

Effect of chewing training on masticatory efficiency

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A special, hard chewing gum was used to study the effects of chewing training on masticatory efficiency. An experimental group of 17 individuals used this chewing gum 1 h daily for 28 days, while a control group of 8 individuals performed no chewing-gum training. The percentage of masticatory efficiency was measured with a special sieve system, and the time for 10 chewing cycles was taken from EMG recordings. These measurements were made in trained and untrained condition before and after 30 min of intense chewing. The results indicate that intense chewing for 30 min decreased the masticatory efficiency and increased the frequency of the chewing cycles significantly in both trained and untrained individuals, possibly due to fatigue of the masticatory muscles. However, chewing training for 28 days did not influence these factors significantly. □ *Clinical study; fatigue; mastication; masticatory muscles*

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Chewing is a process that is terminated by swallowing and which involves an interaction between an extrinsic input (solid food particles) and an intrinsic response (work and saliva production) to produce the output (smaller, wetter food particles). Several factors are involved in swallowing, including food particle size, amount of fluid in the mouth, taste, and even the deformability of food. The size of particles swallowed by subjects varies for each subject, and the distribution of particle size depends also on the rate of breakdown per chew (1). The physical properties of food are also of some consideration (2), as different foods break down differently. Furthermore, subjects with poor chewing ability tend to swallow larger particles than those with good ability (3). Masticatory efficiency is usually defined as the capacity to reduce food during mastication. As it differs from individual to individual and depends on all the factors mentioned, it is usually measured with a comminution test (4). Many factors have been shown to influence masticatory efficiency, most of them related to the state of the dentition (for example, number of teeth, quality and type of prosthetic

appliances, occlusal morphology) but also to the tongue and other oral soft tissues, chewing habits, and dysfunction of the masticatory system (5–7). Chewing training has been found to have numerous effects on conditions in the stomatognathic system, such as muscle morphology (8) and the postural position of the mandible (9). Chewing training has also been found to increase bite force (10), and it would therefore be assumed to be of importance also for masticatory efficiency. No study of these factors seems to have been published, however. It was therefore the aim of this paper to study any possible short- and long-term effects of chewing training on masticatory efficiency.

Materials and methods

The subjects of the study were 11 male and 14 female dental students aged 20–31 years, who all participated voluntarily after having received thorough information about the experiments. The participants were in good health, had a complete or almost complete natural dentition, and reported no symptoms of craniomandibular disorders. The subjects

were divided into an experimental group of 7 men and 10 women and a control group of 4 men and 4 women.

The experimental group was instructed to use a special chewing gum for systematic training 1 h a day, preferably after a meal, for a month. The chewing gum used was the resin obtained from the bark of the mastiche tree growing on the Greek island of Chios. It was selected because of its hardness in chewing. Two subjects from the experimental group did not complete the required training: one woman developed signs and symptoms of dysfunction in the stomatognathic system 3 days after the start of the chewing training, and one man was excluded owing to lack of cooperation. The subjects in the control group did not perform any chewing training but took part in registrations of the masticatory efficiency at the same intervals as the experimental group. Further details of the experimental design have been presented previously (9).

The masticatory efficiency of the subjects was measured with a method specially designed for this experiment, using almonds and a sieve system in combination with coffee filters, weighed to the nearest 0.001 g. Every almond was dried under the same conditions in an oven and also weighed accurately to the nearest 0.001 g. The weight of one almond was approximately 1 g. The room temperature was 24°C. The sieve had meshes of 0.7 mm and was made to fit exactly on the top of the filter holder (Fig. 1a). The subject was asked to chew an almond for 10 sec and spit it into the sieve (Fig. 1b). A glass of water was then given to the subject, to rinse the mouth and spit into the sieve again. Every subject had to repeat this twice. After the sieve had been rinsed under water, the small pieces remaining were those that could not pass through the sieve meshes (Fig. 1c). These were collected into the filter by turning the sieve upside-down into the filter holder, using running water to rinse the sieve (Fig. 1d). The filter was dried at room temperature (24°C) for 24 h and then weighed as before, to calculate the weight of the remaining pieces of the almond. The masticatory efficiency (ME) was calculated from the weight of the almond before (*A*) and the

weight of the pieces of the almond collected after the test (*B*), using the formula: $ME = (A - B)/A$. ME thus gives the percentage of the test food that was reduced during the chewing. The mean values of the repeated registrations were used in the analysis.

The time of 10 chewing cycles was calculated from electromyographic (EMG) recordings of the masseter muscle. Further details about the EMG method and results of the study of muscle activity will be presented in a future article.

Recordings were performed in accordance with the following schedule: I) 2 weeks before the start of the experiments (base-line registration); II) the day when the chewing training started, before (a) and after (b) 30 min of intense chewing; and III) after 4 weeks of daily chewing training, before (a) and after (b) 30 min of intense chewing. In the control group measurements were made at the same sessions but the subjects did not participate in any chewing with the Chios chewing gum.

Error of the methods

The error of the method for chewing efficiency was calculated after double recordings on 24 subjects in a 2-week interval in

accordance with the formula $SE = \sqrt{\frac{\sum d^2}{2n}}$,

presented by Dahlberg (11), where *d* denotes the difference between the first and second recording, and *n* is the number of subjects. The error of the method was 3.7%. There was no statistically significant difference between the first and second registration.

Statistical methods

For the statistical analysis the mean values of two repeated measurements on every occasion were used. Analysis, using a paired *t* test, was performed to determine differences between the recording sessions. Statistically significant differences were those with *p* < 0.05.

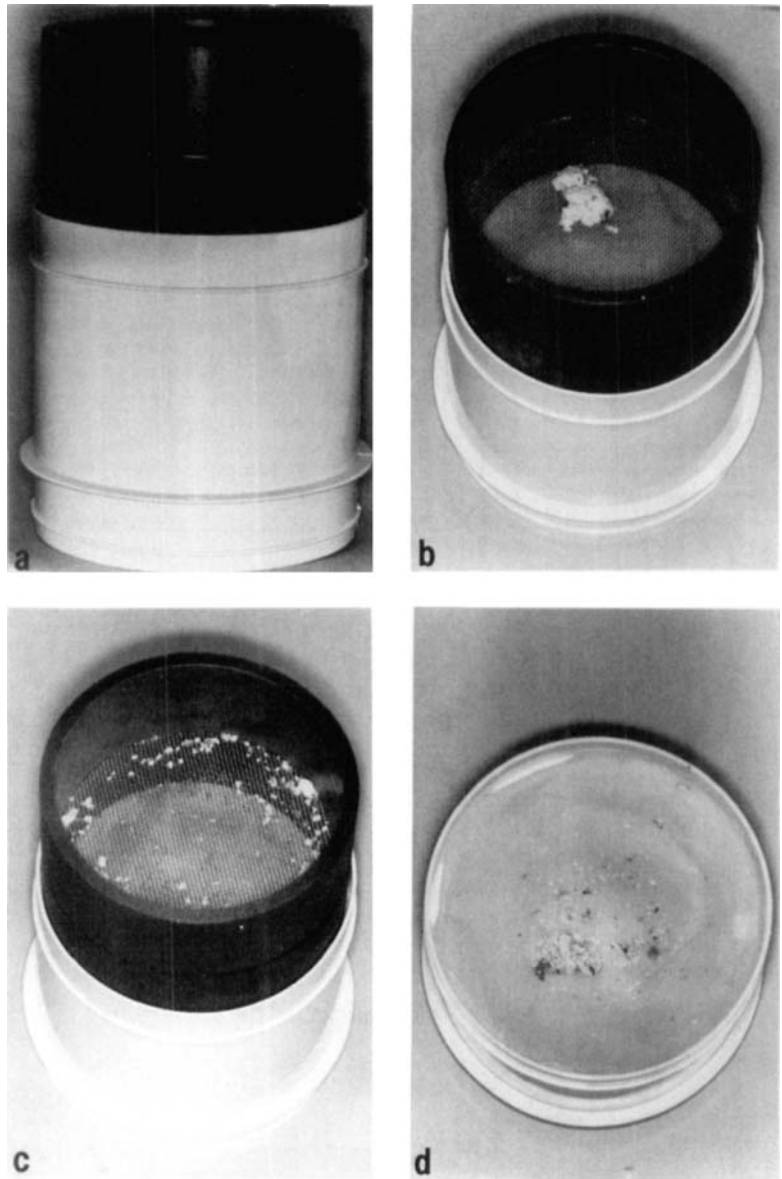


Fig. 1. Masticatory efficiency was measured by means of almonds and a sieve system in combination with coffee filters. The sieve used has meshes of 0.7 mm and was made to fit exactly on the top of the filter holder (1a). The subject was asked to chew an almond and spit it into the sieve (1b). After the sieve had been rinsed under water the small pieces remaining were those that could not pass through the sieve meshes (1c). These were collected into the filter by turning the sieve upside-down into the filter holder, using running water to rinse the sieve (1d).

Results

Experimental group

No change in masticatory efficiency was found between the first (base-line) registration and the second registration at the start of the training. After 30 min of chewing training there was a decrease of the masticatory efficiency ($p < 0.001$; Fig. 2). Dur-

ing the experimental period of 1 month of daily chewing training no significant change in the masticatory efficiency was found. The 30-min chewing at the end of the training period led to a decrease of the masticatory efficiency ($p < 0.001$). The electromyographically registered time for 10 chewing cycles is presented in Fig. 3. After 30 min of chewing this time decreased both before and

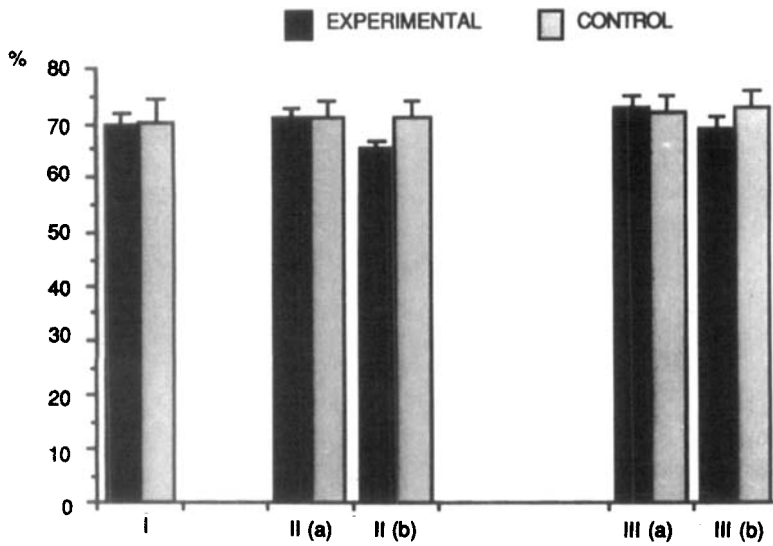


Fig. 2. Masticatory efficiency (mean \pm standard error of the mean (SEM)) for the 15 experimental and the 8 control subjects during the different recording sessions of the experiment: I) 2 weeks before the start of the experiments (base-line registration); II) the day when the chewing training started, before (a) and after (b) 30 min of intense chewing; and III) after 4 weeks of daily chewing training, before (a) and after (b) 30 min of intense chewing training. The controls did not perform any training.

after the training period of 1 month (before, $p < 0.001$; after, $p < 0.01$). A comparison of the chewing time before and after the training period did not show any statistically significant change.

Control group

In the control group no significant changes of masticatory efficiency or the time for 10 chewing cycles occurred during the observation period.

Discussion

The method developed for measuring masticatory efficiency gives a percentage value, theoretically varying between 0 and 100. This should be an advantage in comparison with indices using few scores when trying to distinguish among individuals. The participants of our study had a mean ME of 70%, with individual values ranging from 54% to 84%. Helkimo et al. (12), using a 5-grade index for chewing efficiency, found that 19 of 20

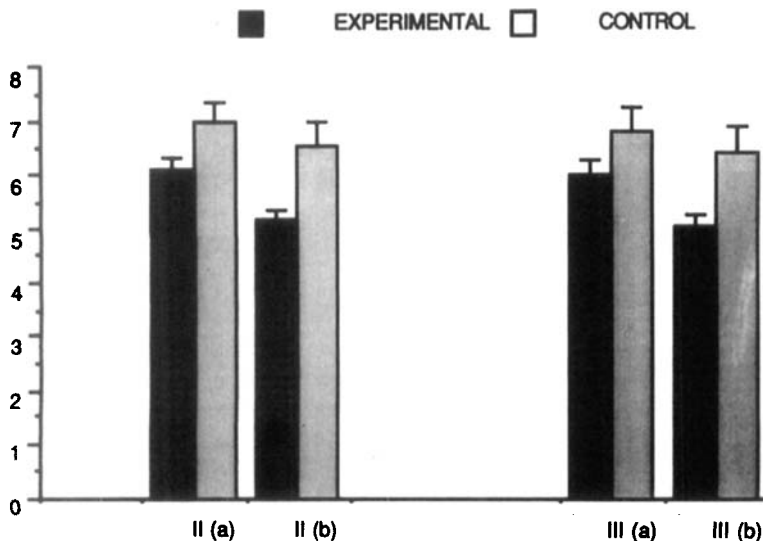


Fig. 3. Time in seconds (mean \pm SEM) for 10 chewing cycles, for the 15 experimental and the 8 control subjects, during the different recording sessions of the experiment; II) the day when the chewing training started, before (a) and after (b) 30 min of intense chewing, and III) after 4 weeks of daily chewing training, before (a) and after (b) 30 min of intense chewing training. The controls did not perform any training.

students were assigned a value of 1, and 1 individual a value of 2. It is thus not possible to use that index in longitudinal experiments on subjects with a complete natural dentition. However, the discriminatory ability of the method is also related to its precision. This has been analyzed in this study by means of repeated determinations and thus included the error of the method and the variation of performance. When investigating masticatory efficiency, it has been found that test-retest differences may be more attributed to variation of performance of the test person (biologic variation) than to lack of precision of the method per se (method error). With regard to this the combined error of 3.7% of ME indicates that the precision of the method is acceptable. The ability of the method to differentiate among subjects is shown by the 30% range of ME. In longitudinal studies such as this one the best possible precision of the method is important. In cross-sectional epidemiologic studies this has not been regarded as critical (12).

The results showed that 30 min of intense chewing decreased the masticatory efficiency in both the trained and untrained masticatory system. This is probably an effect of muscular fatigue. Fatigue of a skeletal muscle is defined as the inability to produce a preexisting level of force following static or dynamic activity (13). Teeth clenching and fatigue has been extensively studied and discussed by Christensen (14), but the relationship between intense chewing and fatigue does not seem to have been investigated systematically. It was somewhat surprising that the masticatory efficiency was not influenced by the relatively long training period. One may hypothesize that healthy individuals, having a complete natural dentition and already a satisfactory chewing performance, may not improve their masticatory efficiency despite chewing training. Hence, it may be argued that the tested subjects already had an optimal masticatory efficiency with regard to the method used, and therefore the method might not be capable of improving preexisting satisfactory values, while it might be effective in patients with poor masticatory efficiency, such as in

muscular dystrophy or craniomandibular disorders. Furthermore, the possible increase in the maximal bite force after the 4-week chewing training period (as shown in a previous experimental study (10)) does not necessarily mean that the bite force used during natural chewing also changed.

Since the gradation of a muscle contraction is dependent on the number of active motor units and their frequency of excitation (15), the fast-twitch motor units were those that have been activated to achieve hard chewing and which became fatigued during the 30 min of dynamic contractions. Fatigue of these motor units may have induced reduction of the masticatory forces, which in turn may have reduced the masticatory efficiency. A correlation between bite force and chewing efficiency has been found in several studies (16, 17).

The frequency of the masticatory cycles increased when the masticatory muscles were activated to low functional demands (18). This decrease of the period of the masticatory cycle was based mainly on the fact that fewer recruited motor units, especially those with a high threshold, were needed during light contractions. In the present study the decrease of the masticatory cycle period may also depend on fewer high-threshold motor units being recruited, owing to fatigue.

It can be concluded that prolonged intense chewing decreased the masticatory efficiency, possibly because of fatigue of the masticatory muscles, and chewing training for 1 month did not influence the masticatory efficiency. Further investigations are necessary to study more closely the short- and long-term effects of intense chewing on the behavior of the masticatory muscles.

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References

1. Lucas PW, Luke DA, Voon FCT, Chew LC, Ow R. Food breakdown patterns produced by human subjects possessing artificial and natural teeth. *J Oral Rehabil* 1986;13:205-14.

2. Lucas PW, Luke DA. Is food particle size a criterion for the initiation of swallowing? *J Oral Rehabil* 1986;13:127-36.
3. Yurkstas A. Compensation for inadequate mastication. *Br Dent J* 1951;91:261-2.
4. Carlsson GE. Masticatory efficiency: The effect of age, the loss of teeth and prosthetic rehabilitation. *Int Dent J* 1984;34:93-7.
5. Carlsson GE. Bite force and chewing efficiency: In: Kawamura Y, ed. *Frontiers of oral physiology*. Vol. I. Physiology of mastication. Basel: Karger, 1974:265.
6. Bates JF, Stafford GD, Harrison A. Masticatory function—A review of the literature. III. Masticatory performance and efficiency. *J Oral Rehabil* 1976;3:57-67.
7. Gunne J. Masticatory ability in patients with removable dentures. *Swed Dent J* 1985(suppl 27).
8. Kiliaridis S, Engström C, Thilander B. Histochemical analysis of masticatory muscle in the growing rat, after prolonged alteration in the consistency of the diet. *Arch Oral Biol* 1988;33:187-93.
9. Tzakis GM, Carlsson GE, Kiliaridis S. Effects of chewing training on the mandibular postural position. *J Oral Rehabil* 1989;16 (in press).
10. Brekhuis PJ, Armstrong WD, Simon WJ. Stimulation of the muscles of mastication. *J Dent Res* 1941;20:78-92.
11. Dahlberg G. *Statistical methods for medical and biological students*. New York: Interscience Publications, 1940.
12. Helkimo E, Carlsson GE, Helkimo M. Chewing efficiency and state of dentition. A methodological study. *Acta Odontol Scand* 1978;36:33-41.
13. Edwards RHT. New techniques for studying human muscle function, metabolism, and fatigue. *Muscle Nerve* 1984;7:599-609.
14. Christensen LV. Experimental teeth clenching in man. *Swed Dent J* 1989(suppl 60).
15. Åstrand P-O, Rodahl K. *Textbook of work physiology. Physiological basis of exercise*. New York: McGraw-Hill Book Co., 1986.
16. Haraldson T. *Functional evaluation of bridges on osseointegrated implants in the edentulous jaw* [Thesis]. Faculty of Odontology, University of Gothenburg, Sweden, 1979.
17. Lindquist LW, Carlsson GE, Hedegård B. Changes in bite force and chewing efficiency after denture treatment in edentulous patients with denture adaptation difficulties. *J Oral Rehabil* 1986;13:21-9.
18. Thomas NR, Peyton SC. An electromyographic study of mastication in the freely-moving rat. *Arch Oral Biol* 1983;28:939-45.

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