The effect of muscle function in discriminating thickness differences interocclusally and the duration of the perceptive memory

PENTTI LAINE & HANNU S. SIIRILÄ

Department of Prosthetics, Institute of Dentistry, University of Helsinki, Finland.

Laine, P. & Siirilä, H.S. The effect of muscle function in discriminating thickness differences interocclusally and the duration of the perceptive memory. *Acta Odont. Scand.* 35, 147–153

The thresholds in discriminating the thickness differences interocclusally were measured with three different mouth openings on subjects having natural dentitions. Also the duration of the perceptive memory was studied.

The results showed that the functional activation or fatiguing of masticatory muscles and the degree of mouth opening affect size discrimination interocclusally. The ability to perceive thickness differences between the incisors was more accurate after 1 hour's chewing than normally. The trend was significant with 0.5 mm and 10 mm mouth openings ($2P < 0.01$) and highly significant with an 20 mm mouth opening ($2P < 0.001$). With a 20 mm mouth opening ($2P < 0.01$) and 10 mm mouth opening ($2P < 0.05$) size discrimination was less accurate after two hours' fatiguing chewing than after one hour's conventional chewing.

After 30 seconds' forceful isometric contraction and with a 20 mm mouth opening discrimination was more accurate than normally ($2P < 0.01$). The trend was the same with a 10 mm mouth opening, but no difference could be observed when the mouth opening was 0.5 mm.

The memory tests showed that with a 0.5 mm mouth opening thickness differences of 0.3–0.5 mm were most commonly correctly perceived twenty-four hours later, but when the mouth openings were 10 and 20 mm an interval of only 1 min between the reference and test piece trial impaired the performance.

Key-words: Physiology; sensation; size perception; kinesthesis

Pentti Laine, Fabianinkatu 24, SF-00100 Helsinki 10, Finland

Received for publication, October 1, 1976

Sensory impulses from the nerve endings of the periodontium are supposed to be essential for accurate size discrimination between occluding teeth (*Siirilä & Laine*, 1963, 1969, 1972; *Riis & Giddon*, 1970; *Öwall*, 1974). As the degree of mouth opening is increased, the importance of periodontal receptors diminishes and size discrimination is assumed to depend mainly on the proprioceptive sensations from the temporomandibular joints and possibly from the masticatory muscles (*Manly et al.*, 1962; *Kawamura & Watanabe*, 1960). The awareness of the spatial location of the mandible is suggested to depend critically on the afferent input to the brain from the mechanoreceptors in the capsules of the temporomandibular joints (*Thilander*, 1961; *Ransjö & Thilander*, 1963; *Storey*, 1968; *Wyke*, 1974). *Thilander* (1961) demonstrated impairment of the perception of mandibular position resulting from anaesthesia of the joint capsule and the temporomandibular ligament.

The experiments made by the present authors (*Siirilä & Laine*, 1972) showed that anaesthetizing the joints did not diminish the size discrimination ability. It was assumed, on the basis of the results, that mainly the receptors in the muscles were responsible for the discrimination of size differences. *Christensen & Troest* (1975) suggest that the muscle spindles in the lateral pterygoid muscle as well as the mechanoreceptors in the joint capsule are active in percepting and/or controlling mandibular postures.

Discrimination of thickness-differences interocclusally is demonstrated to be most accurate near the contact position. The mean threshold value increases from 0.02 mm to 2.79 mm in almost linear proportion to the degree of mouth opening (*Siirilä & Laine*, 1972). Differing results have been reported by *Ringel, Saxman & Brooks* (1967) as well as by *Williams, Lapointe & Thornby* (1974). They stated that the degree of mouth opening had no significant effect on the performance. The mouth openings varied from 9.9 mm to 28.8 mm in the former investigation and from 10 mm to 20 mm in the latter, while the corresponding values in the investigation made by the present authors (*Siirilä & Laine*, 1972) ranged from micro-discrimination level 0.03 mm to maximal opening minus 10 mm.

The ability to remember a reference size is necessary in size-discrimination tests. Some preliminary trials made in the previous investigation (*Siirilä & Laine*, 1972) indicated that time factor was not critical when the interval was under 30 sec.

We have not succeeded in finding reports dealing with the possible effect of the time factor in connection with perceptional memory. According to *Grant, Stern & Everett* (1972) the proprioceptive «periodontal» memory is a fleeting memory that may be recaptured or reestablished repeatedly.

The aim of the present study was to obtain more information on the role of muscle function, conventional chewing prolonged fatiguing chewing and isometric contraction in discriminating thickness differences interocclusally and the duration of the perceptive memory.

MATERIAL AND METHODS

The muscle activating test (= MA-test) involved 16 subjects (8 males and 8 females), the prolonged muscle fatiguing test (= MF-test) 8 (4 + 4), the isometric muscle fatiguing test (= MI-test) 10 (6 + 4), the first memory test 6 (4 + 2) and the second 15 (5 + 10). All the subjects had natural dentitions without any disorders in the masticatory system. They were mainly dental students and nurses (aged 20–28 years) with the exception of one dentist (41) and two men (15 and 62 years).

In discriminating thickness differences the thresholds were measured for every subject in three different mouth openings, the reference thicknesses between the incisors being 0.5 mm, 10 mm and 20 mm. Thicknesses under 1 mm were evaluated with the blades of an ordinary [illegible]nical gap measuring device (for spark plugs). The unit of change was 0.1 mm. For the two larger mouth openings the

measuring device used was a modified precision sliding caliper. The steel tips of the sliding caliper were ground to make the outer surfaces parallel and rounded the total thickness being 5 mm when the tips were closed. The unit of change between the different series was 0.5 mm and the distance of the tips could be set with an accuracy of 0.1 mm.

The tests were performed in a quiet room, the subject sitting comfortably upright in a dental chair with a headrest. The measuring device was parallel to the occlusal plane and always between the same incisors. The changes in thickness were made without the test person seeing it.

The thresholds were measured in pairs of comparison in series. The same reference thickness was tried by the subject before each trial of a new thickness. The new size was ready for trial 5–15 s after the reference size. The subject was allowed to evaluate the body for approximately 5 s and tap his teeth lightly against it if he wished so. The tongue or the lips were not allowed to touch the test piece. After the trial, the subject was asked whether the last test piece was thicker, thinner or the same size as the reference piece. Initially the differences between the thicknesses were greater an order to familiarize the subject with the test. Then they were gradually decreased until he began to make mistakes.

Base values for thresholds

The test series were made in sequences of 15 trials at random, 5 times thicker, 5 times thinner and 5 times the reference size. Perception of change was considered certain if at least 12 trials out of 15 were correct. Otherwise the changes from the reference size were increased until the criterion was met.

Effect of conventional chewing

The same measuring procedure was repeated in the next session. The subject had to chew chewing gum for one hour before the test (MA-test), but total chewing time did not exceed two hours. If the series were not completed within this time, the experiment was continued another time.

Effect of prolonged fatiguing chewing

In the MF-test the subject had been chewing a piece of a tough film (Parafilm «M» R American Can Company) for two hours before measuring the thresholds. This film was considerably more tough to chew and caused muscular strain easier than chewing gum. The subjects were instructed to chew continuously until they had a distinct feeling of tiredness or tenderness in the masticatory muscles when the test was to begin. In all these tests chewing had to be continued all through the test, between each trial.

Effect of isometric muscle fatiguing

In the MI-test the subject first tried the reference thickness, compressed his teeth together as strong as he could for 30 s, whereafter the test piece was immediately placed between the teeth.

The first memory test

In the base threshold value tests the time interval between reference and test thicknesses was 5–15 s. In the first memory test the corresponding time interval was changed to 60 s. The base threshold value series were then repeated with the above mentioned modification.

The second memory test

In the second memory test twenty-four hours was let to elapse between the reference and test piece trials. This test was performed with reference thickness of 0.5 mm. The thicknesses of the test pieces were 0.2 mm and 1 mm. These thicknesses were chosen, because they represented the greatest border values of thickness discrimination thresholds observed in all previous tests with this mouth opening.

The subjects of the second memory test took part only in this test with no previous experience in discriminating thickness differences between the teeth.

Table I. *The normal and muscle activation test (MA-test) range and mean threshold values (mm) of 16 experiment persons, discriminating thickness differences between the teeth*

Reference (mm)	To thinner direction from the reference thickness				To thicker direction from the reference thickness			
	normal		MA-test		normal		MA-test	
	range	mean	range	mean	range	mean	range	mean
0.5	0.2–0.3	0.26	0.2–0.3	0.23	0.2–0.4	0.30	0.2–0.4	0.27
10	1 –2.5	1.60	1 –1.5	1.22	1 –2.5	1.60	1 –1.5	1.22
20	2 –3.5	2.53	1.5–3	1.87	2 –3	2.50	1 –2.5	1.75

According to sign test the discrimination of thickness differences was significantly more accurate in MA-test than normally, except with 0.5 mm reference size to thinner direction.

The sign test was considered to be adequate statistical method in the evaluation of the results. The P-values were counted on the basis of paired comparisons of the sign test.

RESULTS

The results of the MA-test are presented in Table I. The ability to perceive thickness differences between the incisors was more accurate after one hour's chewing than normally. This was significant with 0.5 mm and 10 mm mouth openings ($2\ P < 0.01$ and highly significant with a 20 mm mouth opening ($2\ P < 0.001$).

The normal, MA- and MF-test mean thresholds are shown in Table II. In all 8 cases discrimination was less accurate in the MF-test than in the MA-test with a 20 mm mouth opening ($2\ P < 0.01$) and in 7 cases with a 10 mm mouth opening ($2\ P < 0.05$). Four out of eight subjects had the same threshold in both tests and the other four had a greater threshold in the MF-test than in the MA-test with a 0.5 mm mouth opening.

The MI-test results are presented in Table III. With 20 mm mouth opening the thresholds were smaller after 30 s isometric contraction than normally ($2\ P < 0.01$). The trend was the same in seven cases out of ten with a 10 mm mouth opening. The 0.5 mm mouth opening showed no difference.

In the first memory test all 6 subjects perceived correctly their normal thresholds with a 0.5 mm mouth opening. With a 10 mm mouth opening 3 out of 6 subjects and with a 20 mm mouth opening 4 out of 6 perceived correctly their normal thresholds.

In the second memory test the selected test pieces (0.2, 0.5 and 1.0 mm) were correctly perceived by 12 subjects out of 15 when a time interval of twenty-four hours was allowed between the reference and test trials.

DISCUSSION

The tests in this study confirmed that the threshold values were dependent on the degree of mouth opening (*Siirilä & Laine*, 1972). The different results of *Ringel et al.* (1967) and *Williams et al.* (1974) may be due to methodological differences.

The discrepancy between the results of our previous studies and the commonly accepted view of the decisive significance of the temporomandibular joint receptors or the «joint sense» in positional and discriminatory sensory perceptions (*Kawamura & Watanabe*, 1960; *Thilander*, 1961; *Storey*,

Table II. *The normal and muscle activating (MA) and prolonged muscle fatiguing (MF) test mean threshold values (mm) of 8 experiment persons, who participated in all three tests. The range values are within parentheses under the mean threshold values*

Reference size (mm)	Normal mean threshold		MA-test mean threshold		MF-test mean threshold	
	to thinner direction	to thicker direction	to thinner direction	to thicker direction	to thinner direction	to thicker direction
0.5	0.28 (0.2–0.3)	0.34 (0.2–0.4)	0.23 (0.2–0.3)	0.28 (0.2–0.4)	0.29 (0.2–0.3)	0.34 (0.2–0.5)
10	1.63 (1.0–2.0)	1.63 (1.0–2.0)	1.25 (1.0–1.5)	1.25 (1.0–1.5)	2.00 (1.5–2.5)	2.00 (1.5–2.5)
20	2.50 (2.0–3.0)	2.50 (2.0–3.0)	1.88 (1.5–2.5)	1.88 (1.5–2.5)	2.94 (2.0–3.5)	2.94 (2.0–3.5)

According to sign test the discrimination of thickness differences was significantly less accurate in MF-test than in MA-test with 20 mm reference size. The difference was almost significant with 10 mm reference size.

Table III. *The normal and isometric muscle fatiguing (MI) test range and mean threshold values (mm) of 10 experiment persons*

Reference size (mm)	To thinner direction from the reference thickness				To thicker direction from the reference thickness			
	normal thresholds		MI-test thresholds		normal thresholds		MI-test thresholds	
	range	mean	range	mean	range	mean	range	mean
0.5	0.2–0.3	0.27	0.2–0.3	0.27	0.2–0.4	0.29	0.2–0.4	0.29
10	1 –2	1.55	1 –1.5	1.15	1 –2	1.55	1 –1.5	1.15
20	2 –3	2.55	1 –2.5	1.85	2 –3	2.55	1 –2.5	1.85

According to sign test the discrimination of thickness differences was significantly more accurate in MI-test with 20 mm reference size than normally.

1968; *Wyke*, 1974) gave an impetus to this study. It is also suggested that the receptors from the temporomandibular joint capsule may play an important role even on the micro-discrimination level in determining the tactile occlusal perception (Caffesse et al. 1973).

The results of the present study support the hypothesis that muscle receptors are mainly responsible for the discrimination of size differences between the teeth. The size-discrimination seems to be an area of «muscle sense» with the prerequisite of tooth contact. The situation may be different in percepting mandibular positions when the teeth are not occluding. In that case the positional perception is evidently based on the interplay of the receptors in muscles and joints, as seems to be the case with other parts of the body.

After one hour's chewing size-discrimination seems to be more accurate

than normally. The lower threshold values may be explained by the masticatory muscles being in an «activated state» during chewing, improving the acuity of discrimination. Several control test series showed that this improvement was not caused by learning. The normal thresholds were naturally measured first. Therefore, the following tests could be thought to give lower thresholds with the test experience growing. Before the chewing test was made, one hour's chewing was thought to have a tiring effect on the muscles, impairing the accuracy of perception. The time of chewing needed to develope the active state in muscles was not measured in this study. Some preliminary trials showed, however, that it is much less than one hour.

The fatique test was made in order to see if the feeling of tiredness in muscles had any effect on discrimination. The degree of tiredness after two hours' chewing of tough bolus was based on the subjective feeling and judgement of the subject and varied from subject to subject. Anyway, the results indicate that size-discrimination with «tired masticatory muscles» is less accurate than with «activated muscles». As compared with the normal mean thresholds, the MF-test mean thresholds were slightly higher with 10 and 20 mm mouth openings.

In the isometric muscle fatiguing test only one series was performed at a time, because the subjects experienced the compression time of 30 s rather unpleasant. Clenching of teeth has been observed to cause pain in the muscles on the average of about one minute after clenching had begun *(Christensen,* 1970).

The material of the first memory test, i.e. 6 subjects, was fairly small. It would also have been interesting to test with longer time intervals than 1 min, between the referance thickness and test piece. Taking into account the time consuming nature of this test it was considered, however, to be trend giving as such. Thus, it seems evident that the perceptive memory picture remains longer near the contract position than with greater mouth openings. The test pieces in the second memory test were correctly recognized by most of the experiment persons twenty-four hours later. Preliminary trials showed that some subjects recognized correctly the thickness differences even after an interval of 3 days.

The idea of bite raising procedures is based on the ability of the masticatory organ to adapt to changes. In the process of adaptation and coordination of muscle function the periodontal sensory information plays an important role. The proprioceptive periodontal memory picture of the earlier interocclusal relationships fades away little by little and a new picture is built up. *Carlsson & Ericsson* (1967) have observed that during the first 12 days after inserting new full dentures, which were higher than the old ones, the mean postural height increased, both with and without the dentures inserted. Within 12 days the former memory picture of the postural position had vanished and a new one accepted and maintained.

The present memory tests show that the perceptive memory picture, in discriminating thickness differences between natural teeth near the contact position, remains quite generally for twenty-four hours and, in some cases, it can be supposed to remain for several days.

REFERENCES

Caffesee, R.G., Carraro, J.J., & Albano, E.A. 1973. Influence of temporomandibular joint receptors on tactile occlusal perception. J. Periodont. Res. 8, 400–403

Carlsson, G.E. & Ericson,S. 1967. Postural face height in full dentures wearers. Acta Odont. Scand. 25, 145–162

Christensen, L.V. 1970. Facial pain from experimental tooth clenching. Tandlaegebladet 74, 175–182

Christensen, L.V. & Troest, T. 1975. Clinical kinesthetic experiments on the lateral pterygoid muscle and temporomandibular joint in man. Scand. J. Dent. Res. 83, 238–244

Grant, D.A., Stern, I.B. & Everett, F.G. 1972. *Orban's Periodontics.* 4th ed. The C.V. Mosby Company, St. Louis. p 595

Kawamura, Y. & Watanabe, M. 1960. Studies on oral sensory thresholds. I The discrimination

of small differences in thickness of steel wires in persons with natural and artifical dentitions. Med. J. Osaka Univ. 10, 291–301

Manly, R.S., Pfaffman, C., Lathrop, D. & Keyser, J. 1952. Oral sensory threshold of persons with natural and artificial dentitions. J. Dent. Res. 31, 305–312

Ransjö, K. & Thilander, B. 1963. Perception of mandibular position in cases of temporomandibular joint disorders. Odont. T. 71, 134–144

Riis, D. & Giddon, D.B. 1970. Interdental discrimination of small thickness differences. J. Prosth. Dent. 24, 324–334

Ringel, R.L., Saxman, J.H. & Brooks, A.R. 1967. Oral perception: mandibular kinesthesia. J. Speech Res. 10, 637–641

Siirilä, H.S. & Laine, P. 1963. The tactile sensibility of the parodontium to slight axial loadings of the teeth. Acta Odont. Scand. 21, 415–429

Siirilä, H.S. & Laine, P. 1969. Occlusal tactile threshold in denture wearers. Acta Odont. Scand. 27, 193–197

Siirilä, H.S. & Laine, P. 1972. Sensory thresholds in discriminating differences in thickness between the teeth, by different degrees of mouth opening. Suom. Hammaslääk. Toim. 68, 134–139

Storey, A.T. 1968. Sensory functions of the temporomandibular joint. J. Canad. Dent. Ass. 34, 294–300

Thilander, B. 1961. Innervation of the temporomandibular joint capsule in man. Trans. Roy. Schools Dent., Stockh. Umeå No 7.1.–76

Williams, W.N., Lapointe, L.L. & Thornby, J.I. 1974. Interdental thickness discrimination by normal subjects. J. Dent. Res. 53, 1404–1407

Wyke, B.D. 1974. Neuromuscular mechanisms influencing mandibular posture: a neurologist's review of current concepts. J. Dent. 2, 111–120

Öwall, B. 1974. Studies on oral perception during chewing. Odont. Revy 25: Suppl. 28