THE MASTICATORY EFFICIENCY OF MANDIBULAR IMPLANT-SUPPORTED OVERDENTURES AS COMPARED WITH TOOTH-SUPPORTED OVERDENTURES AND COMPLETE DENTURES

Li Chen, MD, DDS
Qiufei Xie, MD, DDS
Hailan Feng, MD, DDS
Ye Lin, MD, DDS
Jianhui Li, MD, DDS

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All authors are affiliated with the School of Stomatology, Peking University, Beijing 100081, China.

***Li Chen, MD, DDS,** is with the Department of Prosthodontics. Address correspondence to Dr Chen at 32-31 70th Street, Elmhurst, NY 11370.*

***Qiufei Xie, MD, DDS,** and **Hailan Feng, MD, DDS,** are with the Department of Prosthodontics.*

***Ye Lin, MD, DDS,** and **Jianhui Li, MD, DDS,** are with the Department of Implant Dentistry.*

This study assesses the comparative masticatory efficiency (CME) of mandibular implant-supported overdentures (ISOs) to tooth-supported overdentures (TSOs) and complete dentures (CDs). Three groups of patients in equal numbers were evaluated by assessing chewing efficiency, and the results were correlated with tracings of mandibular excursion (ME) and electromyographic (EMG) computerized analysis. CME was measured by utilizing standardized portions of 2 food staples with fixed masticatory sequencing. In a following session, utilizing the same fixed masticatory sequence, tracings of ME and EMG of the masseter and temporal muscles were recorded and analyzed. The results revealed that the ISO provided the greatest degree of efficiency, followed by the TSO and then the CD group. CME is more correlated to ME and less correlated to EMG.

INTRODUCTION

Published international reports demonstrate a global trend of increased longevity of the elderly. Therefore, the actual number of partially and fully edentulous patients will remain constant.[1] Clinicians have various treatment modalities available for these patients. Conventional complete dentures (CDs), tooth-supported overdentures (TSOs), and implant-supported overdentures (ISOs) are commonly seen.

A large number of studies report the benefits of overdenture treatment, which include TSOs and ISOs, as compared to CD treatment.[1–4] Several recent studies demonstrate that ISOs are as efficient as a fixed prosthesis with respect to masticatory function and patient satisfaction.[5] The advantages of ISOs instead of TSOs are that the caries risk is nonexistent, implants can be more stable in many cases, and clinicians can offer a variety of denture designs. Disadvantages are that sensory feedback may be reduced and costs may be higher.[1]

Since there are few studies comparing ISOs and TSOs, one question may arise: should teeth be saved or replaced with implants when the 2 methods are accessible and acceptable to a patient? The aim of this study was to compare the masticatory efficiency (CME), mandibular excursion (ME), and surface electromyography (EMG) of the masseter and temporal muscles in CD, TSO, and ISO wearers at rest and when clenching and chewing.

Material and Methods

Subjects

Patients were selected from the Department of Prosthodontics and Implant Center, Stomatology School of Peking University. The protocol was replicated in 3 groups of subjects, all of whom had a CD in the maxilla and a CD, TSO, or ISO in the mandible. Each group comprised 14 patients, in which the CD group had 9 men and 5 women with an average age of 63 years (range 30–83). The TSO group consisted of 8 men and 6 women with an average age of 69 years (range 60–79). The ISO group consisted of 10 men and 4 women with an average age of 57 years (range 30–74). All subjects were well adjusted to their initial prostheses for at least 6 months. The patients were selected on the basis of (1) adequate retention and stability, (2) adequate denture-base extension, (3) satisfactory vertical and centric relationships, (4) no need for denture adhesive, and (5) absence of inflammation or pathologic lesions of the oral tissues. All patients were fully informed of the nature of the investigation and agreed to take part.

CME tests

In the protocol, masticatory efficiency is defined as the weight percentage of chewed food that passes through a sieve with meshes of 2.4 mm in diameter after 1 minute of chewing. The weight of any liquid introduced into the chewed food by the patient was also taken into account.

In 1 procedure, patients chewed 2 g of dried small almonds for 1 minute, after which the chewed sample was collected and placed in a sieve with 2.4 mm round apertures before being washed for 1 minute. The chewed almonds that did not pass through the apertures were dried at 65°C for 4 hours and weighed. For each patient, this procedure was repeated using 3 g of jujubes. Each jujube was cut into 4 pieces and predried at room temperature for 24 hours prior to use. The almond and jujube cycles were each repeated 2 times by the patient, and the final weight was averaged (A). In separate procedures, 2 g of unchewed almonds and 3 g of unchewed jujubes were dried at 65°C for 4 hours, repeated 2 times for each and the final weights were averaged (B). With these values, the masticatory performance of each patient was calculated using the formula $(B - A)/B = \text{ME}$, where B is the weight of the original sample after drying, and A is the weight of chewed food after drying.

Recording and evaluation of ME

ME was recorded with a kinesiograph (K5AR, Myotronics Inc, Tukwila, Wash). Excursions in 3 dimensions were traced with a variance rate of 0.1 mm. The device comprises (1) the guide magnet, (2) a sensor array supported by a facebow, and (3) the display system. The magnet was fixed to the lower central incisors precisely perpendicular to the median plane and out of contact with the upper incisors. The correct placement of the sensors was checked before and immediately after each tracing was registered.

The subjects were instructed about the procedures beforehand. They were seated upright with arms resting on their legs and asked to make maximum lateral and vertical excursions, as well as the patient's habitual chewing excursions starting from centric occlusion. Tracings were recorded in frontal and sagittal planes and evaluated from the following 3 aspects:

- Control of chewing cycles was excellent (less than 5% abnormal masticatory cycles), regular (less than 30% of the abnormal cycles), or poor (more than 30% of abnormal cycles), evaluated according to the standard chewing cycle outline of the classification of Ahlgren.[6]
- End tracings were excellently centralized (the end tracings of chewing cycles appeared as a point and its diameter was no more than 0.2 mm), well centralized (the end tracings showed as a point and its diameter was more than 0.2 mm and less than 0.4 mm), or poorly centralized (the diameter of end tracings was more than 0.4 mm).
- The lateral occlusal slide tracings in the frontal plane were classified as X (the lateral slide tracings in opening and closing paths of the chewing cycles were all coincident with that in the maximum lateral excursion), Y (only the lateral slide tracings in the closing path of chewing cycles were coincident with it), and Z (there were no lateral occlusal slides in the chewing cycles).

EMG quantitative analysis

Two patients in the ISO group did not accept the EMG test. The EMG recordings were performed with MEB-5508K EMG equipment (Nihon Kohden Inc, Tokyo, Japan) when at rest, clenching, and during each patient's habitual chewing of the almonds and jujubes. During the recordings, the patient sat upright in a dental chair with the head against the headrest. Bipolar surface Ag/Agcl electrodes were taped bilaterally over the superficial masseter and the anterior and posterior temporal muscles in the main direction of the muscle fibers as ascertained by palpation. The interelectrode distance was approximately 20 mm. For each patient the position of the electrodes at the first session was marked on a chart to be used as a guide for reproducibility at future recording sessions.[7] Sensitivity was set at 50 μV, filters between 20

Hz and 10 kHz, and sweep speed at 5 ms/division.

Analysis of EMG interference signals was performed with programs of MEB-5508K. The number of turns per second, the peak amplitude, and the integrated value were determined over a 2-second period. Turns were defined as reversals in the slope of the myoelectric signal with a minimal amplitude difference of 50 μV and integrated value as the area within the EMG envelope tracing.[8] Final values of indices are the averages of those of right and left muscles.

Statistics

The results were analyzed using an analysis of variance (ANOVA). Differentials between groups were compared through analysis utilizing both the Student *t* test and the nonparametric Mann-Whitney *U* test. A level of $P < .05$ was accepted as significant.

RESULTS

Comparative masticatory efficiency

The average CMEs of the ISO group when chewing almonds and jujubes were highest of the 3 groups. Those of the CD group were lowest (Table 1). The differentials between the ISO group and the CD group were significant ($P < .01$), whereas those between the TSO group and the ISO group were insignificant ($P > .05$). The CME of jujube in the TSO group was not significantly greater ($P > .05$), whereas that of almond was significantly greater than that of the CD group ($P < .01$).

Mandibular excursion

The control of chewing cycles and centralization of end tracings in the cycles of the ISO group were better than those of the TSO group and the CD group, and those of the TSO group were better than those of the CD group. The control differential between the ISO and the CD groups was significant ($P < .05$), as was the differentials of end centralization ($P < .01$), whereas other differentials among these 3 groups were insignificant (Table 2).

The X, Y, and Z types of lateral occlusal contact slides, respectively, accounted for 50%, 50%, and 0% in the ISO group; 35.7%, 57.3%, and 7% in the TSO group; and 14.3%, 78.7%, and 7% in the CD group. However, the differentials among 3 groups were insignificant (Table 3).

TABLE 1

Comparative masticatory efficiency (CME) of three groups (average ± SE)†

Test Food	CD Group	TSO Group	ISO Group
Jujube	42.0 ± 24.8	57.7 ± 15.3	64.1 ± 8.3*
Almond	49.3 ± 30.0	76.3 ± 18.4*	79.4 ± 9.7*

†CD indicates complete dentures; TSO, tooth-supported overdentures; ISO, implant-supported overdentures.
*$P < .01$ (differentials between the TSO and ISO group and the CD group).

TABLE 2

Control and ends centralization of chewing cycle tracings (cases)†

Groups	Control			Ends Centralization (jujube)			Ends Centralization (almond)		
	Excellent	Regular	Poor	Excellent	Well	Poor	Excellent	Well	Poor
CD (n = 14)	3	8	3	3	8	3	2	8	4
TSO (n = 14)	6	7	1	9	3	2	7	4	3
ISO (n = 14)	10	4	0	14	0	0	11	3	0
*P**		<.05			<.01			<.01	

†CD indicates complete dentures; TSO, tooth-supported overdentures; ISO, implant-supported overdentures.
**P* shows the comparison between the ISO group and the CD group, whereas those of other comparisons are more than .05.

TABLE 3

Lateral occlusal slides analysis (cases)†

Groups	Type X	Type Y	Type Z
CD (n = 14)	2	11	1
TSO (n = 14)	5	8	1
ISO (n = 14)	7	7	0
*P**		>.05	

†CD indicates complete dentures; TSO, tooth-supported overdentures; ISO, implant-supported overdentures.
**P* stands for the comparisons among the 3 groups, which are all insignificant.

Amplitude of EMG

The differentials between the TSO group and the CD and ISO groups related to the anterior temporal muscle when chewing jujubes were significant ($P < .05$; Table 4).

Turns of EMG

The differentials between the TSO group and the CD and ISO groups related to the posterior temporal muscle when chewing jujubes were significant ($P < .05$; Table 5).

Integrated value (area) of EMG

The differentials between the TSO group and the CD and ISO groups related to the anterior temporal muscle when chewing jujubes were significant ($P < .05$; Table 6). In this test, we also assessed the patient's masticatory muscle activities pattern by observing the differences between area values of the masseter and temporal muscles. When the difference was positive, we classified the patient's masticatory muscle

TABLE 4

Amplitude of masseter, anterior temporal, and posterior temporal muscles†

	Masseter			Anterior Temporal			Posterior Temporal		
	CD	TSO	ISO	CD	TSO	ISO	CD	TSO	ISO
Clench									
Average	873.2	605.2	719.3	539.4	723.8	570.6	311.5	366.2	243.2
SD	655.4	471.0	358.7	303.2	334.0	371.3	314.4	159.1	204.1
Chewing (jujube)									
Average	853.1	852.3	756.0	586.8	963.4*	677.5	596.2	575.5	318.8
SD	489.0	540.1	495.3	195.2	521.4	460.7	745.8	248.9	198.3
Chewing (almond)									
Average	872.2	876.0	887.0	595.4	958.8	757.8	627.6	517.0	382.4
SD	485.6	659.1	542.8	249.6	560.1	501.9	730.8	178.3	205.6

†CD indicates complete dentures; TSO, tooth-supported overdentures; ISO, implant-supported overdentures.
*$P < .05$ (differentials between the TSO group and the CD and ISO groups).

TABLE 5

Turns of masseter, anterior temporal, and posterior temporal muscles†

	Masseter			Anterior Temporal			Posterior Temporal		
	CD	TSO	ISO	CD	TSO	ISO	CD	TSO	ISO
Clench									
Average	83.2	73.0	85.5	71.5	72.3	69.1	48.4	68.6	48.9
SD	26.8	8.7	28.3	39.0	8.7	16.4	32.2	19.4	20.0
Chewing (jujube)									
Average	70.4	69.6	64.4	66.3	68.5	62.9	57.3	68.4*	50.8
SD	18.3	18.7	8.2	12.6	16.1	12.2	14.2	10.7	20.2
Chewing (almond)									
Average	71.3	65.9	62.4	68.6	64.5	61.0	57.8	63.7	56.8
SD	22.2	12.3	10.7	12.8	8.3	11.2	19.2	8.5	19.4

†CD indicates complete dentures; TSO, tooth-supported overdentures; ISO, implant-supported overdentures.
*$P < .05$ (differentials between the TSO group and the CD and ISO groups).

TABLE 6

Area value of masseter, anterior temporal, and posterior temporal muscles†

	Masseter			Anterior Temporal			Posterior Temporal		
	CD	TSO	ISO	CD	TSO	ISO	CD	TSO	ISO
Clench									
Average	382.8	256.7	347.4	235.0	313.5	274.4	136.2	166.9	118.0
SD	273.2	183.4	185.4	126.9	155.6	207.4	122.6	71.4	99.9
Chewing (jujube)									
Average	53.7	55.7	50.5	37.8	59.6*	44.8	31.9	38.1	23.6
SD	30.4	32.9	33.9	13.5	32.9	28.1	23.4	16.9	13.8
Chewing (almond)									
Average	55.1	59.2	58.5	38.0	64.4	49.0	33.8	39.5	28.1
SD	26.4	52.2	39.8	16.2	52.8	32.8	20.2	18.7	15.6

†CD indicates complete dentures; TSO, tooth-supported overdentures; ISO, implant-supported overdentures.
*$P < .05$ (differentials between the TSO group and the CD and ISO groups).

pattern as masseter preponderant; otherwise we classified the patient's masticatory muscle pattern as temporal preponderant.

Of 40 patients, 28 adopted the temporal preponderant pattern during clenching, whereas 33 adopted it during habitual chewing. There were 3 patients using different activity patterns at the clench and the habitual chewing state in the CD group (21.4%) and the ISO group (25%), whereas in the TSO group only 1 patient exhibited different activity patterns (Table 7). The differentials among the 3 groups were not significant.

DISCUSSION

Comparative masticatory efficiency

Similar with other researchers' reports,[1–4] the patients in the CME test restored with ISOs and TSOs showed higher CME than those restored with conventional CDs, whereas the differentials between ISOs and TSOs were insignificant.

The CME of the ISO group, although not significant, had the tendency of being higher than that of the TSO group, especially in the case of food that is difficult to chew (jujube). This conclusion needs further study.

Mandibular excursion

In the ME test, the patients with ISOs showed significantly better control and end-centralization of chewing cycles over CD patients. The TSO patients' control was insignificantly better than measured for successful CD patients. These results suggested that ISOs could help improve patients' mandibular chewing cycle movements, which may be related to increasing CME. This result is not identical with the study of Leung and Haag,[9] which concluded less ability to control jaw-closing forces in the case of overdenture wearers.

Previous ME research demonstrated that the component of the chewing cycle that most influenced the increase in functional area is the lateral one, which also correlated with CME.[10] However, in this test there were no significant differentials in lateral occlusal slide tracings of the 3 groups of patients, although the differentials in CME were significant. The reason may be that we did not record quantitative statistics for the lateral slides.

Simple jaw reflexes are the fundamental drives of the chewing cycle. A single cycle is separable into an opening and then a closing reflex. The

TABLE 7

The masticatory muscles activity pattern of three groups of patients (cases)*

	Clenching			Habitual Chewing		
	MP	TP	Total	MP	TP	Total
CD	7 (50.0%)	7 (50.0%)	14 (100.0%)	5 (35.7%)	9 (64.3%)	14 (100.0%)
TSO	2 (14.3%)	12 (85.7%)	14 (100.0%)	1 (7.1%)	13 (92.9%)	14 (100.0%)
ISO	4 (33.3%)	8 (66.7%)	12 (100.0%)	1 (8.3%)	11(91.7%)	12 (100.0%)

*MP indicates masseter preponderant; TP, temporal preponderant; CD, complete dentures; TSO, tooth-supported overdentures; ISO, implant-supported overdentures.

opening reflex is activated by the stimulation of the proprioreceptors underlying the skin, oral mucosa, periosteum, periodontal ligaments, and adjacent tissues, whereas the closing reflex is activated by highly specialized receptors implanted in voluntary musculature.[11] From the different results of lateral slide tracings of the 3 groups, we observed that most of the patients with CDs have lateral slides in closing tracings, whereas more patients with ISOs and TSOs had lateral slides during opening tracings. This result suggested that more proprioreceptors existed in the periodontal tissues of ISO and TSO wearers, which supported the hypothesis of Jacob[12] that the rapid elastic bone deformation during implant loading might trigger periosteal receptors.

The good control and end centralization of chewing cycles in ISO wearers demonstrated that the neuromuscular chewing patterns could be nearer to normal in these edentulous patients than those of TSO and CD wearers. In addition to the proprioreceptors in the periosteum, the excellent retention and stability of ISOs may contribute to this finding.

Electromyographic computerized analysis

The results showed that the patients with TSOs displayed a greater amplitude and integrated value of EMG in the temporal muscle, which suggested the largest force of muscle contraction. Haraldson et al[13] demonstrated that in all masticatory muscles, only the amplitude of the temporal muscle is positively related to occlusal force. We inferred that the partly preserved periodontal proprioceptors might be beneficial to the preservation of masticatory muscle function.

In this study, 33 of the 40 edentulous patients adopted a temporal preponderant pattern in chewing, which was similar to the results of Gartner et al.[14] Compared with CD wearers, although of no significant differential, more patients with TSOs and ISOs chewed with this masticatory muscle–cooperating pattern. This suggested that the temporal preponderant cooperative pattern in chewing might be more applicable to edentulous patients than other patterns, since occlusal force increased linearly with the amplitude of temporal muscle contraction.

Analysis of the 3 indices of masticatory function suggest that CME is more correlated to ME and less correlated to masticatory muscle bioelectric activity. This is in agreement with the study of Slagter et al,[15] which showed that the peak amplitudes of masticatory muscles in chewing excursions were only slightly related to the reduction in particle size of chewed food.

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REFERENCES

1. Ejvind BJ. *Prosthodontics for the Elderly: Diagnosis and Treatment.* Chicago: Quintessence; 2001.

2. David RB. Mandibular implant overdenture treatment: consensus and controversy. *J Prosthodont.* 2000;9:37–46.

3. Fenton AH. The decade of overdentures: 1970–1980. *J Prosthet Dent.* 1998;79:31–36.

4. Fontijn-Tekamp FA, Slagter AP, Van Der Bilt A, et al. Biting and chewing in overdentures, full dentures, and natural dentitions. *J Dent Res.* 2000;79: 1519–1524.

5. Feine JS, de Grandmont P, Boudrias P, Donohue WB, Tanguay R, Lund JP. Within-subject comparisons of implant-supported mandibular prostheses: choice of prosthesis. *J Dent Res.* 1994;73:1105–1111.

6. Ahlgren J. Mechanism of mastication. *Acta Odontol Scand.* 1966; 24(suppl 44):1.

7. Tallgren A, Lang BR, Holden S, Huyser DJ, Miller RL. Longitudinal electromyographic study of chewing patterns in complete-denture wearers. *Int J Prosthodont.* 1992;5:415–423.

8. Grubwieser G, Flatz A, Grunert I, et al. Quantitative analysis of masseter and temporalis EMGs: a comparison of anterior guided versus balanced occlusal concepts in patients wearing complete dentures. *J Oral Rehabil.* 1999;26:731–736.

9. Leung T, Haag BM. Control of jaw closing forces: a comparison between implant-stabilised overdenture wearers and complete denture wearers. *Eur J Prosthodont Restor Dent.* 2000; 8:145–148.

10. Pera P, Bassi F, Schierano G, Appendino P, Preti G. Implant anchored complete mandibular denture: evaluation of masticatory efficiency, oral function and degree of satisfaction. *J Oral Rehabil.* 1998;25:462–467.

11. Lloyd DuBrul E. *Sicher and DuBrul's Oral Anatomy.* 8th ed. St. Louis: Ishiyaku EuroAmerica; 1988:129–131.

12. Jacobs R., van Steenberghe D. Role of periodontal ligament receptors in the tactile function of teeth: a review. *J Periodont Res.* 1994;29:153–167.

13. Haraldson T, Carlsson GE,

Dahlstrom L, Jansson T. Relationship between myoelectric activity in masticatory muscle and bite force. *Scand J Dent Res.* 1985;93:539–545.

14. Gartner JL, Mushimoto K, Weber HP, Nishimura I. Effect of osseointegrated implants on the coordination of masticatory muscles: a pilot study. *J Prosthet Dent.* 2000;84:185–193.

15. Slagter AP, Bosman F, van der Glas HW, van der Bilt A. Human jaw-elevator muscle activity and food comminution in the dentate and edentulous state. *Arch Oral Biol.* 1993;38:195–205.