Journal of Oral Rehabilitation 2002 **29**; 986–991

EMG activity of the masseter muscle in implant supported overdenture wearers during chewing of hard and soft food

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SUMMARY **The influence of texture of food on the surface electromyographic (EMG) activity of the masseter muscle was investigated in a sample of mandibular implant overdenture wearers. Six experienced denture wearers (mean age 57·8 years) with mandibular overdentures supported by two implants, consented to participate in this study. Fresh raw carrots and peeled apples of similar size and weight were chosen as representing hard and soft food, respectively. The findings were in line with those earlier reported in dentate subjects and complete denture wearers in that harder foods require higher chewing rates, higher EMG activity and higher relative contraction times, accompanied by shorter cycle durations. It was also concluded that rehabilitation with implant retained mandibular dentures may result in more regular chewing patterns with higher electrical activity of the masseter muscles, thus providing improved chewing function and comfort.**
KEYWORDS: **implant, overdentures, EMG, masseter, chewing**

Introduction

Mastication is a learned function that matures with growth in conjunction with tooth eruption. It comprises complex and highly co-ordinated neuromuscular events such as fast effective movements of the jaws, coordination of tongue, lips and cheeks for the controlled movement of the bolus, salivation and oscillations of the head (Linden, 1998).

On the other hand, edentulous persons, even those with well-adapted dentures, are considered as oral invalids with reduced capacity in various functions such as bite force, chewing efficiency, tactile thresholds and oral perception of the hardness and thickness of objects (Manly *et al*., 1952; Bates, Stafford & Harrison, 1975; Haraldson, Karlsson & Carlsson, 1979b). Stabilization of the occlusion by means of fixed prostheses or dentures supported by osseo-integrated implants in the edentulous jaws, has shown considerable improvement of the masticatory muscle activity and jaw movements (Haraldson, Carlsson, & Ingervall, 1979a; Jemt, Lindquist, & Hedegard, 1985; Jemt & Stalblad, 1986; Agakawa *et al*., 1989). So the study of the functional responses to variations in food consistency may provide some additional information about the neurophysiological mechanisms regulating the complex masticatory action (Horio & Kawamura, 1989).

In previous studies of young dentate subjects and older denture wearers the effect of texture of food on masseter electromyographic (EMG) activity during chewing was reported (Karkazis & Kossion, 1997; Karkazis & Kossioni, 1998). The objective of the present preliminary investigation was to extend the experiments on a sample of implant overdenture wearers and also to evaluate the hypothesis that the use of this type of prosthesis would improve some chewing function parameters.

Materials and methods

Material

A total of six edentulous persons (four females and two males), 51–61 years of age (mean age 57·8 years) were carefully selected and consented to participate in this study. All participants had been referred to the Department of Removable Prosthodontics to receive implant treatment because of dissatisfaction especially with their lower dentures. All of them were experienced denture wearers, and the old dentures had been used for at least 4 years. A detailed description of the criteria used for the selection of the patients had been given in a previous report (Karkazis & Kossioni, 1998).

Surgical and prosthodontic procedures

Two fixtures were inserted into each mandible in the canine areas at equal distances from the midline symphysis. Fixture installation was followed by standardized post-operative procedures including tissue conditioner* in the existing lower denture for 1 month, followed by a permanent relining. After a healing period of 6 months the two fixtures were provided with ball attachments† and new mandibular overdentures were fabricated with rubber O rings† incorporated into their fitting surfaces (Figs 1 and 2).

Standard recalls were set at 1 week, 1 month, and 6 months, unless patients requested additional visits. All EMG recordings were made after the third recall on the complete absence of any discomfort, when patients were presumed to have adapted to the overdentures.

Fig. 1. Clinical view showing the two abutments for ball attachments in place (Nobel Biocare SDCB 115-0).

Fig. 2. Mandibular overdenture with plastic caps and rubber O-rings incorporated into the tissue surface (Nobel Biocare DCB 113-0).

Methods

Detailed description of the applied EMG techniques has been previously reported (Karkazis & Kossioni, 1997). For better comprehension of the findings however, the experimental protocol, data capture and data analysis will be briefly repeated. Fresh raw carrots and crisp peeled apples were chosen as representing hard and soft food, respectively. Subjects were asked to chew deliberately on the preferred chewing side as stated by themselves. Four sequential registrations, two for each test food, were made in a random order, and the means of both recordings were incorporated in the analysis. The EMG activity was obtained from the masseter muscle of the preferred chewing side by bipolar surface electrodes, while a computerized system was used for recording and analysis of the collected EMG data. Analysis of the results was performed off-line and the following parameters were studied: (i) Chewing rate (the number of chewing bursts in 10 s), (ii) mean peak Root Mean Square (RMS) activity during chewing (iii) duration of chewing cycle, (iv) duration of chewing burst, (v) relative contraction period (percent of burst to total cycle duration) and (vi) coefficient of variation (CV%) of cycle duration as an index of chewing rhythm regularity. Data analysis was performed by the same experienced examiner, and the 'within-observer' variation in defining onsets and cessations of activity was low. Finally the 'within-session' reproducibility of EMG patterns was found to be good. Mean values and s.d. for each test food were calculated and compared by the paired *t*-test (0·05 level of significance). All calculations were based on mean values of the two registrations made for each food.

Results

The mean values of all measured parameters and the results of the statistical comparisons are summarized in

*Viscogel, Dentsply, Surrey, U.K.
†Nobel Biocare SDCB115-0 & DCB 113-0, Nobel Biocare AB, Göteborg, Sweden.

Table 1. Statistically significant differences between the two test foods (with higher values for carrot chewing) were revealed in the mean peak RMS activity, chewing rate and relative contraction period. The chewing burst duration and the coefficient of variation of cycle duration were also numerically higher for carrot chewing. On the contrary the overall mean for cycle duration was higher for apple chewing. Generally the analysis of the EMG recordings revealed individual variations, although some characteristic patterns could be observed for each person. For example, in one subject the chewing pattern was characterized by low regularity (CV 18%), while two other subjects showed remarkable uniformity of chewing cycles with sharp onset and cessation of activity at the beginning and the end of the chewing bursts (CV 9·58%) (Fig. 3). Finally a close-up view of the chewing session of another subject, revealed a characteristic progressive (from cycle to cycle) diminution of the mean peak RMS activity, as the bolus was ground up.

Discussion

Implant retained overdentures. Neurophysiological aspects

The use of implant retained overdentures with two implants placed in the mandibular canine (or first premolar) region has become a routine procedure. In a recent review of 35 relevant papers published over the period 1988–99, it was revealed that by far the vast majority of the studies included prosthodontic follow-up of mandibular overdentures supported by two implants, either connected with bars or unsplinted using ball abutments or magnets (Payne & Solomons, 2000). It is evident from the literature that implant retained overdentures are an efficacious modality for providing an improved chewing function for the completely edentulous patients (Jemt & Stalblad, 1986; Schmitt & Zarb, 1998; Naert *et al.*, 1999). In the present study the subjective assessment of the oral function revealed that all the subjects were more satisfied with stability of their dentures and their

Table 1. Variation of EMG activity during chewing of two test foods

Variable	Apple		Carrot				
$n = 6$	x	s.d.	x	s.d.	d.f.	t	P-value
Chewing rate (No)	12·8	2·4	14·4	1·8	5	−3·74	0·013*
Cycle duration (ms)	752·5	143·5	695·2	100·8	5	2·02	0·098
Burst duration (ms)	356·9	84·4	366	64	5	−0·65	0·544
RCP (%)	47·2	5·5	52·6	5·8	5	−5·14	0·003*
CV cycle (%)	12·7	2·4	13·6	7·9	5	−1·07	0·343
RMS (mV)	690·5	214·5	964·7	161·3	5	−5·25	0·003*

*Statistically significant at 95%.
n, number of subjects in the group; x, group mean of individual means; RMS, mV at the input to AD converter; t, paired t-value; CV, coefficient of variation; RCP, relative contraction period.

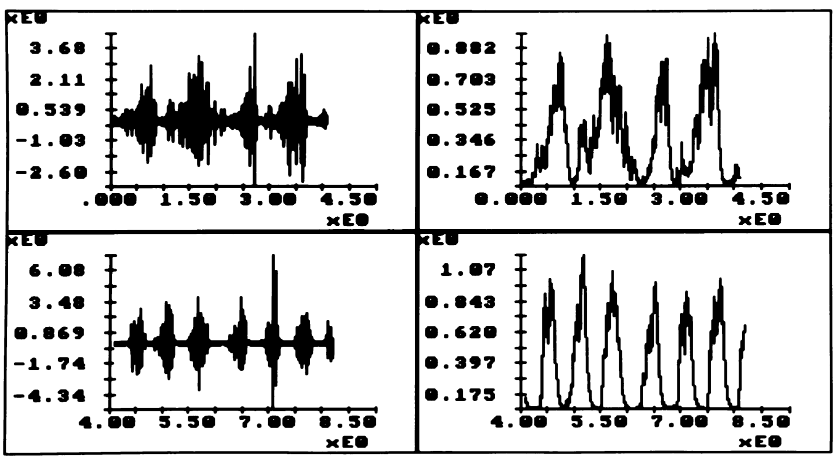

Fig. 3. Natural random variation of masseter patterns of activity during carrot chewing in two subjects. Upper traces: relatively low regularity of chewing bursts. Lower traces: uniformity of chewing bursts with sharp onset and cessation of activity (Left: raw EMGs, right: RMS values. Calibrations: y-axis, volts at the input to A/D converter; x-axis, real time in seconds).

overall oral function compared with the previous situation. From the neurophysiological point of view implant retained overdentures although equivalent to the conventional root retained overdentures, present some fundamental differences. The lack of periodontal ligament mechanoreceptors with their specific functions results in considerable alterations of the oral sensory perception skills.

However activation of periosteal mechanoreceptors, or other intra-osseous neural endings through bone deformation, might be an explanation for the capacity of most implant patients to discriminate interocclusal thickness and perceive loads, a situation similar to the 'osseoperception' seen in patients with osseo-integrated amputation prostheses (Jacobs & Van Steenberghe, 1993; Branemark, 1998; Mericske-Stern, 1998; Rydevik, 1998). Finally the mucosal support of the overdentures offers additional neural input through stimulation of the mucosal exteroceptors which seem to take over, to some extent, the role of the lost periodontal receptors (Karkazis & Kossioni, 1998).

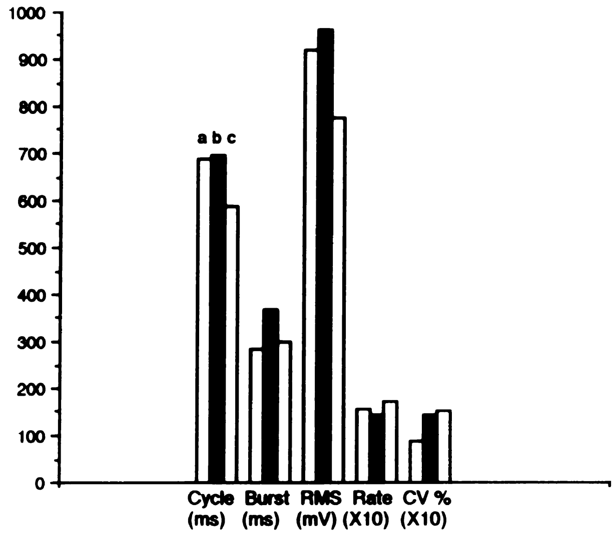

Fig. 4. Mean values of chewing cycle and chewing burst duration, mean peak RMS activity, chewing rate and CV of cycle duration in young dentate persons (a), implant overdenture wearers (b), and conventional denture wearers (c), during chewing of carrot (Data from the present study with data from Karkazis & Kossioni, 1997, 1998).

Chewing rate duration of chewing cycle and chewing burst

As it has been previously observed chewing rhythm is closely related to food consistency. Higher foods require higher rates of chewing modulated through peripheral induction regardless of the presence or absence of periodontal ligament receptors. In the present study, the average chewing rate expressed as the number of bursts carried out in 10 s, was 12·8 ± 2·4 for apple (soft food) and 14·4 ± 1·8 for carrot (hard food) while in an age-matched group of denture wearers studied earlier, the chewing rate was 14·4 ± 2·9 for the apple and 17·1 ± 2·8 for carrot. The values found in the present study however, were rather closer to those recorded in young dentate persons using similar experimental set-up (12·7 ± 3·4 for the gum – soft food and 15·7 ± 3·8 for the carrot – hard food) (Fig. 4). Any changes in chewing rate have analogous effect on the duration of the chewing cycle and more precisely the higher the rate of chewing the lower the duration of the chewing cycle and vice versa (Dahlberg, 1946; Steiner, Michman & Litman, 1974). In the present study the mean duration of the chewing cycle was 752·5 ± 143·5 ms for apple and 695·2 ± 100·8 for carrot. In general chewing cycle duration was longer than that recorded in complete denture wearers and this is probably because of the better stability of the lower denture that enables more extreme chewing movements (Tallgren, Mizutani, & Tryde, 1989). Self-confidence during chewing was also reflected in the relatively lower coefficients of variation (12·7 and 13·6%, respectively) that among others indicate chewing regularity with more uniform and repetitive cycles. In the present study the overall duration of the chewing burst remained rather unaffected by food consistency (356·9 ± 84·4 ms for apple and 366 ± 64 ms for carrot) as in the dentate subjects. When transferring however, the absolute duration of chewing burst into percentage of the total cycle duration, carrot chewing (52·6%), presented clearly higher values than apple chewing (47·2%). This is expected as the relative contraction period reflects better the higher energy levels required in chewing harder foods.

RMS activity during chewing

For the six subjects investigated the mean peak RMS activity was significantly higher for chewing carrots (964·7 ± 161·3 mv) than chewing apples (690·5 ± 214·5 mv) and this probably reflects the modulation of the contraction mechanisms through information from intra-oral receptors (Ahlgren, 1966; Plesh, Bishop & McCall, 1986; Horio & Kawamura, 1989). In general implant overdenture wearers presented significantly higher activity during chewing compared with denture wearers and in some instances the recorded values were even higher than those of the young dentate persons (Fig. 4). This can be the result of the absence of periodontal ligament receptors and therefore loss of inhibitory reflexes. The reduced tactile function could lead to an impaired control of the maximum biting force which is well-reflected in the high RMS activity during chewing.

Conclusions

Similar tendencies (characterized by alterations in chewing rate, duration of the chewing cycle and chewing burst and RMS activity) were recorded when chewing soft and hard foods in dentate persons, denture wearers and mandibular implant overdenture wearers. The use of two implants for the retention of the mandibular dentures improves some EMG parameters of chewing function and brings them closer to the levels of dentate persons. Better stability and retention and improved oral perception skills might be the explanation for these findings. In general when a complete denture is exchanged for a more stable and well-supported prosthesis, various chewing parameters are expected to improve. On the other hand, individual analysis of the EMG tracings revealed an individual basic EMG pattern stable in repeated registrations. This finding suggests the existence of a stable background mechanism obviously capable of modifying itself with changes in the oral situation (teeth–dentures–implants). From the clinical point of view the results of the present and the previous two studies (Karkazis & Kossioni, 1997, 1998) indicate the need for clinical methods that can enhance quick and effective adaptation to dentures. The mandibular implant retained overdenture is a relatively simple and low cost treatment modality that meets the demands of most edentulous persons suffering from retention and stability problems, because of the progressive reduction of the alveolar bone.

Acknowledgments

This study was supported by the Hellenic Ministry of Education, Grant 70/4/4954.

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