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POSITIONS AND MOVEMENTS OF MANDIBLE AND HYOID BONE DURING SWALLOWING

A CINERADIOGRAPHIC STUDY OF SWALLOWING WITH AND WITHOUT ANAESTHESIA OF THE TEMPOROMANDIBULAR JOINTS

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The positions and movements of the mandible and the hyoid bone during swallowing with and without anaesthesia of the temporomandibular joint capsules were studied cineradiographically in 11 female subjects aged 19—31 years. Swallowing with contact between the teeth was found to be more common than swallowing without contact. The contact was established most often in the intercuspal position but contact occurred also anteriorly and posteriorly to the intercuspal position and in the retruded position of the mandible. No difference was found in the occurrence or localisation of the contact between the teeth on comparison between swallowing before and during the anaesthesia.

The pattern of movements of the hyoid bone were found to be regular in some persons with an even circular or elliptic path of movement during the act of swallowing, while in others the path was more irregular, sometimes with crossing pathways. The pattern of movement did not vary with the medium swallowed (saliva, watery barium and viscous barium). The pattern of movement was independent of the presence and localisation of contact between the teeth during swallowing and was not affected by temporomandibular joint anaesthesia.

During the act of swallowing the mandible is often stabilized by contact between the upper and lower teeth (*Rushmer & Hendron*, 1951). Contact between the upper and lower teeth has been regarded by some authors (*Rix*, 1946; *Gwynne-Evans*, 1954) as one of the criteria for normal swallowing, but normal swallowing without such contact has also been reported (*Cleall*, 1965; *Hedges, McLean & Thompson*, 1965; *Møller*, 1966). The position of the mandible during tooth contact in the act of swallowing is still a controversial question. Several authors claim that the contact occurs when the mandible is in its most retruded position (*Jankelson, Hoffman & Hendron*,

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1953; *Kydd & Sander*, 1961; *Ramfjord*, 1961 a, 1961 b; *Graf & Zander*, 1963), while others claim that the contact takes place with the mandible in intercuspal position (*Posselt*, 1958; *Hickey et al.*, 1963; *Møller*, 1966). In recent telemetric studies contact between the teeth during the act of swallowing has been reported to occur only sporadically in retruded position, while contact occurs most often with the mandible in intercuspal position (*Pameijer et al.*, 1970 a, 1970 b). Also gliding contact, from retruded position to intercuspal position, or in the opposite direction, from intercuspal position to retruded position, or from a protruded position of the mandible to intercuspal position, has been reported (*Schärer & Stallard*, 1965; *Pameijer et al.*, 1970 a, 1970 b).

In a previous investigation (*Ingervall, Carlsson & Helkimo*, 1970) it was shown how the hyoid bone varies in position with the position of the mandible. The hyoid bone was found to occupy a lower and more posterior position when the mandible was in retruded contact position than when it was in intercuspal position. Swallowing with contact between the teeth with the mandible in retruded or in intercuspal position may therefore possibly be reflected in differences in the pattern of movement of the hyoid bone during swallowing with the two types of contact between the teeth.

The receptors in the temporomandibular joints have proved to be of importance for the subject's perception of the position of the mandible. Experiments in man have thus revealed that the perception of the position of the mandible is clearly impaired during anaesthesia of the temporomandibular joint capsules (*Thilander*, 1961). Application of external pressure against the temporomandibular joints activates the receptors and thereby counteracts the impairment of perception caused by anaesthesia or distracting stimuli (*Larsson & Thilander*, 1964). The receptors of the temporomandibular joint capsules have also been shown to be of importance for limiting maximal opening of the mouth, which increased during anaesthesia of the capsules (*Posselt & Thilander*, 1965). In animal experiments impulses from the receptors of the temporomandibular joints to the central nervous system have been demonstrated on movement on the mandible (*Kawamura & Majima*, 1964; *Kawamura, Majima & Kato*, 1967; *Klineberg, Greenfield & Wyke*, 1970 a). The receptors of the temporomandibular joints have therefore been thought to play an important role in the control of muscle activity in movements of the mandible (*Klineberg, Greenfield & Wyke*, 1970 b). On electromyographic recording of the muscle activity during chewing in two subjects and simultaneous telemetric recording of tooth contact during chewing, however, anaesthesia of the temporomandibular joint capsules and teeth and parodontium were found not to affect mandibular

movements or muscle activity or contact between the teeth during chewing (*Schaerer, Legault & Zander*, 1966). The experiments by Schaerer and coworkers may suggest that chewing movements are controlled by the proprioceptors of the muscles while, for example, the receptors in the temporomandibular joints in man are of less importance during chewing. But it has not been clarified whether the receptors of the temporomandibular joints play any role in the movements of the mandible and hyoid bone or their positions during the act of swallowing.

The purpose of the present investigation was cineradiographically to record the act of swallowing in order to clarify whetеher contact between the teeth occurs with the mandible in intercuspal or retruded position and to study movements of the hyoid bone during swallowing. By comparing swallowing before and during anaesthesia of the temporomandibular joint capsules the investigation also aimed at ascertaining whether blockade of the receptors of the temporomandibular joints affects the positions of the mandible and the hyoid bone and their movements during the act of swallowing.

MATERIAL AND METHODS

The material consisted of 11 female dental students, aged 19 to 31 years (mean 23 years). The subjects were not selected according to any particular type of occlusion. Their number of teeth varied between 27 and 31. The antero-posterior distance between intercuspal position and retruded contact position was measured in profile radiographs according to a method described previously (*Ingervall*, 1964), and the results are given in Table I.

The functional state of the masticatory system was evaluated by examination of occlusion and articulation, recording of the range of movement of the mandible and the pattern of movements as well as from palpation of the temporomandibular joints and muscles according to stomatognathic physiological routine examination methods (*Carlsson et al.*, 1970). None of the subjects had symptoms of functional disturbances of the masticatory system.

Cineradiographic recording. The cineradiographic recording was performed in a roentgen-stand type Diagnost 60 (Philips) with a 9 inch image intensifyer and TV-chain. A 35 mm Arriflex camera was used. The examination was performed with cinepulse technique. Exposures were made at 120 kV with automatic mA correction. Film speed was 25 pictures/sec.

Profile films were taken with the median plane of the head parallel to the plane of the film and with the central ray running through the lower first molar. The head was placed in position with Campers plane horizontal and

fixed with a neck- and nose support, which prevented movements of the head, without causing any discomfort to the subject being examined, and thus not preventing natural swallowing. In order to obtain definite reference points for analysis of the radiographs lead pellets 3 mm in diameter were fixed with Kerr impression compound in the interproximal space between the central incisors in the upper and lower jaws.

In ten of the subjects two series of recordings were made, one before and one during bilateral anaesthesia of the temporomandibular joint capsules. In one subject recordings were made only without such anaesthesia. Each series comprised the following recordings:

1. Positions of the mandible and hyoid bone in
   a) retruded contact position
   b) intercuspal position
   c) postural position
2. Swallowing of water
3. Swallowing of watery barium
4. Swallowing of viscous barium

On radiographic recording of the retruded contact position the mandible was stabilized with a wax index (Alminax, Associated Dental Products, Ltd., London). The recording of the retruded position was made after the mandible had been retruded passively (without intentional co-operation by the subject) by the method described previously (*Ingervall*, 1964). On roentgen recording of the intercuspal position the subject was instructed to bite his teeth in this position and on registration of the postural position the subject was instructed to relax the masticatory muscles after which the exposure was made.

In the swallowings of water, watery barium and viscous barium the subject was given 5 ml of each medium and roentgenography was started when the subject was ready to swallow and was continued until the end of the swallowing. The watery barium consisted of a suspension of barium in water and was thin while the viscous barium (Mixobar Oesophagus®, Astra-Meditec) was of creamy, sticky consistence and adhered to the mucous membrane.

After recording of steps 1—4 the temporomandibular joint capsules were anaesthetised bilaterally. The anaesthetic used was 1 % Xylocain, about 0.4 ml of which was deposited laterally in the joint capsules according to the method described by *Thilander* (1961). The anaesthesia was checked by measuring the perception of the mandible *a.m. Thilander* (1961) before and during anaesthesia. The cineradiographic recordings (steps 1—4) were repeated during the local anaesthesia of the joints.

Analysis of roentgenograms. The cinefilms were analysed frame by frame in an ordinary film projector. For each series of recordings a tracing was made of the hard and soft tissue structures of the upper face and of the lead pellet in the upper jaw.

On this master tracing the position of the lead pellet in the lower jaw was marked as well as the position of the body of the hyoid bone when the mandible was in retruded contact position, in intercuspal position and in postural position. On comparison between different roentgenograms superimposition of the pictures was made with the aid of the lead pellet in the upper jaw and other distinct structures of the upper face in the median plane, particularly the hard palate. The tracing with the three marked positions of the mandible was used as a pattern for analysis of the positions of the lead pellet in the lower jaw, of the soft tissues, of the bolus and of the positions of the hyoid bone during different phases of the act of swallowing and these positions were registered on the tracing.

RESULTS

Tooth contact during swallowing

The act of swallowing was recorded in 63 sequences. In 52 of these sequences the mandible was not in contact position at the beginning of the swallowing. In most of these cases the mandible was moved, during swallowing, from its original position without contact to a position with contact between the upper and lower teeth. The occurrence of contact between the teeth during swallowing is given in Table I. It is clear from the table that tooth contact occurred on 49 of the 63 sequences of swallowing recorded (78 %). Swallowing without contact between the teeth occurred on 7 occasions before anaesthesia and on 7 during anaesthesia. Of the 49 acts of swallowing with contact between the teeth such contact occurred in 30 cases with the mandible in the intercuspal position and in 4 in the retruded position. Contact anteriorly to the intercuspal position occurred in 6 cases and between intercuspal position and retruded position in 5. Gliding from the retruded position to intercuspal position occurred in 3 cases and in 1 case from retruded position to intercuspal position and back to retruded position. Thus, in all together 13 (27 %) cases contact occurred posteriorly to the intercuspal position.

There was possibly a tendency to contact in a more posterior position of the mandible during swallowing of viscous barium than during swallowing of water or watery barium. Contact anteriorly to the intercuspal position

Table I.

Contact between teeth during swallowing of water, watery barium and viscous barium before and during anaesthesia of the temporomandibular joint capsules

Subject	Distance between intercuspal position and retruded contact position	Before anaesthesia			During anaesthesia		
		Water	Watery barium	Viscous barium	Water	Watery barium	Viscous barium
1	1.2	NC	NC	IP	NC	NC	RP
2	1.3	IP	IP	IP	NC	IP	NC
3	0.7	ANT	ANT	IP	RP-IP	IP	RP-IP
4	0.9	ANT	NC	RP	NC	NC	RP-IP-RP
5	1.0	ANT	POST	IP	ANT	POST	IP
6	1.6	POST	IP	IP	IP	IP	IP
7	1.1	RP-IP	POST	RP	IP	IP	POST
8	1.1	NC	IP	IP	NC	IP	IP
9	1.1	NC	ANT	IP	RP	IP	IP
10	0.4	IP	IP	NC	IP	IP	IP
11	1.2	IP	IP	NC			

Abbreviations:
NC no contact
IP contact in intercuspal position
ANT contact anteriorly to intercuspal position
POST contact between intercuspal position and retruded position
RP contact in retruded position
— gliding contact from one position to another

Table II.

Position of bolus on establishment and cessation of contact between teeth in intercuspal position or retruded position during swallowing of viscous barium

Position of bolus	Before anaesthesia		During anaesthesia		Total	
	Contact between teeth established	ceased	Contact between teeth established	ceased	Contact between teeth established	ceased
Anterior part of oral cavity	2*		2		4	
Posterior part of oral cavity	3		2		5	
Between oral cavity and pharynx	2		1		3	
Upper part of oropharynx	1	3			1	3
Lower part of oropharynx	1	3	1	2	2	5
Hypopharynx		3		1		4
	9	9	6	3	15	12

* = Number of sequences

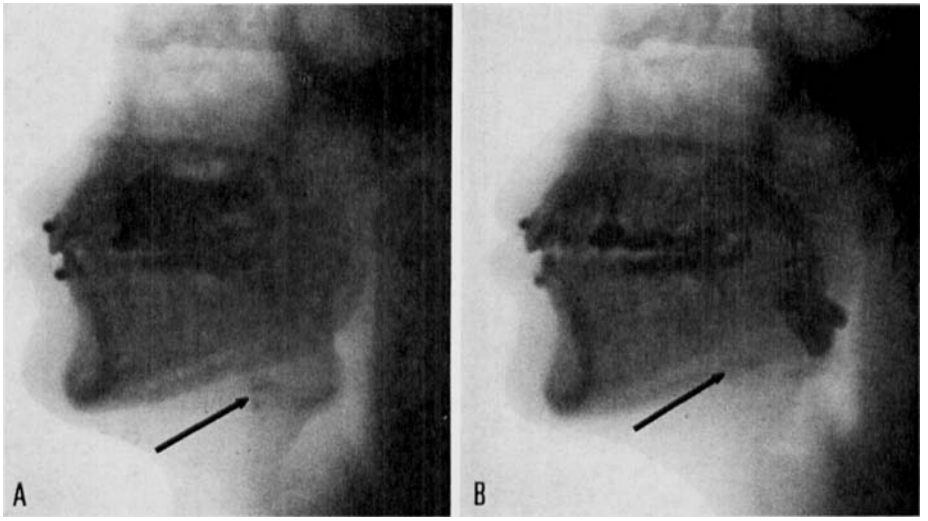
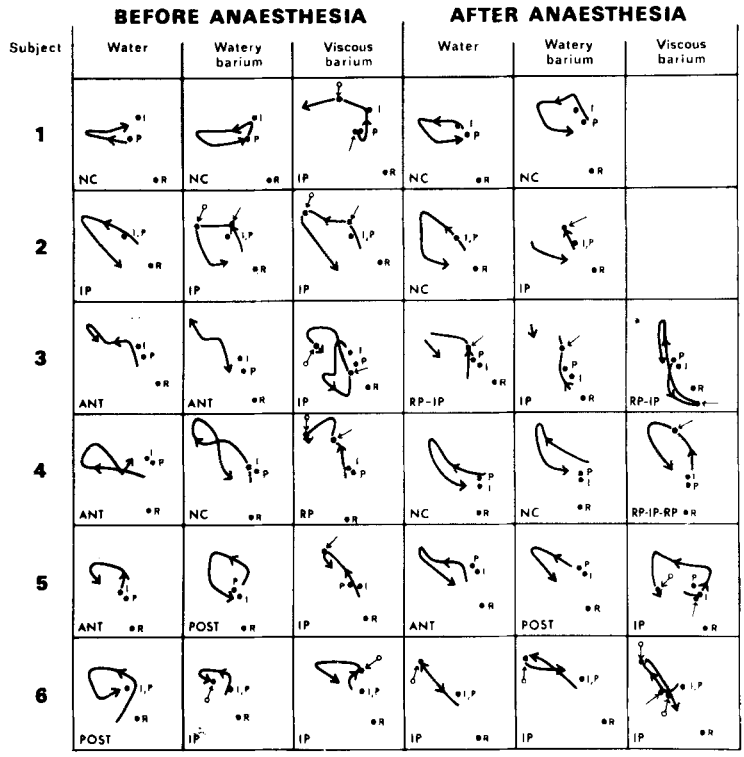


Fig. 1. Cineradiographic reproductions of a subject. A. Bolus (viscous barium) position at moment of establishment of contact between the teeth and B on cessation of contact. Observe the movement of the hyoid bone between A and B.

thus never occurred during swallowing of the viscous barium. There appeared to be no difference in the occurrence or localisation of the contact between the teeth on comparison between swallowing with and without temporomandibular joint anaesthesia.

During swallowing of viscous barium it was possible in most cases to judge the position of the bolus at the moment of establishment and of cessation of contact between the teeth in intercuspal or retruded position. The analysis did not include cases with contact only anteriorly to intercuspal position or between intercuspal position and retruded position because in such cases the exact time of first contact was difficult to define. The position of the bolus was judged from its central parts. The position of the bolus at the time of beginning and of cessation of contact between the teeth is given in Table II and Fig. 1. It is clear from the table that there was a relatively wide variation in the position of the bolus at the time of establishment of contact between the teeth, while the variation in the position of the bolus at the time of cessation of contact was less pronounced. There appeared to be no difference in the position of the bolus at the time of contact between the teeth on comparison between swallowing before and during temporomandibular joint anaesthesia.



Figs. 2 and 3. Movement of the most antero-superior

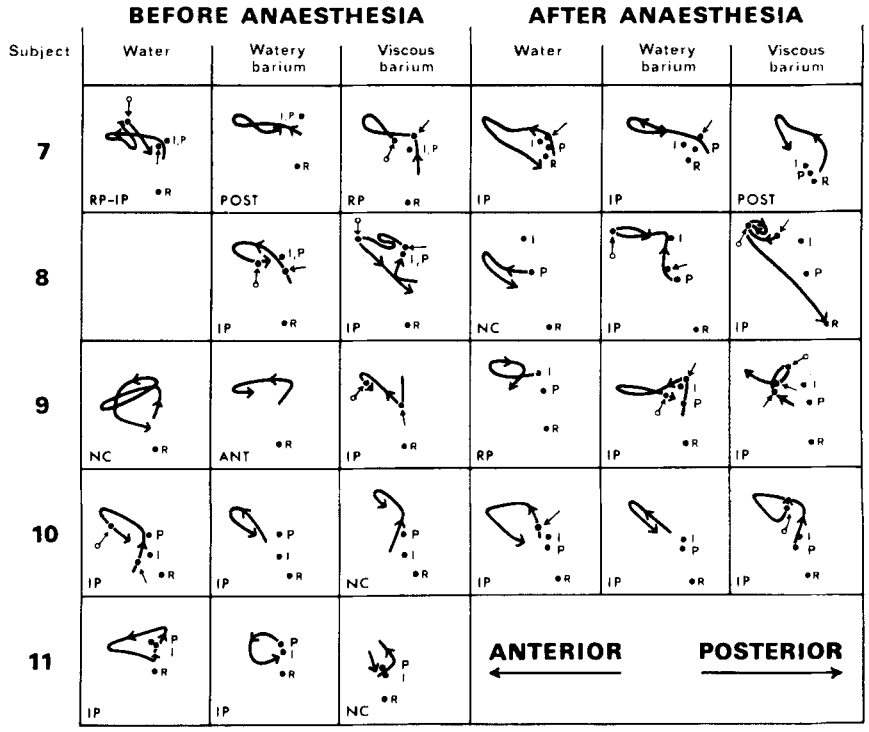
Symbols:

I	position of hyoid bone with mandible in intercuspal position
P	position of hyoid bone with mandible in postural position
R	position of hyoid bone with mandible in retruded position
→	tooth contact established in intercuspal or retruded position
o→	tooth contact in intercuspal or retruded position ceased

Pattern of movement of hyoid bone during swallowing

The movement of the most antero-superior part of the body of the hyoid bone during swallowing is given in Figs. 2 and 3. The x-axis in the figures is parallel to the contour of the floor of the nose in the roentgenograms. As is apparent from the figures the pattern of movement of the hyoid bone in certain subjects (Nos. 2, 5, 6, 10, 11) was regular with an even circular movement during swallowing, while in other subjects the pattern of movement was more irregular, sometimes with crossing paths of movement.

The pattern of movement of the hyoid bone and the extent of its movements appeared not to be affected by temporomandibular joint anaesthesia.



point of the body of the hyoid bone during swallowing.

Type of tooth contact:

NC no contact
IP intercuspal position
ANT anterior of intercuspal position
POST between intercuspal and retruded position
RP retruded position

When the pattern of movement was regular before anaesthesia it usually remained so during anaesthesia and in those cases where the pattern was irregular before anaesthesia it was most often irregular also during anaesthesia.

The pattern and extent of movement of the hyoid bone appeared to be independent of the type of contact between the teeth. During swallowing with contact in retruded position or between intercuspal position and retruded position the pattern of movement of the hyoid bone did not differ from that during swallowing without contact or with other types of contact. Only exceptionally (subjects 3, 7 and 8, swallowing of viscous barium during

Table III.

Position of bolus during most rapid movement of the hyoid bone in supero-anterior direction and with the hyoid bone in its most supero-anterior position

Position of bolus	On most rapid movement of hyoid bone				When hyoid bone was in most supero-anterior position			
	Before anaesthesia		During anaesthesia		Before anaesthesia		During anaesthesia	
	*	**	*	**	*	**	*	**
Posterior part of oral cavity	1			1				
Between oral cavity and pharynx	5	6	5	1	1			1
Upper part of oropharynx	4	5	3	6		1		
Lower part of oropharynx	1				5	5	4	5
Hypopharynx					5	4	4	2

* swallowing of watery barium
** swallowing of viscous barium

anaesthesia) did the hyoid bone approach the position it occupied when the mandible was in retruded position. In most cases contact between the teeth was not established until the hyoid bone had begun to move. The hyoid bone was often in a more superior position when contact between the teeth ceased than when it was established.

The positions of the central part of the bolus during the most rapid movement of the hyoid bone in supero-anterior direction and when the hyoid bone was in its most supero-anterior position are given in Table III. The time in the course of the act of swallowing of the most rapid movement of the hyoid bone like the most supero-anterior position of the hyoid bone appear to be the same whether the subject was swallowing watery barium or viscous barium and do not seem to be affected by temporomandibular joint anaesthesia.

DISCUSSION

In the present study the tooth contact and the movements of the hyoid bone during swallowing have been reported. The findings of the registrations of the postural position will be presented in a separate paper.

The investigation confirmed the findings by earlier investigators (*Cleall*, 1965; *Møller*, 1966) that the act of swallowing may be performed with and without contact between the teeth. In the present material swallowing with contact between the teeth was most common.

Contact was thus found during 78 % of the swallowing sequences studied, which was higher than the frequency found by Cleall, *i.e.* in 60 % of subjects with normal occlusion. Cleall's frequency however, refers to swallowing of saliva. In the present investigation there was contact between the teeth in 67 % of the recordings of swallowing of water which agrees well with Cleall's results and with the observation of Møller (1966) that 65 % of the subjects studied made tooth contact during swallowing of water and apple. Contact between the teeth in all six acts of swallowing recorded was, however, observed only in four subjects, which shows that both inter- and intraindividual variations occur.

In the vast majority of cases the contact between the teeth occurred with the mandible in intercuspal position, a finding in agreement with recent studies of such contact during swallowing with (*Pameijer et al.*, 1970 a, 1970 b) and without (*Møller*, 1966) telemetric recording. The findings reported by certain authors (*Jankelson, Hoffman & Hendron*, 1953; *Kydd & Sander*, 1961; *Graf & Zander*, 1963) that swallowing contacts often occur in retruded position or in the occlusal area between intercuspal position and retruded position could not be verified in the present investigation because the contacts posteriorly to the intercuspal position constituted only 27 % of the total number of contacts between the teeth. On the other hand, the results showed that the swallowing contact sometimes occurs posteriorly to the intercuspal position and 7 of the 11 subjects had at least one such contact during the experiments. Cuspal interferences in this occlusal area might perhaps give rise to disturbances in the functional pattern of the masticatory muscles during swallowing as reported by *Ramfjord* (1961 a, 1961 b) in his series of electromyographic examinations of patients with dysfunction of the temporomandibular joints and masticatory muscles. It is noteworthy that contact between the teeth on deviation from the intercuspal position often occurs anteriorly to the intercuspal position, as pointed out also by *Pameijer, Clickman & Roeber* (1969).

The time of first contact between the teeth during the act of swallowing appears to vary. In some cases it occurs relatively late when the bolus passes between the oral cavity and the pharynx or when the bolus is already in the pharynx. Also the supero-anterior movement of the hyoid bone during swallowing has usually started before contact between the teeth occurs.

The contact between the teeth during swallowing must probably be regarded as stabilizing the mandible on the marked supero-anterior movement of the hyoid bone and the larynx during the later part of the act of swallowing. The observation that contact between the teeth does not occur in the earliest phase of the swallowing but somewhat later in the act is in agree-

ment with observations reported by *Rushmer & Hendron* (1951), *Ardran & Kemp* (1955), *Cleall* (1965) and *Hedges, McLean & Thompson* (1965).

The findings of the recordings of the path of movement of the hyoid bone are in agreement with the results of *Ardran & Kemp* (1955), *Ramsey et al.* (1955) and *Shelton, Bosma & Sheets* (1960). Thus, the hyoid bone undergoes marked supero-anterior movement during the later part of the act of swallowing and reaches its most supero-anterior position when the bolus is in the lower part of the oropharynx or in the hypopharynx (cf. *Ardran & Kemp*, 1955; *Christrup*, 1964).

The supero-anterior movement and the return of the hyoid bone to its original position sometimes describes an even circular or elliptic path while in other cases the pattern of the movement is irregular with crossing paths of movement. That the pattern of movement is regular in some individuals and irregular in others has also been pointed out by *Sloan et al.* (1967), but the opinion of these authors that an irregular pattern of movement is associated with swallowing without contact between the teeth could not be verified.

As in a previous investigation (*Ingervall, Carlsson & Helkimo*, 1970) the hyoid bone was found to occupy a distinctly more infero-posterior position when the mandible was in retruded contact position than when it was in intercuspal position. During swallowing, however, the movements of the hyoid bone are such that it rarely ever approaches the position it has when the mandible is in retruded position. This was also the case when there was contact between the teeth in retruded position or posteriorly to the intercuspal position. The pattern of movement of the hyoid bone appears to be the same in the presence as in the absence of contact between the teeth and appears to be independent of the position of the mandible during contact.

Recording of the movement of the hyoid bone therefore gives no information on contact between the teeth during swallowing.

Neither did the pattern of movement of the hyoid bone vary with the medium swallowed (saliva, watery barium or viscous barium) so that the observations by *Hanson et al.* (1970) could not be verified. According to *Ramsey et al.* (1955), the path of movement is diagonal during swallowing of a large bolus and circular during swallowing of a small bolus. In the present investigation the bolus was always of the same size so that it was not possible to test the variation of the path of movement with the size of the bolus.

Blockade of the receptors of the temporomandibular joints by local anaesthesia did not affect the occurrence or localisation of contact between the teeth during swallowing or the extent and pattern of movement of the hyoid bone.

The receptors of the temporomandibular joints therefore appear to have

no effect on contact between the teeth or movements of the hyoid bone during the act of swallowing. *Schaerer, Legault & Zander* (1966) also found no influence on the mandibular movements, muscular activity or contact between the teeth during chewing on comparison between recordings made with and without temporomandibular joint anaesthesia.

As shown by *Thilander* (1961), on the other hand, the receptors of the temporomandibular joints are important for perception of the position of the mandible and for limiting maximal opening of the mouth (*Posselt & Thilander*, 1965).

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