Long-term effects on chewing with mandibular fixed prostheses on osseointegrated implants

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Twenty-seven edentulous patients with denture adaptation problems were first given optimal conventional complete dentures and then a fixed prosthesis on osseointegrated dental implants in the lower jaw (and a complete maxillary denture). Masticatory function was evaluated by means of a questionnaire, a comminution test for chewing efficiency, and bite force measurements on four occasions: with the original (I) and optimal complete dentures (II) and 2 months (III) and 3 years (IV) after insertion of the fixed mandibular prosthesis on implants. No significant improvement of masticatory function was found after conventional denture treatment. After insertion of the fixed mandibular implant bridge, a marked improvement of the patients' assessment of their chewing ability and of the results of the chewing efficiency test and the bite force measurements was recorded. The test results were further improved after the 3-year observation period, which indicates that adaptation to the new prosthetic situation is a gradual process. □ *Bite force; chewing efficiency; dental implantation; mastication; prosthesis*

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At a conference in 1978 on dental implants in clinical use in the USA (1), it was acknowledged that reporting of results in the dental implant field had been unrealistic. The lack of well-controlled scientific documentation also meant that no dental implant technique was recommended for general clinical use. However, the favorable clinical long-term results of treatment with osseointegrated dental implants are well documented (2–4). The Swedish National Board of Health and Welfare approved this treatment as a legitimate method as long ago as in 1975 (5). Evaluations of patients with bridges on implants (OIB) in accordance with this osseointegration principle have indicated a substantial functional rehabilitation after treatment (6, 7). These investigations were cross-sectional, however, and longitudinal results have been lacking. Recently, some short-term follow-up studies have been presented (8, 9). The purpose of this paper is to present a 3-year follow-up study of the results of two functional tests—bite force and chewing efficiency—in a group of edentulous patients who received an OIB in the lower jaw but still wore a complete denture in the upper jaw.

Materials and methods

The biological background, the principles of treatment and the proposed mechanism of osseointegration have been discussed in detail (2, 10). The design of this study has been presented earlier (8) and is summarized in Fig. 1.

The original group of patients comprised 28 edentulous persons less than 65 years of age. They had worn complete dentures in both jaws for at least 1 year. Because of great difficulties with their dentures, they had been referred to, or had themselves consulted, the Dental School of the University of Gothenburg for possible treatment with OIBs.

After initial examinations and recordings, the patients were given treatment aiming at achieving optimal conditions with conventional complete dentures. If their dentures

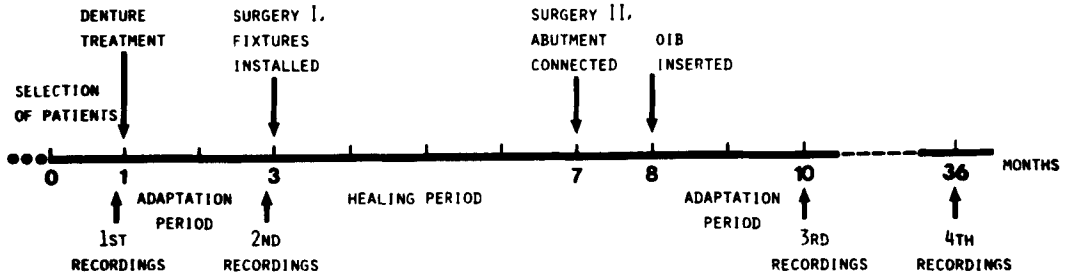

Fig. 1. Study design and time schedule for the treatment procedures for insertion of an OIB in the lower jaw.

were technically unsatisfactory or if they were more than 1 year old, new complete dentures were made. If the existing dentures were recently made and found to be of good technical quality, only necessary relinings, peripheral corrections, and occlusal adjustments were performed. After an adaptation period of 2 months, new examinations and recordings were made. One woman adapted so well to the new dentures that she did not wish to continue with the implant treatment. The remaining 27 patients received an OIB in the lower jaw in accordance with principles described earlier (11). All these 27 patients also took part in the 2-month follow-up study (8). At the control examination 3 years after the insertion of the mandibular OIB, 24 patients were examined; 1 had died and 2 could not attend during the period set up for the recordings.

Chewing efficiency

The patients' capacity to comminute a test food, scalded almonds, was estimated by means of a sieve system (12). The results of the tests were used to calculate a 5-point chewing efficiency index, C_i, in which 1 denotes a very good and 5 a very poor capacity to comminute the test food.

The chewing time and the number of chewing strokes and swallows for completion of the chewing of an almond were recorded. The time and number of chews up to the first swallow were also recorded. All the tests were repeated and the mean values of the two recordings were used in the analyses.

Bite force

Bite force was recorded with an apparatus described previously (13) and used in similar studies (6, 7). It consisted of a steel bite fork with strain gauge transducers. The results were recorded graphically. The bite fork was placed between a maxillary and a mandibular tooth in the regions of the second premolars and the canines on both sides and the incisors. The patients were asked to use two levels of bite force: a) one equivalent to that used in chewing and b) powerful biting. They were then asked to bite with maximal force in the 'best biting position'—where it was felt to be most comfortable to bite as hard as possible. The series of 11 recordings were then repeated. For the maximal bite force, the highest value was chosen; for the others, the means of the two recordings were used.

The maximal finger force between the thumb and the forefinger was measured for both hands with the same apparatus.

Chewing ability

A questionnaire was used for the patients' own evaluation of their ability (1 = easy; 2 = difficult; 3 = very difficult/impossible) to chew eight foods: apple, bacon, carrot (raw), chicken, crispbread, ham, pork, and potato (boiled).

At the 3-year follow-up study a visual analogue scale was used for the patients' self-rating of their present chewing ability and their chewing ability with the original complete dentures. They were given a paper with two 100-mm-long horizontal lines, marked

on the left with the (supposed) chewing ability of an edentulous person without dentures (=0%) and on the right with that of a person with a complete natural dentition (= 100%), and they were asked to mark their present and previous chewing ability somewhere on the lines. A theoretical value between 0 and 100 was thus obtained.

Statistical methods

Significance tests for differences between sexes and age groups and for correlations were performed with Pitman's permutation test, whereas effects of treatment were tested with a linear permutation test for paired observations (14). For correlation analysis, the non-parametric Spearman rank correlation test was used (15).

Results

Chewing

The chewing efficiency index value, C_i, did not change significantly after denture treatment but decreased significantly after insertion of the mandibular OIB ($p < 0.01$). At the 3-year follow-up study the C_i was still lower (Table 1). This means that the capacity to comminute the test food increased after the OIB treatment and that it had improved further during the observation period.

The total time necessary for chewing and swallowing an almond decreased insignificantly after denture treatment. After OIB treatment the mean time decreased to about half the value obtained with optimal dentures ($p < 0.01$). A great reduction of the variance also occurred (Fig. 2). No further significant changes were recorded at the 3-year follow-up study. The number of chewing strokes for a whole chewing sequence for the test food showed the same development (Table 2). The mean number of swallows decreased significantly ($p < 0.01$) after denture treatment, but the further changes after OIB treatment and during the observation period were not statistically significant. The highest values (>5), however, disappeared (Table 2). The values for chewing time and number of chewing strokes up to the first swallow showed the same types of changes as just described for the whole sequence.

Table 1. Chewing efficiency index (median (M), mean ($\bar{x}$), standard error of the mean (SEM), and range; 1 denotes a good and 5 a very poor comminution efficiency) estimated on four occasions (I = with original dentures, II = after denture treatment, III = 2 months and IV = 3 years after insertion of an OIB in the lower jaw, complete denture in the upper jaw)

Test occasion	M	$\bar{x}$	SEM	Range
I	3.5	3.5	0.25	1–5
II	4.0	3.8	0.23	2–5
III	2.5	2.5	0.17	1–5
IV	1.5	2.1	0.14	1–3

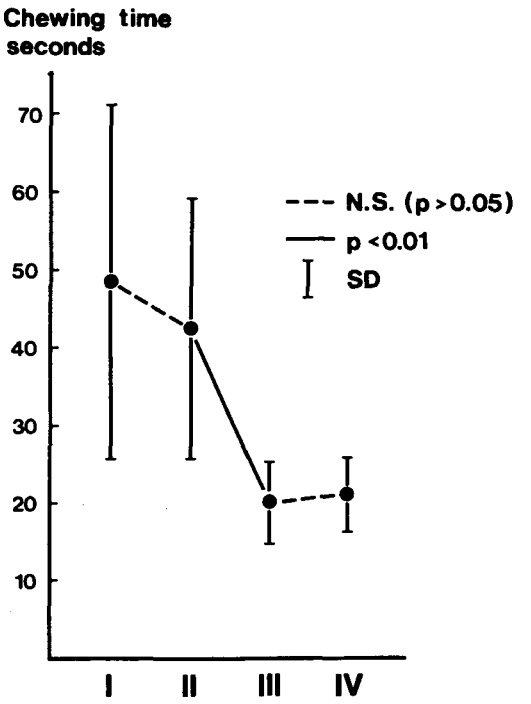

Fig. 2. Chewing time (total time in seconds for chewing and swallowing the test food) in 24 edentulous subjects on four occasions (I = with old dentures, II = after denture treatment, III = 2 months and IV = 3 years after insertion of a mandibular OIB).

Bite force

There were great individual variations of the bite force measurements at all three force

Table 2. Chewing time (sec), number of chewing strokes and number of swallows (mean ($\bar{x}$), standard error of the mean (SEM), and range) for a whole chewing sequence on four occasions (I = with original dentures, II = after denture treatment, III = 2 months and IV = 3 years after insertion of an OIB in the lower jaw, complete denture in the upper jaw)

Test occasion	$\bar{x}$	SEM	Range
Chewing strokes			
I	56.8	11.8	17–320
II	49.7	5.4	14–138
III	27.9	2.2	12–59
IV	29.7	2.5	16–60
Swallows			
I	3.0	0.4	1–9
II	2.0	0.3	1–9
III	1.7	0.2	1–5
IV	1.8	0.2	1–4

Table 4. Maximal bite force (mean ($\bar{x}$), standard error of the mean (SEM), in N) recorded in 'the best biting position' on four occasions (I = with original dentures, II = after denture treatment, III = 2 months and IV = 3 years after insertion of an OIB in the lower jaw, complete denture in the upper jaw). The maximal finger force values of the right hand are also given for comparison

Test occasion	Maximal bite force (N)		Maximal finger force (N)	
	$\bar{x}$	SEM	$\bar{x}$	SEM
I	64.4	5.5	79.5	5.0
II	74.1	6.0	80.0	4.9
III	137.7	10.7	74.5	4.6
IV	190.7	15.9	82.0	6.8

levels used (Tables 3 and 4). After denture treatment there was a significant increase of bite force at the submaximal levels only for the right premolar regions, whereas the recordings in the other four test positions did not change. The insertion of an OIB in the lower jaw increased all recordings significantly ($p < 0.001$). At the 3-year follow-up study all mean values were still higher (Table 3). The maximal force recorded in the 'best biting position' (usually in the region of the most posterior implant) increased on average slightly after denture treatment but was about twice as high as the original value after the mandibular OIB treatment. At the 3-year follow-up study the mean value was almost three times the original value (Fig. 3). There were no significant changes of the maximal finger force of either hand during the observation period (Table 4).

Evaluation of chewing ability

The patients' own evaluation of their ability to chew different foods changed only slightly after denture treatment, whereas a dramatic improvement was reported after insertion of the mandibular OIB. This improvement was maintained during the observation period (Table 5).

The self-rating of the present chewing ability by means of a visual analogue scale (Fig. 4) showed a mean value of 77% (median, 80%; range, 97–33%), whereas the cor-

Table 3. Bite force (mean ($\bar{x}$), standard error of the mean (SEM), and range, in N) recorded on four occasions (I = with original dentures, II = after denture treatment, III = 2 months and IV = 3 years after insertion of an OIB in the lower jaw, complete denture in the upper jaw). Two force levels were used. Only the recordings on the right side and in the incisor region are presented

Force level	Test occasion	Region 15/45			Region 13/43			Region 11–21/41–31		
		$\bar{x}$	SEM	Range	$\bar{x}$	SEM	Range	$\bar{x}$	SEM	Range
As in chewing	I	37.6	4.0	8–89	28.9	3.3	5–76	23.5	2.8	5–53
	II	44.2	4.3	15–118	28.6	3.3	11–92	23.6	2.6	4–60
	III	71.6	6.3	25–155	52.0	4.7	18–93	45.1	4.4	14–80
	IV	79.4	7.8	15–148	59.8	6.7	13–134	53.9	5.2	13–98
Powerful biting	I	53.6	4.9	17–118	38.3	3.7	8–81	31.0	3.3	8–69
	II	62.0	5.3	17–125	38.9	3.9	10–86	32.1	3.0	5–70
	III	103.5	7.8	37–194	72.6	5.8	18–123	62.4	6.2	9–146
	IV	147.7	13.6	47–338	98.2	10.4	15–251	88.9	7.4	18–158

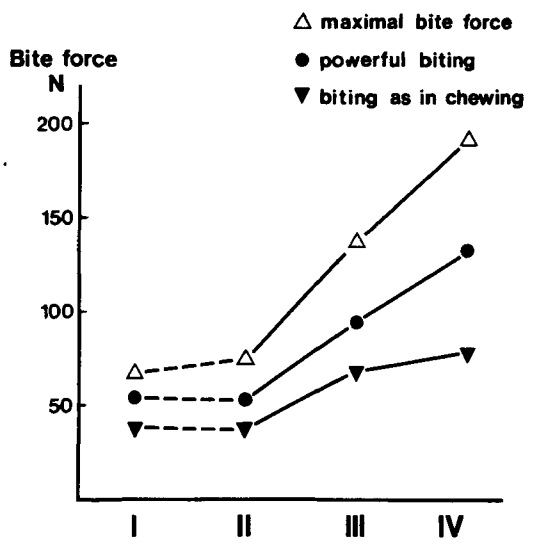

Fig. 3. Bite force. Means, in N, of bite force measurements in 24 edentulous subjects at three force levels on four occasions (I = with old dentures, II = after denture treatment, III = 2 months and IV = 3 years after insertion of a mandibular OIB).

responding value for the original complete dentures was 24% (median, 20%; range, 61–2%). All patients indicated a substantial improvement.

Correlations

The chewing ability index before treatment (based on the patients' own evaluation of their chewing difficulties with eight different foods) was not significantly correlated to the chewing efficiency index, C_i, or to any of the other variables tested, including the bite force measurements. The chewing ability index after OIB treatment was, however, significantly correlated to bite force values with the OIB. The C_i was weakly correlated to the bite force measurements (Table 6). The subjective assessment of chewing capacity (percentage scale) at the 3-year follow-up study was strongly correlated to the maximal bite force ($r_s = 0.72$; $p < 0.001$) but not to the C_i ($r_s = 0.35$; NS). The maximal bite force with the OIB was closely correlated to the mean of the powerful bite force recordings on the same occasion ($r_s = 0.7$–0.9; $p < 0.001$). It showed weaker correlations with the other force measurements (Table 6). The maximal bite force at the 3-year control was significantly correlated to the maximal finger force in both hands (both $r_s = 0.49$). The change in C_i from the first to the third occasion (original dentures to OIB) was significantly correlated to changes in chewing time and number of chews (both $r_s = 0.50$; $p < 0.01$) and to the bite force before treatment ($r_s = -0.47$ and -0.43 for the mean value of bite force 'as in chewing' and powerful biting, respectively, both $p < 0.05$). This indicates that the improvement of C_i was greater in those patients with lower original bite force values.

Table 5. Chewing ability. Median (M) and means ($\bar{x}$) of the patients' evaluation of their ability to chew 8 different foods in accordance with a 3-point scale (1 = easy, 2 = difficult, 3 = very difficult/impossible to chew) on four occasions (I = with original dentures, II = after denture treatment, III = 2 months and IV = 3 years after insertion of an OIB in the lower jaw). The foods are listed by chewing difficulty on the first occasion

Food	I		II		III		IV	
	M	$\bar{x}$	M	$\bar{x}$	M	$\bar{x}$	M	$\bar{x}$
Raw carrot	3	2.9	3	2.8	1	1.4	1	1.5
Apple	3	2.8	3	2.6	1	1.1	1	1.3
Bacon	2	2.2	2	1.9	1	1.1	1	1.0
Pork	2	1.7	2	1.4	1	1.0	1	1.0
Crispbread	2	1.7	1	1.4	1	1.0	1	1.0
Chicken	2	1.7	1	1.5	1	1.0	1	1.0
Ham	1	1.4	1	1.1	1	1.0	1	1.0
Boiled potato	1	1.1	1	1.0	1	1.0	1	1.0
Chewing ability index		1.9		1.7		1.1		1.1

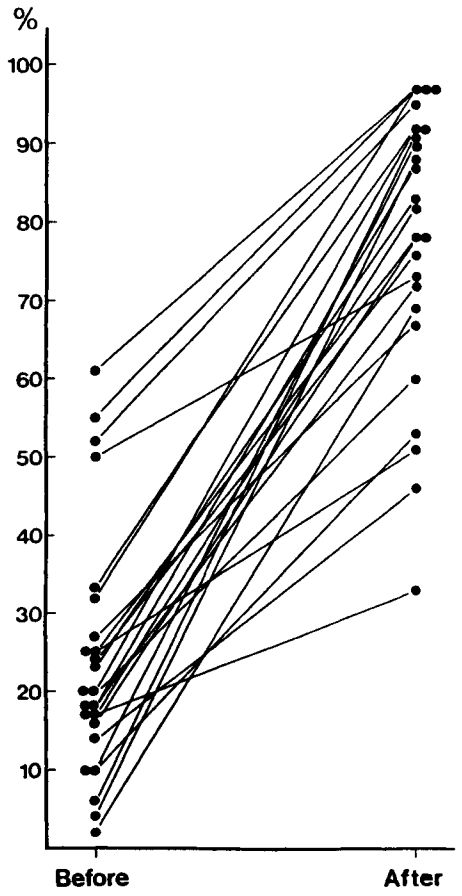

Fig. 4. Chewing ability in 24 complete denture wearers before and 3 years after treatment with an OIB in the lower jaw (self-rating performed at the 3-year follow-up study). 100% corresponds to the chewing ability of a dentate person with a full set of good natural teeth, 0% = that of an edentulous person without dentures.

Discussion

The marked improvement of chewing capacity after insertion of a bridge on osseointegrated implants in the lower jaw in edentulous patients reported previously (8) was obviously maintained during the 3 years covered in this study. The results of the functional tests used were even better after 3 years than at the first examination 2 months after treatment. This is probably due to gradual adaptation to the new prosthetic situation. The adaptation to dentures is a complicated process that often takes a long time

Table 6. Spearman rank correlation coefficients (r_s) between chewing efficiency index (C_i; 1 = very good, 5 = poor) and maximal bite force 3 years after mandibular OIB treatment (occasion IV) and some other variables (I = before, II = after denture treatment, and III = 2 months after OIB treatment)

Variable		C_i IV	Maximal bite force IV
Chewing efficiency (C_i)	I	0.44*	−0.21
	II	0.35	−0.32
	III	0.35	−0.53*
	IV	1.00	−0.30
Maximal bite force	I	−0.23	0.27
	II	−0.28	0.43*
	III	−0.46*	0.76***
	IV	−0.30	1.00
Bite force 'as in chewing' region 15/45	I	−0.01	0.04
	II	−0.19	0.33
	III	−0.28	0.50*
	IV	−0.01	0.58**
Bite force as in powerful biting region 15/45	I	0.03	0.28
	II	−0.08	0.59**
	III	−0.52*	0.64**
	IV	−0.10	0.88***

* $0.01 < p \leq 0.05$; ** $0.001 < p \leq 0.01$; *** $p \leq 0.001$.

(16). This is probably also true for the combination of a mandibular OIB and a complete maxillary denture. The functional methods used have been tested and analyzed previously (6–8, 12, 13). The method of determining the chewing efficiency index has a rather poor reproducibility, probably owing to biological variation in chewing rather than to lack of precision of the method per se (12). By means of duplicate tests, this disadvantage has been reduced, and the method is obviously good enough to show the subjectively perceived improvement. Considering that the patients still wore a complete denture in the upper jaw, the improvement of C_i after insertion of a mandibular OIB is impressive, especially as the denture treatment failed to change the mean value of the index. The great change in the patients' evaluation of their chewing ability is perhaps still more surprising considering that they still wore a removable complete maxillary denture.

The relationship between chewing ability and chewing efficiency is complicated (17–

19). The subjective evaluation of masticatory difficulties in patients with denture problems has many psychological implications. The chewing ability index used here was not significantly correlated to any of the tested variables before treatment. After OIB treatment, however, it was correlated to some bite force values. It thereby resembled the C_i (comminution test), but the two indices were still not significantly correlated. The self-rating by means of the visual analogue scale correlated more closely with maximal bite force than any of the other chewing indices.

The subjective improvement of masticatory function was verified not only by the change in C_i but also by substantial changes of some other physiological variables, such as chewing time, number of chews, and bite force. This explains much of the satisfaction with OIBs expressed by most of the patients, also reflecting positive responses to psychological and 'quality of life' judgements (20, 21). It is noteworthy that such marked changes have been attained after OIB treatment in the lower jaw only. An interesting question is whether OIB treatment in the upper jaw also would further improve masticatory function. The patients were asked this question after the 3-year follow-up study. Most answered that they believed it would and would like to have such treatment. Some of these patients have now been treated with OIBs in the upper jaw also and they are being studied for further functional changes.

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