TOOTH CONTACT PATTERNS IN MASTICATION

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The physiology of mastication and its underlying neuromuscular mechanisms are incompletely understood. Statements about the role of occlusion and tooth contact in these mechanisms have been made in the literature but only a few are based upon experimental evidence. The clinical experience of successful treatment of temporomandibular joint and muscle disturbances, as well as bruxism, by occlusal adjustment (equilibration) and splints is an indication that occlusion has a significant role in the neuromuscular mechanisms. Under experimental conditions, occlusal interferences have been shown to influence electromyographic patterns.3

These clinical and experimental observations are indirect evidence that occlusal contacts play an important role in the reflex systems of the masticatory apparatus.

Controversy has surrounded the occurrence of occlusal tooth contacts per se during functional movements and there is no published evidence on the precise jaw relationship during such contacts, or on their duration.

Early attempts to measure occlusal tooth contact were the investigation of Hesse6 who studied the masticatory movements of the mandible. His report was concerned with empty movements and his paper, given in Paris, described functional movements.6 He used the space of a missing tooth to contain a lead pencil with a recording layer on the opposing tooth. His experiments showed the occurrence of occlusal tooth contacts during chewing in maximum intercuspation as well as during lateral excursions.

The recordings of Jankelson and others7 were the first which measured directly the occurrence of tooth contact. Their attempts to detect tooth contact by means of cinefluorography were not successful. Subsequently, they developed a method which applied an electrical potential between two antagonistic full crowns. Upon contact, the circuit was closed and the potential difference was recorded on an oscillograph. Based upon this study they state: "...it cannot be stressed too forcefully that it was only during the act of deglutition that functional contact of opposing teeth was demonstrated." Anderson and Picton8 recorded tooth

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contact electrically between two antagonistic amalgam fillings. Their studies reveal frequent contacts during almost every chewing stroke.

The variations in maxillomandibular positions, in which observations were made, may have been responsible for the divergency in the findings of Anderson and Picton\textsuperscript{8} from those of Jankelson.\textsuperscript{7}

This study was undertaken to investigate whether or not tooth contact occurs in the intercuspal position\textsuperscript{*} and/or retruded contact position\textsuperscript{*} during mastication and swallowing of food. If such contact occurred, what would be its frequency, duration, and distribution during eating?

**MATERIALS AND METHODS**

*Five adult human subjects (2 women and 3 men) were studied.*

Since the purpose of this study was to investigate physiologic aspects of the masticatory system, the subjects were required to fulfill the following criteria: (1) no clinical evidence of temporomandibular joint disturbances, (2) no clinical evidence of neuromuscular disturbances, (3) absence of periodontal pockets or increased tooth mobility, (4) no previous orthodontic treatment, (5) posterior tooth contacts on both sides and bilateral posterior contacting surfaces in the molar region, (6) space in the second premolar or first molar region, sufficient to accommodate the transmitter, (7) "normal" occlusion (the occlusions all fell within Angle's Class I), and (8) The intercuspal position and the retruded contact position had to be distinguishable by clinical examination, i.e., subjects with coinciding positions were excluded.

*Three bridges (fixed partial dentures) were constructed for each subject with utilization of prepared abutment teeth and reproduction of their original morphology. One of these carried an ordinary acrylic resin pontic tooth for the subject to wear between experiments. The other two were fitted with radio transmitter pontics (Fig. 1).\textsuperscript{10-13} Thus the subject's occlusion remained identical throughout the study.*

A switch was fitted in each of the two transmitter bridges in order to record tooth contact in a single maxillomandibular relationship (Fig. 1). To supply the contact from the opposing tooth, a cusp tip was chosen in a tooth which would oppose the switch area of the transmitter (Fig. 2). The two relationships studied were the intercuspal position and the retruded contact position.

The subject wearing the bridge was seated comfortably. The tooth contact signal was received and amplified to light a small neon bulb mounted close to the subject's face outside his field of vision (Fig. 3).

*The subject was offered an ad libitum amount of peanuts\textsuperscript{\dagger} or a slice of rye bread\textsuperscript{\ddagger} and was asked to eat the food in a normal way. No directions concern-

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\*Posselt's nomenclature is used:

*The intermaxillary relationship when intercuspatation has occurred upon closure. This is usually the most cranial position of the mandible in which the cusps and sides of the mandibular and maxillary teeth mesh tightly.*

*Contact position with the mandible in terminal hinge relation. The relation of the mandible to the cranium when it is able to make a terminal hinge movement. The hindmost rotary opening or closing movement of the mandible.*

\*Planters salted cocktail peanuts, vacuum packed.

\*Rye bread, German style.
Fig. 1.—An acrylic resin fixed partial denture containing a radio transmitter and power supply. The switch consists of two insulated gold bars connected to the terminals of the transmitter.

Fig. 2.—The inlay on the tip of the cusp of the second bicuspid provides the contact area for the switch in opposing the lower tooth.

Fig. 3.—The size of the frames of the motion pictures. The neon light bulb in the upper left corner of the picture indicates a tooth contact.

ing the manner of chewing were given, nor were any instruction given to chew on one side or the other side.

Motion picture sequences of several eating acts were taken at a speed of 24 frames per second. The exposures were made with available light in the room with a high sensitivity film in order to avoid “blinding” of the subject. A telephoto lens of 105 mm. focal length permitted suitable photography from a distance of 5 feet from the subject’s face. The size of the frame (Fig. 3) allowed observation of movements of the lower half of the face and of the neck region.
A special movie analyzer projector* was used to analyze the films frame-by-frame. Its cooling system and electronic equipment allowed it to stop, advance, and reverse the film, frame-by-frame, without damage. A frame counter was included so that any frame on the film roll could be relocated accurately.

In order to make a frame-by-frame analysis of the motion pictures, the movements of mastication had to be divided so that the number of frames of the different phases of motion could be counted. Our analysis and division of masticatory movements was as follows:

The entire act of eating a portion of food started with incision or introduction of the food into the oral cavity. It ended with motionless rest of the face after the bolus had been swallowed and the mouth cleaned. The start of the act of eating in the analysis of the films was determined by the widest opening of the mouth prior to incision or insertion of food. From this frame on, closing movement was counted until the first obvious frame of opening appeared. This frame was not added to the closing count but was included as the first frame of opening movement, which terminated at the widest opening of the mandible. One closing and opening movement together are referred to as masticatory cycle. When tooth contact occurred, as indicated by the light bulb, the number of frames was counted and recorded, as part of the closing movement. The onset of the act of deglutition, including swallowing and cleansing movements, was determined by the most obvious contraction of the perioral musculature (m. orbicularis oris) detected by movement of the modiolus.15,16 The upward movement of the larynx was taken as confirmation of swallowing, except in some female subjects in whom it was sometimes not detectable. The duration of tooth contacts was recorded and related in time to the onset of deglutition.

Since the films were exposed at a constant speed of 24 frames per second, the conversion of film frames into time was possible. Although the accuracy of time determination is limited, it was sufficient for the purpose of this study. Indication of contact on a single frame means only that such contact occurred at some point during the exposure of that frame. It can only be said that the duration of that contact was less than 1/12 of a second. If it continued over two frames it was 1/12 of a second or more, but less than 1/8 of a second.

It should be appreciated that this study has been concerned only with tooth contacts in the two maxillomandibular relationships described above. This does not mean that tooth contacts in other positions do not occur or are not important. Indeed, studies of tooth contacts in other positions are currently in progress in this laboratory.

The tooth contact patterns of each subject in the two different maxillomandibular relationships investigated are represented in the form of histograms. The time interval between tooth contacts, and the duration of these contacts, are shown in them. The contacts are related to other events in the act of eating such as opening, closing, cleansing, and swallowing movements. The rate of chewing can also be read from the histograms. The horizontal axis shows the total time in seconds of an act of eating and includes the sequence of events during this

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*Kodak Analyst Projector, Weinberg-Watson modification, Model C.
time. The vertical axis represents duration of tooth contact and, for clarity, is enlarged five times.

Each of the four segments of the histograms starts with the closing movement following the insertion of a food sample. The sequence of events up to final swallowing is then illustrated as follows:

**Tooth Contact**

- **Closing**
- **Opening**
- **Swallowing and Cleansing**

**Masticatory Cycle**

**RESULTS**

The results are given in Figs. 4 to 8 for the 5 subjects studied. All subjects made tooth contacts during masticatory cycles in the intercuspal position but none in the retruded contact position. There was variation in the frequency of these chewing contacts in different individuals; it occurred in one eating act during every masticatory cycle, whereas, in another, only 8 of 34 cycles showed contact.

One subject had chewing contacts lasting less than 1/8 of a second. The 4 other subjects showed a range of duration of contact between 1/12 and 2/3 of a second. In these 4 individuals, some sequences of contacts increased in duration from stroke to stroke to a maximum and then gradually decreased.

During swallowing and cleansing movements, the retruded contact position was reached by 4 of the 5 subjects. The number of these contacts varied from one to six. A similar number of contacts during swallowing occurred in the intercuspal position. The longest tooth contacts were seen in all subjects in the intercuspal position during swallowing.

Examination of the individual records showed that every subject had some individuality in pattern, both in the rate of chewing and in the frequency and duration of tooth contacts. Some people chewed peanuts in the manner in which others chewed rye bread and vice versa.

**DISCUSSION**

The investigation being reported was designed to overcome the limitations of the methods used by previous workers in this field. The development of a miniaturized radio transmitter and switch apparatus in a fixed bridge allowed observation of subjects under normal environmental circumstances and made possible the direct measurement of the frequency and duration of tooth contact in two different maxillomandibular relationships.

Previous investigators\(^5-8\) have been unable to distinguish between contacts occurring in different maxillomandibular relationships during mastication. Indeed, Hesse,\(^6\) whose method came closest to accomplishing this, admits that his investigations were inconclusive.
Fig. 4.—Histograms of B.H. (27-year-old woman).

A, In the Intercuspal position. The subject used 38 masticatory cycles to complete chewing, swallowing, and cleansing of four bites of bread. It took her 57.2 seconds. During this time tooth contact occurred 46 times. The mean duration of these contacts was about 1/7 of a second. Thirty-three of the 46 contacts occurred during masticatory cycles and were of a mean duration of 1/8 of a second. The remaining contacts were associated with the five swallowing and cleansing movements and had a mean duration of about 1/5 of a second. The subject chewed at a rate of 53 strokes per minute.

B, In the Retruded contact position. The four eating acts lasted 83.2 seconds and represent a total of 44 masticatory cycles. No contact occurred in this maxillomandibular relationship during chewing of bread. It was reached only in association with swallowing and cleansing. Tooth contact was associated with all the swallowing and cleansing movements. The total 19 contacts varied from 1 to 7 frames. The subject chewed at a rate of 59 strokes per minute.
Fig. 5.—Histograms of R. H. (38-year-old-man).

A, In the intercuspal position. The subject used 102 masticatory cycles to eat four bites of bread. It took him 102.9 seconds to complete chewing, swallowing, and cleansing. During this time tooth contact occurred 84 times. The mean duration of the contacts was 4 frames or 1/6 of a second. Seventy-four of the 84 contacts occurred during masticatory cycles and were of a mean duration of 3.5 frames. The remaining 6 contacts were associated with the four swallowing and cleansing movements at the end of the eating acts and had a mean duration of 7.6 frames or almost ¼ of a second. The subject chewed at a rate of 86 strokes per minute.

B, In the retruded contact position. The four eating acts lasted 82.0 seconds and represent a total of 74 masticatory cycles. No contact occurred in this maxillomandibular relationship, either during the masticatory cycles or in association with swallowing and cleansing of bread from the mouth. The subject chewed at a speed of 85 strokes per minute.
B, In the retruded contact position. The eating of four portions of peanuts lasted 109.5 seconds and represents a total of 130 masticatory cycles. No contact occurred in this maxillomandibular relationship during chewing. It was reached only in association with swallowing and cleansing. None of the 9 contacts exceeded $\frac{1}{2}$ of a second. This subject chewed at a rate of 99 strokes per minute.
Fig. 7.—Histograms of C. H. (31-year-old woman).

A. In the intercuspal position. The subject used 68 masticatory cycles to eat four samples of peanuts. It took her 106.2 seconds to complete chewing, swallowing, and cleansing. During this time, tooth contact occurred 67 times. The mean duration of these contacts was a little more than 1/4 of a second. Sixty-one of the 67 contacts occurred during masticatory cycles. The third eating act shows contact with every masticatory cycle. The remaining 6 contacts were associated with the four swallowing and cleansing movements at the end of the eating acts. The subject chewed at a rate of 51 strokes per minute.

B. In the retruded contact position. The four acts of eating lasted 102.0 seconds and represent a total of 65 masticatory cycles. No contact occurred in this maxillomandibular relationship during the chewing of peanuts. It was reached only in association with two of the swallowing and cleansing movements. The contacts varied in duration from not quite 1/4 of a second to less than 1/12 of a second. The subject chewed at a rate of 57 strokes per minute.
A. In the intercuspal position. The subject used 31 masticatory cycles to eat three bites of bread. It took him 39.4 seconds to complete chewing, swallowing, and cleansing. During this time tooth contact occurred 24 times. Twenty-one of the 24 contacts occurred during masticatory cycles and were of a mean duration of about 1/10 of a second. The remaining contacts were associated with the three swallowing and cleansing movements and had a mean duration of more than 1.5 seconds. The subject chewed at a rate of 67 strokes per minute.

B. In the retruded contact position. The three acts of eating lasted 65.9 seconds and represent a total of 42 masticatory cycles. No contact occurred in this maxillomandibular relationship during chewing of the samples of peanuts. It was reached only in association with swallowing and cleansing. Tooth contact occurred in 4 of the 5 swallowing and cleansing movements. The 6 contacts were all of a duration of less than 1/12 of a second. The subject chewed at a rate of 83 strokes per minute.
Our study has revealed that the tooth contact patterns for the intercuspal and retruded maxillomandibular relationships, which we were able to record, are different, and each has its own characteristics in various test subjects. While some of the features of these contact patterns can be attributed to individual variations between the masticatory cycles of the test subjects, others are common to all and must, therefore, be regarded as functions of underlying neuromuscular mechanisms.

The records of masticatory cycles in the intercuspal position revealed individual patterns of contacts in the 5 subjects (Figs. 4-8). In some subjects, there appears to be an increase in tooth contact duration during the chewing of food, while in others a wavy pattern of increase and decrease is apparent. In one individual (Fig. 6) only fleeting contacts occurred.

In contrast, the records of masticatory cycles in the retruded position showed that contact was never reached during chewing. However, they did occur regularly during swallowing. This seems to indicate that the swallowing reflex brings the mandible more posteriorly than the masticatory stroke as already suggested by Kydd and Sander.

During swallowing and cleansing movements, both the intercuspal position and the retruded contact position were reached frequently by 4 of the 5 subjects, and a comparison of the number of contacts in these two positions suggests that there is a relationship between them. It is likely that corresponding contacts represent a slide from one position to the other, but the limitations of the method do not allow any definite conclusions on this point.

A finding of interest resulted from a comparison of the duration of the contacts in the intercuspal and retruded position during swallowing and cleansing. This showed that those in the intercuspal position are generally longer in duration than those in the retruded contact position. This may have its explanation in the fact that the mandible is more efficiently stabilized in the former position.

Our finding that contact occurred during masticatory cycles in the intercuspal but not in the retruded position serves to reconcile the divergent statements of Jankelson that “. . . contact of teeth seldom occurs during the act” (of mastication) and that of Anderson and Picton that “. . . the teeth came into contact for more than one half the chewing thrusts in most subjects. In some subjects every thrust made contact.” The difference could depend on whether the observations were made in the retruded position (Jankelson’s “centric occlusion”) or the intercuspal position (“chewing thrusts” of Anderson and Picton).

CONCLUSIONS

1. Teeth contact in the intercuspal position during the mastication and swallowing of food.
2. Tooth contacts in the retruded position occur only during swallowing and cleansing.
3. The frequency, duration, and distribution of these tooth contacts during mastication made up an individual pattern for each of the subjects of the study.
REFERENCES


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