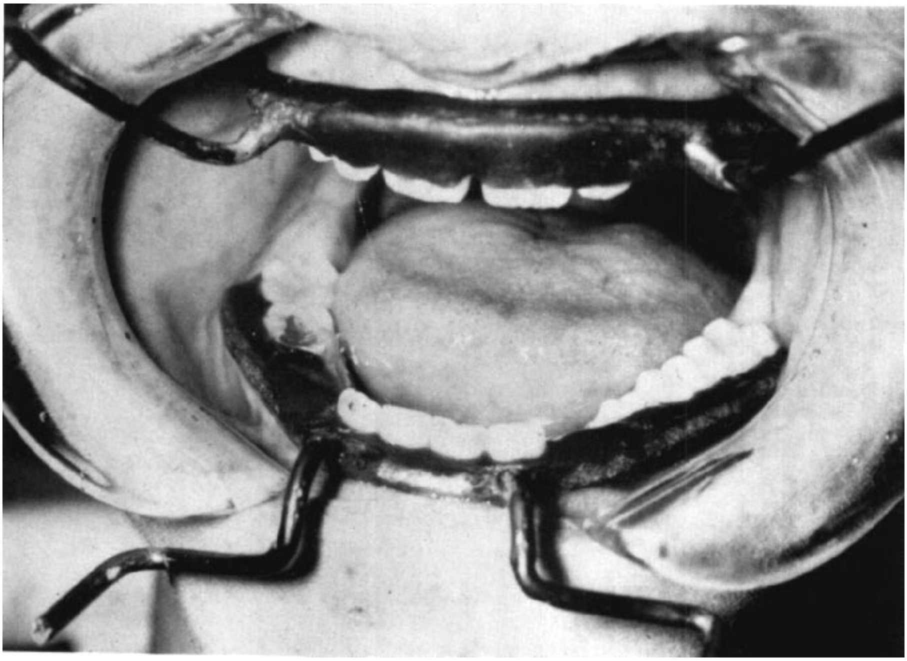

Fig. 6 Intraoral clutches bonded to facial surfaces of the teeth without disturbance to occlusion or mandibular movements.

subject then shifts to the intercuspal (habitual occlusal) position. Border movements in frontal and sagittal planes are also manually directed by the investigator to insure that extreme movements are recorded.

Unilateral chewing movements are recorded for each side. The child sits upright without a headrest during chewing recordings (Fig. 7). The food is first place by the investigator on the right posterior dentition and the subject is directed to chew the food and swallow it when ready. The sequence is then repeated for the left side. The test foods consist of cheese, raisins, carrots, and peanuts. All are portioned to bite size. The use of test foods with different consistencies is important in order to assess any different chewing patterns which may occur as a result of differences in the biting force required for mastication. Chewing gum is also used to record mandibular function which is non-preparatory for swallowing.

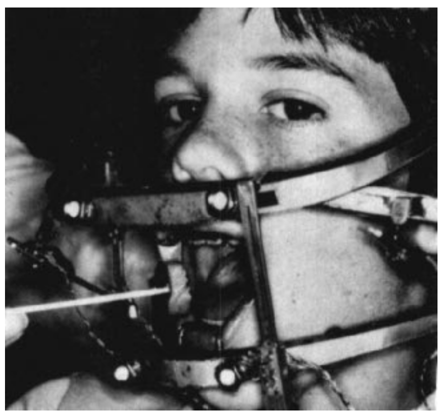

Fig. 7 Investigator places hard food (carrot) on right side in preparation for chewing.

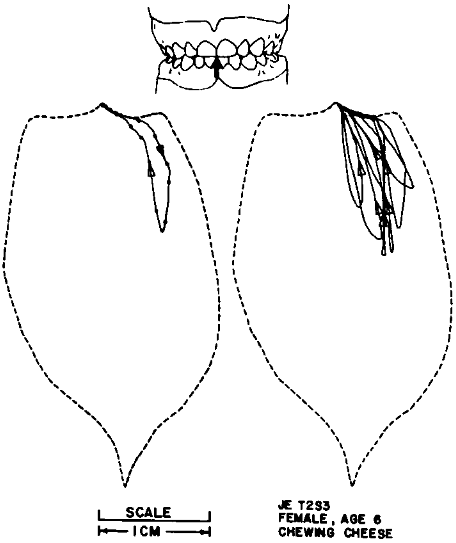

Fig. 8 Frontal view computer plots: chewing soft food on the left side (solid lines); border movements (dashed lines). Chewing in young subject is characterized by wide lateral movement in opening and decreased lateral movement in closure.

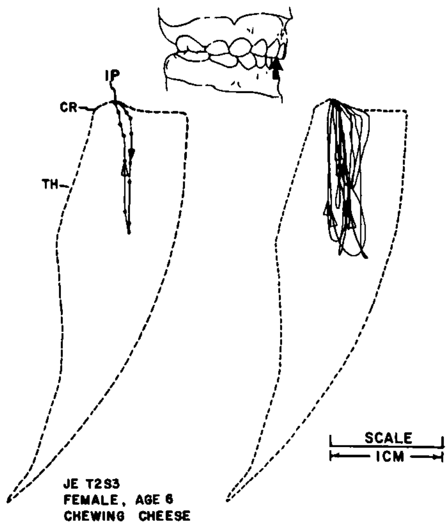

Fig. 9 Profile view computer plots: chewing soft food on the left side (solid lines); border movements (dashed lines). The anterior component of the occlusal slide from initial retruded contact (CR) to the intercuspal position (IP) is extremely large (2.5 mm) for this child. There was considerable anterior movement during opening in chewing.

Findings

Chewing movements of the young child in the primary dentition stage of development were characterized by wide lateral movements toward the food (working) side on opening and a smaller degree of lateral movement on closure (Fig. 8). As the profile view indicates, there was considerable anterior movement during opening (Fig. 9).

The border movements are shown in the dashed lines (Figs. 8 and 9). The border movements in the profile view (Fig. 9) form the familiar diagram as described by Posselt.[8] The anterior component of the occlusal slide from initial contact to the intercuspal position is extremely large, 2.5 mm, for this six-year old subject. This same child demonstrated a slide of only 0.5 mm by age 11, which is in the range of the normal child and adult dentition. The reduction in slide occurred naturally as the subject was not in orthodontic therapy. Only two of the "normal" children in our study of 27 normals have demonstrated occlusal slides greater than 2 mm.

Tooth gliding during chewing as evidenced by coincidence with the border path occurred frequently during both opening and closing. Opening glides were observed to be generally longer than closing glides in the deciduous dentition subjects.

The degree of lateral movement during opening tended to decrease with age. By ages 10-12 opening was

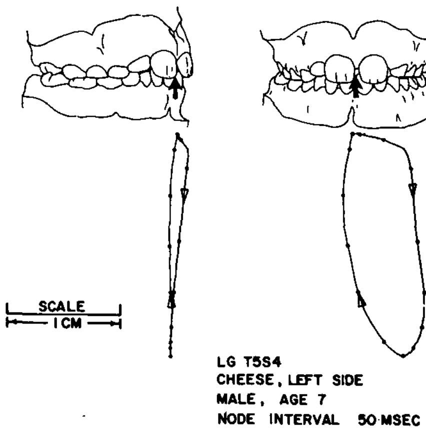

Fig. 10 A child subject with early mixed dentition demonstrates the wide lateral opening stroke typical of a child with deciduous dentition.

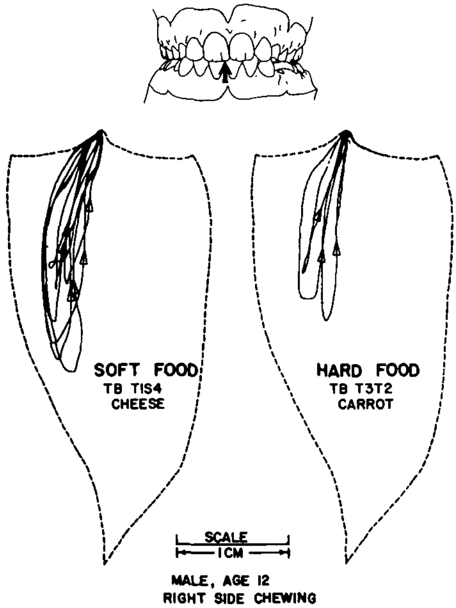

Fig. 11 The chewing of hard versus soft food in this child subject did not appear to make a large difference in the chewing pattern.

generally near vertical, which is typical for the adult. There was considerable variability from subject to subject on this point. The same subject in the mixed dentition phase would often display the wide lateral opening pattern typical of the deciduous dentition (Fig. 10), yet close in a less lateral path which is more typical in the mixed dentition.

The time interval dots on the chewing plots begin at the intercuspal position and mark 50-millisecond intervals. As indicated by the distance between the interval nodes, maximum velocity usually occurred in the opening phase of the chewing cycle and slowed as the intercuspal position was reached.

The chewing of hard versus soft food in the child subject did not appear to make a large difference in the chewing pattern, except perhaps for a slight tendency for more medial and shorter closing paths as shown in Fig. 11.

The extent of vertical opening and lateral deviation on closure at the incisor point are shown in Table 1.

Vertical jaw opening as a function of time during a typical chewing series is shown for a child in the deciduous dentition in Fig. 12. The

TABLE 1
Chewing Movements at the Central Incisor

Dentition Stage	*Average Vertical Opening (mm)*	*Average Lateral Deviation in Closure (mm)*	*N*
Deciduous	11.7	3.2	5
Mixed	14.6	4.1	5
Early Permanent	16.1	4.8	2

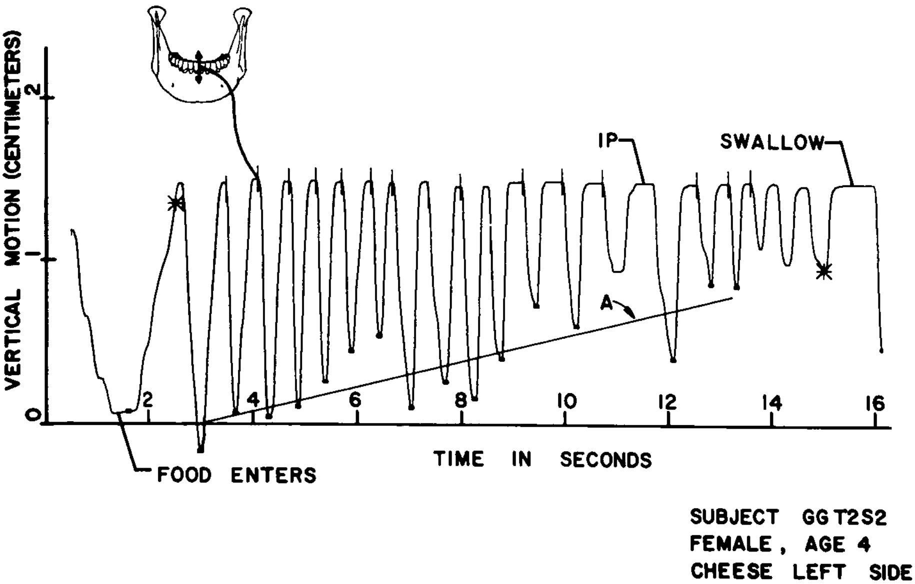

Fig. 12 Vertical jaw opening versus time during a typical chewing series for a child with deciduous dentition. The amount of jaw opening decreased as the bolus was reduced. A best fit line (A) through the maximum opening points is a measure of this decrease. The flat tops at the intercuspal position (IP) indicate a pause in jaw movement.

amount of jaw opening decreases as the bolus is reduced. A best fit line (A) through the maximum opening points is an indication of this decrease.

Of particular interest are the flat tops, indicating a pause in movement at the intercuspal position. The pause during swallowing was typically about three times as long as the pause during chewing. The average pause at the intercuspal position (IP) was 147 msec. in the deciduous dentition, 162 msec. in the mixed dentition, and 142 msec. in the early permanent dentition.

Discussion

As previously mentioned, the study of the development of mastication in the normally growing child has received little attention in the literature. One notable exception is a detailed study by Ahlgren[9] which represented a quantitative cinematographic and electromyographic study of masticatory movement in children, with special reference to occlusion of the teeth. In his study of 35 subjects, Ahlgren divided masticatory movements into seven classifications according to the movement of the lower incisor in the frontal plane.

In a later investigation of 320 children, Ahlgren[9] used direct observation to examine the patterns of chewing as measured by his seven classifications. The mean age of the children in his first study was 12 years and in the later study 13 years, with a range of 8-16 years. This is significant in regard to the present study. The wide lateral opening movement which we see typically occurring in the deciduous dentition child was not dominant in Ahlgren's findings. We

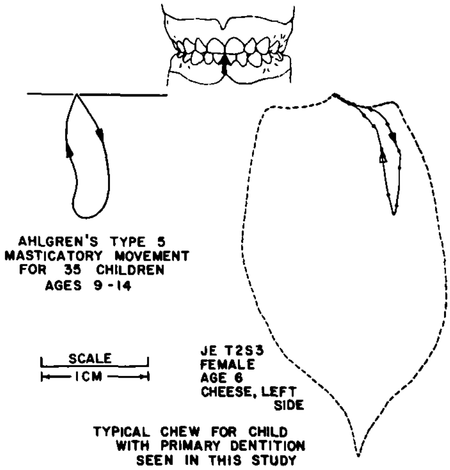

Fig. 13 The Type Five chewing pattern from Ahlgren's studies[9,10] was the closest match to the pattern found in this study in subjects with a deciduous dentition. Ahlgren's pattern differs in the lack of a wide lateral swing in opening. His subjects (average age 12 and 13) were too old to display the unique deciduous dentition chewing pattern.

feel the reason is that his subjects were too old to routinely demonstrate this wide lateral opening. Ahlgren's Type 5 chewing pattern is most like that of our findings for the child with deciduous dentition (Fig. 13). Ahlgren[10] reported his Type 5 chewing pattern to occur in 11% of malocclusion cases and never in normal children.

Ahlgren[9] reported a mean opening of 19.1 mm and a lateral movement from the midline of 5.3 mm for carrot chewing. These values are only slightly higher than the 16.1 mm and 4.8 mm reported in this study for the young adult chewing carrots. The pause in the intercuspal position reported in this study (147 msec—primary dentition, 162 msec—mixed dentition, and 142 msec—early permanent dentition) was longer than the 83 to 125 msec values reported by Ahlgren.

In this study the closing paths in the child with the deciduous dentition became more vertical with harder foods. This is in accord with the more vertical chewing pattern reported for carrot chewing versus gum chewing by Ahlgren.[9]

Ingervall and Thilander[11] reported in 52 children a mean of 21.7 chewing cycles before swallowing and an average chew time of 13.5 seconds. This is very similar to the 20 chewing strokes and 12 seconds reported in this study (Fig. 12).

Conclusions

1. The chewing pattern is well established in the child with a complete deciduous dentition.

2. The chewing pattern of the child with a deciduous dentition is characterized by wide lateral excursions in opening; lateral movement in opening is typically greater than that in closing. As the child matures, the lateral movement in opening decreases and lateral movement in closing increases. By the age of 12 to 14 the typical chewing pattern has changed almost completely and is characterized by sagittal opening and wide lateral closing movements.

3. A return to the intercuspal position and an associated pause in jaw movement are typical of chewing in all children as well as adults with normal dentitions.

REFERENCES

1. Thurow, R. C. *Atlas of Orthodontic Principles,* 2nd ed., 171-185, C. V. Mosby, St. Louis 1977.
2. Hannam, A. G.: Mastication in man. *Oral Motor Behavior—Impact on Oral Conditions and Dental Treatment.* Workshop Proceedings, NIH Publication No. 79-1845, pp. 104-105. Bethesda, MD, May 16-17, 1979.
3. Cannon, D. C., Reswick, J. B. and Messerman, T.: Instrumentation for the investigation of mandibular movements. *Engineering Design Center Report,* EDC-4-64-8. Cleveland, OH: Case Western Reserve University, 1964.
4. Gibbs, C. H., Messerman, T. and Reswick, J. B.: The Case gnathic replicator for the investigation of mandibular movements. *Engineering Design Center Report,* EDC-4-66-14. Cleveland, OH: Case Western Reserve University, 1966.
5. Gibbs, C. H., Messerman, T. and Reswick, J. B.: Functional movements of the mandible. *Engineering Design Center Report,* EDC-4-69-24. Cleveland, OH: Case Western Reserve University, 1969.
6. Gibbs, C. H. and Lundeen, H. C.: Jaw movements and forces during chewing and swallowing and their clinical significance. Chapter 1 in *Advances in Occlusion.* Edited by Lundeen, H. C. and Gibbs, C. H. Publishing Sciences Groups, Littleton, MA (In Press), 1981.
7. Lupkiewicz, S. M., Gibbs, C. H., Mahan, P. E. and Lundeen, H. C.: The instantaneous hinge axis—possible indicator for dysfunction. *J. Dent. Res.* 59 (Special Issue A): 316 (Abstract #193), 1980.
8. Posselt, U.: *Physiology of Occlusion and Rehabilitation.* F. A. Davis Co., Philadelphia, PA, p. 44, 1962.
9. Ahlgren, J.: Mechanism of mastication. *Acta Odontol. Scand. 24* (Supp. 44):1-109, 1966.
10. Ahlgren, J.: Pattern of chewing and malocclusion of teeth: A clinical study. *Acta Odontol. Scand.* 25:3-13, 1967.
11. Ingervall, B. and Thilander, B. Activity of temporal and masseter muscles in children with a lateral forced bite. *Angle Ortho.* 45:249-380, 1975.