

Masticatory efficiency after rehabilitation of acquired maxillary and mandibular defects

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Abstract

The effect of oral cancer with its therapeutic intervention involves significant facial and functional disabilities. It is customary to rehabilitate these patients by surgical or prosthetic means. Studies have been done to assess mastication and other functions after rehabilitation. A review of these studies for assessing masticatory function has been done under separate sections for maxillary and mandibular defects. Different masticatory tests are mentioned. Further scope for research has been highlighted.

Key words: Acquired defects, implants, masticatory efficiency, obturators, oral rehabilitation

INTRODUCTION

Surgical resection of head and neck tumors often create large defects accompanied by dysfunction and disfigurement with radiation producing significant morbidity. Rehabilitation by prosthesis or reconstruction by surgery is always necessary for these defects. Traditionally, recurrence rates and survival have been used to evaluate therapeutic interventions in head and neck cancer. However, in recent years there is an increased interest in the quality of life (QOL) of these patients. Masticatory performance after rehabilitation of acquired defects of maxillae and mandible has been evaluated in various studies. A review of these studies has been done and presented under separate sections for maxillae and mandible. There is a need for continued research to assess the current prosthodontics treatment objectively, identify problems and address them in future rehabilitation efforts.

MAXILLARY DEFECTS

Obturators provide an effective means of rehabilitation of maxillary defect patients.^[1,2] Remaining teeth

or properly positioned osseointegrated implants or a combination of these two, play a major role if a satisfactory outcome is to be achieved.^[3] In edentulous patients, implants provide retention, enhance support, and improve the stability of the obturator prosthesis. Mastication has been assessed by subjective and objective methods by various authors as shown in Table 1.

DISCUSSION

Comparison between prosthetic rehabilitation and surgical reconstruction

Patients who underwent reconstruction with a vascularized bone-containing free flap achieved higher mastication and speech assessment scores with less oronasal reflux than defect-matched patients rehabilitated with a prosthetic obturator. Swallowing QOL and donor site assessments demonstrated that compared with their prosthetic counterparts, surgically reconstructed patients with a vascularized bone-containing free flap enjoyed a better QOL without incurring significant donor site morbidity.^[5] Osteomyocutaneous flap reconstruction of the maxillectomy cavity can obscure surveillance and may make rehabilitation more problematic by obstructing drainage in the remnants of ipsilateral and paranasal sinuses, immobilizing the upper lip,

Access this article online

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DOI:

10.4103/0975-962X.155880

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Table 1: Evaluation of mastication after maxillary defect rehabilitation

Author	Year and study design	Sample size	Evaluation method/factors investigated to evaluate masticatory performance/obturator functioning	Method used
Kornblith <i>et al.</i> ^[4]	1996 Cross-sectional	47	Subjective	Telephone interview OFS* MHI† IES‡
Genden <i>et al.</i> ^[5]	2003 Cross-sectional	4 prosthetically rehabilitated patients 4 surgically rehabilitated patients	Subjective and objective evaluation	QOL for mastication and swallowing threshold Speech and mastication
Koyama <i>et al.</i> ^[6]	2005 Cross-sectional	50 26 dentate, 24 edentulous	Defect size Defect configuration	Sato questionnaire ^[7]
Matsuyama <i>et al.</i> ^[8]	2006 Cross-sectional	20	Maximal bite force	Free chewing ^[9]
Ono <i>et al.</i> ^[10]	2007 Cross-sectional	27	Objective evaluation Extent of the hard palate resection Presence of posterior teeth in the maxilla Maximum occlusal force Mouth opening distance	A testing gummy jelly ^[11,12]
Irish <i>et al.</i> ^[13]	2009 Cross-sectional	42	Subjective evaluation	Questionnaires OFS MHI IES IIRS§ CES-D
Nagy <i>et al.</i> ^[14]	2014 Longitudinal	80 12 maxilla	Subjective	Questionnaires UWQOL# EORTC 35 H and N QOL** DOESAK questionnaire††
Depprich <i>et al.</i> ^[15]	2011 Cross-sectional	31	Subjective	
Kreeft <i>et al.</i> ^[16]	2012 Cross-sectional	32	Subjective Objective	Questionnaire (swallowing complaints and maximal mouth opening) Mastication Chewing strokes (10 and 20 strokes)

*Obturator functioning scale, †Mental health inventory, ‡Impact of events scale, §Illness intrusiveness ratings scale, ||Centre for epidemiologic studies depression scale, #University of Washington quality of life questionnaire, **European organization for research and treatment of cancer-head and neck, ††The citation for DOESAK is the questionnaire developed by German, Austrian and Swiss cooperative group on tumours of maxillofacial region, ††The name of questionnaire is DOESAK. The questionnaire was developed by German, Austrian and Swiss cooperative group on tumours of maxillofacial region, QOL: Quality of life

tethering the free end of the soft palate, and restricting mandibular mobility.^[17]

Comparison between dentate and edentate obturator wearer

Ono *et al.* objectively assessed the mastication.^[10] Patients performed maximal clenching with a pressure sensitive sheet placed between maxilla and mandible. Maximal occlusal force ranged between 15 and 375 N. Matsuyama *et al.* concluded that the presence of critical residual dentition with well-functioning obturator is essential for effective masticatory performance.^[8] Edentulous patients with obturator had worse outcomes than dentate patients, measured by mixing ability test and questionnaire.^[16] It was also found that the number of occluding postcanine teeth and the patient’s sex were factors that influenced masticatory performance. It was most important to improve occlusion in the premolar/molar region.^[18]

Correlation between defect configuration and function

According to Ono *et al.* masticatory performance was better when the extent of the hard palate resection

was less than half, and when there is the presence of mandibular teeth on nonresected side. Furthermore, masticatory performance was better when the occlusal force was > 100 N.^[10] Koyama *et al.* concluded that the presence of teeth and the configuration of defect have significant correlation with masticatory function. There was no significant correlation between number of teeth and size of the defect in dentate group. However, the size of sample was limited in this study.^[6] Kornblith *et al.* based on telephonic questionnaire concluded that masticatory performance did not significantly differ between maxillectomy group and control group.^[4]

Difficulties reported with obturator functioning and surgical reconstruction

Patients reported most difficulty with leakage when swallowing foods. Other areas of difficulty included a dry mouth and chewing difficulty. Patients reported the least difficulty with speech intelligibility, inserting or removing the obturator and avoidance of family and social events.^[13] Good obturator function has been reported to account for improved QOL.^[15]

Use of implants in resected regions

Though implants can be used for retention in rehabilitation cases, specific implant sites reveal variable success rates, with the anterior maxilla being 86% successful compared with the posterior maxilla being 57% successful. Radiation reduces the success rate from 80% to 55%, although it does not eliminate a patient from being a candidate for implantation.^[19] The overall survival rate for implants in this patient population was 69.2%. The percent implant survival rate was 63.6% for the irradiated group (67.0% before radiation, 50.0% after radiation) and 82.6% for the nonirradiated group.^[20]

Acquired mandibular defects

A number of factors affect the patient's functional status after resection. The impairment of motor and/or sensory control, in particular the integrated neuromuscular balance between the tongue, lips, and cheeks, limits the ability of the patient to control saliva, the food bolus, and dentures during function. In addition, deviation of the mandible and the angular pathway of mandibular closure-induce lateral forces upon removable prostheses that tend to dislodge them. During the closure, the abnormal maxillomandibular relationship may prevent proper occlusion of the residual dentition or ideal placement of the denture teeth over their supporting structures.^[21] Frontal plane rotation and unilateral forces of occlusion tend to tip and dislodge both maxillary and mandibular dentures during function. This factor, with the addition of impaired tongue function, may totally compromise mastication in some patients.

In the 1980s, pedicled myocutaneous flaps were used to replace the resected soft tissues and these flaps eliminated the need to approximate the tongue margin to the cheek margin for primary closure of the defect.^[22,23] The residual or reconstructed tongue had improved mobility and was better situated to control the air stream during articulation and manipulate the bolus during mastication. If the patient has dentition remaining in the unresected portion of the mandible or implants to retain the prosthesis, these patients may be able to masticate at a reasonable level dependent upon the amount of remaining tongue and innervation.^[24,25] Patients whose wounds are closed with a myocutaneous or free flap soon attain an acceptable interocclusal relationship, without adjunctive therapy, although some patients whose wounds are closed primarily are never able to achieve an appropriate and stable interocclusal position. Scar contracture; tight wound closure, and muscle imbalances secondary to the primary resection all contribute to mandibular deviation. Mandibular

deviation is most severe following primary closure of the base of the tongue lesions. When a usable occlusal relationship is achieved, the mandibular teeth often occlude distal to the presurgical pattern of cuspal interdigitation. On the nonsurgical side, the buccal slopes of the mandibular buccal cusps function with the central fossae of the maxillary teeth because of mandibular rotation in the frontal plane. The reported success rates of implants in fibula flaps are generally >95%.^[26-28] The results of studies postrehabilitation are summarized in Table 2.

DISCUSSION

Correlation between mandibular continuity and mastication

In the study, it was found that the occlusal force values of mandibulectomy patients were lower than noncancer patients, but there was no statistically significant difference. This could be because of small sample size or because of between and within subject variability seen with occlusal force measurements.^[36] The area of contact was lowest in a patient who lacked mandibular continuity.^[31] This is in accordance with the original belief that mandibular continuity is essential for mastication.

Comparison between surgically reconstructed group and nonreconstructed group

Curtis *et al.* found that although bite force was lower in nonreconstructed patients, the levels were not significantly different from the reconstructed subjects and were probably above the threshold needed for mastication of the typical Western diet. The typical Western diet requires <40 N of biting force, whereas harder-to eat foods, such as nuts and carrots, require an average of 66 N.^[40] Impairment in masticatory ability remained following free flap reconstruction prior to prosthetic rehabilitation.^[42]

Comparison between dentate and edentulous patients

Dentate controls required the least amount of strokes to achieve swallowing threshold, followed by denture wearers and those without dentures. Edentulous patients had least scores with swallowing threshold and mastication. Subjects who had stable dental arch in the opposite jaw with either natural teeth or an implant supported fixed prosthesis (OIFP) had higher chromatic values than those who wore conventional dentures.^[42] According to Marunick and Mathog subjects who were rehabilitated performed better than those without them. Dentate controls required the least number of strokes and time to achieve swallowing. The edentulous cancer patients without dentures had low masticatory performance scores and swallowing threshold performance and required

Table 2: Evaluation of mastication after mandibular defect rehabilitation

Author	Year and study design	Sample size	Factors investigated to evaluate masticatory performance	Method used
Marunick and Mathog ^[29]	1990 Longitudinal	Control-6 dentate patients Subjects-3 (They were evaluated in the beginning of the study. They served as their own controls)	Dentition and occlusion TMJ status and mandibular movements Biting force Salivary function Sensory motor functions	Frito corn chips (0.5 am portion) Chewing cycle of 15-30 strokes Gnathodynamometer and silicone gum rubber ^[30] Unstimulated and stimulated salivary flow
Matsui <i>et al.</i> ^[31]	1996 Cross-sectional	Control-15 normal dentate patients 15 patients 5 (no resection involving floor of the mouth, tongue) 10-Resection involving floor of the mouth and tongue. 7 patients had a defect of the hypoglossal nerve 13-Had OIFP* 2-IRO*	Objective assessment Area of occlusal contact Chewing performance	Dental prescale ^[32,33] Low adhesive color developing chewing gum The developed color was evaluated in the Lab color system with the Chroma mater ^[34,35]
Curtis <i>et al.</i> ^[36]	1999 Cross-sectional	Control 6 dentate patients 6 with prosthetic rehabilitation	Objective assessment The results were compared with a similar computer generated mode ^[33,34] Bite force were recorded at molar level and incisal level EMG during maximal voluntary clenching and gum chewing	Uniaxial beam test ^[37] On the three-dimensional model, maximum occlusal force, JF/TF ratio, and magnitude and direction of mandibular rotation were calculated Gnathohexograph ^[39]
Haraguchi <i>et al.</i> ^[38]	2003 Cross-sectional	Control 3 dentate patients 3 patients	EMG during maximal voluntary clenching and gum chewing	Gnathohexograph ^[39]
Curtis <i>et al.</i> ^[40]	2006 Cross-sectional	10-Surgical reconstruction 10-No surgical reconstruction	Bite force Tongue and cheek function Masticatory performance Number of tooth to tooth contacts	Uniaxial beam test ^[37] Food scale questionnaire ^[41]
Roumanas <i>et al.</i> ^[42]	2006	46 23-CP 15-IP	Masticatory performance Swallowing threshold	Standard masticatory tests ^[43,44] Tests using carrot
Kapur <i>et al.</i> ^[45]	1998	89 diabetic patients 37-conventional complete denture (CD) 52-IP	Subjective assessment Objective assessment	Detailed examination, tests, Questionnaires (Results revealed higher satisfaction in chewing comfort with IP)
Roumanas <i>et al.</i> ^[46]	2002	68 diabetic patients 25-CD 43-IP	Subjective assessment	Questionnaires (results revealed decline in perceived chewing ease and eating frequency more common in conventional prosthesis than implant supported prosthesis)

*Implant supported fixed prosthesis, †Implant retained overdenture, TMJ: Temporomandibular joint, EMG: Electromyographic, JF/TF: Joint force/Tooth force ratio, OIFP: Implant supported fixed prosthesis. Both the studies^[45,46] are included in the article because they compared conventional complete denture with implant supported overdenture

greater number of strokes and time to achieve swallowing threshold performance compared with appropriate control group.^[29] Measurements were made at an interocclusal distance of 13 mm as recommended by Manns *et al.*^[47]

Correlation between tongue innervation and mastication

Of the patient who had defects of the hypoglossal nerve none scored a value greater than the mean of nontumor patient. This is due to the low mobility of the tongue.^[31] This is in agreement with Kapur *et al.* who reported that masticatory function in normal dentate subjects could be reduced through the selective anesthesia of the oral cavity.^[48] Curtis *et al.* also found that occlusal force was poorly correlated with function, whereas measure of tongue function strongly correlated with successful mastication.^[40]

Comparison between implants prosthesis and conventional prosthesis OIFP and implant retained overdenture

Treatment with conventional prosthesis (CP) and implant-supported prosthesis (IP) significantly increased the performance on the defect side only in performance over post surgical interval and were not significantly different from performance at the entry level prior to surgery. Performance at the defect side with IP was significantly greater than the performance with CP. IP greatly increased the number of patients who masticated the test food on the defect side compared to CP. CP and IP may provide improved masticatory ability permitting patients to regain functional level they possessed prior to surgical intervention.^[42]

Implanted patients who had OIFP had higher chromatic values than those who wore implant

retained overdenture.^[31] No statistically significant difference existed between three groups. Subject who had some natural teeth in the implanted jaw were also tested with the chewing side restricted to the prosthesis. However, there was no statistically significant difference between tumor and nontumor group because there were treated with implants. Swallowing threshold performance with IP was similar to that of an average denture wearer.^[42] Garrett *et al.* also found that after treatment with CP 88% of the 25 subjects completing evaluation were able to masticate the test food on the non-defect side, while half of these continued to not be able to masticate on the defect side. After the treatment with the IP 14 of the 15 subjects, completing evaluation could masticate the test food on both sides.^[42]

ELECTROMYOGRAPHIC ACTIVITY IN MARGINAL MANDIBULECTOMY PATIENTS

Haraguchi *et al.* found that the electromyographic (EMG) activity in the patients during maximum voluntary clenching was significantly lower than that in the healthy subjects, and dominant anterior temporalis (TA) activities on the resected side were observed. Since the patients in the current study had undergone marginal resection of the mandible, it is plausible that the decrease in the muscle activity during maximum voluntary contraction (MVC) was observed only in the masseter muscle (MM) on the resected side. More specifically, as the equilibrium between TA and MM tended to compensate each other on one side and to balance between the left and right sides, the result was no difference between the normal and resected sides. However, the patients may not perform MVC aggressively due to psychological damage resulting from surgery.^[38] In his study, burst and chewing time/1 cycle and I EMG of 1 cycle/1 s during Gch in the patients with mandibular continuity were not significantly different from those of the healthy subjects despite having the mandibular defect. Every range of mandibular movement in the anterior-posterior direction/1 cycle during Gch in the patients showed significantly larger movements than that in healthy subjects, and that in a vertical direction also tended to increase. This result shows that patients may produce muscle activities for grinding foods by moving their mandibles to a larger extent in the posterior-down direction.

Masticatory tests used

Standard masticatory function tests have used various food substances and synthetic materials designed primarily for evaluation of natural dentition and denture efficiency.^[43,44] For determining tongue and cheek clearance during mastication peanuts were

used.^[49] Matsuyama *et al.* used originally modified sieve method using hydrocolloid material.^[8,9] A testing gummy jelly was originally developed for measuring masticatory performance (Ezaki Glico).^[11,12] A jelly with texture number 3 was chosen among the 6 textures by Ono *et al.*^[10]

Originally chewing gum method was used for testing functional rehabilitation with implants. The chewing function is indicated by the color developed.^[34,35] Yoshiro used one more method to evaluate mastication because mastication requires a combination of crushing, cutting and mixing actions. He used the dental prescale which is a horseshoe shaped sheet with a thickness of 97 μ that consists of two layers: A layer of microcapsules containing color forming material and a layer of color developing material.^[31-33] The dental prescale system can be used to detect contact areas to which a pressure of >30 kgf/cm² has been applied. This is superior to other tests such as silicone, which provide little resistance to occlusion.^[34,35] By the mixing of two gums, this color is evaluated by chromameter.

Marunick and Mathog in his study found that partial mandibulectomy patients could not incise 0.5 g sample of carrot.^[29] He used Frito corn chips as an ideal test substance because according to him it satisfied the following criteria; soft to avoid local tissue injury or pain, pliable to allow for mastication, particulate for sieve analysis and acceptable to taste. It can be considered ideal for head and neck cancer patients. A customized gnathodynamometer was used to record biting pressure. The sensor portion of gnathodynamometer with silicone gum rubber was placed on the upper member of the bite plate. He made measurements at an interocclusal distance of 13 mm as recommended by Manns *et al.* who found that biting strength is greatest at a vertical dimension of 10–20 mm.^[47] Curtis *et al.* used uniaxial strain beam test, which was first used by Sposetti *et al.*^[36,37] Garrett *et al.* used interleaving beam strain gauge transducer. It is placed in second premolar, and first molar area, and subjects are asked to bite as hard as possible.^[42] Use of easier to chew food items was not considered in the study of Garrett *et al.* as he felt that this would have required extensive testing to verify that the revised masticatory test was sensitive to differences in masticatory ability and would provide sufficient data against which to compare.^[42]

In another study Curtis *et al.* used a food scale questionnaire to subjectively assess mastication.^[40] Food scale questionnaire was developed by List *et al.* and was shown to be reliable and valid specifically to measure masticatory performance of head and neck

cancer patients.^[41] The swallowing threshold test was included to assess the particle size distribution, number of strokes, and the time that was taken for the subject to accept the food as ready to swallow in normal unrestricted mastication. This is because subjects may attempt to compensate for reduced ability using more masticatory strokes, longer time for each stroke or accepting larger particles for ingestion.^[5,16,42] Both unstimulated and stimulated salivary flow rates were recorded because alterations in salivary flow affect mastication.^[29,42] Evaluation for lips and tongue were also done by Marunick and Mathog for assessing sensory motor function.^[29]

Additional studies and tests

The computer model for mandibulectomy subject with reconstructed mandible was generated by simulation of the average person and removing structures to represent anatomic loss.^[36] The model was developed based on the computer modeling program developed by Nelson and Hannam, which was developed according to static equilibrium theory.^[50,51] Computer simulations predicted reconstructed mandibulectomy patients would have 45% less molar clenching force and 50% less incisal clenching force with respect to first molar force. However, the predicted occlusal force values were less than the clinically determined average of 118 N. Muscles can reinsert to neomandible and may have provided the additional pull.^[36] Haraguchi *et al.* conducted a study to measure the mandibular movements and EMG activity of muscles after prosthetic rehabilitation in marginal mandibulectomy patients. The measurements were done using Gnathohexograph. This system is a noncontact-measuring device and has the ability to record three-dimensional measurements of movements of arbitrary points with 6° of freedom.^[38,39]

Implants in the rehabilitation of oral cancer patients

Implant-supported prosthesis may contribute to greater support and stability of the prosthesis resulting in increased use for mastication and superior performance on the defect side compared to CP.^[40] However, this treatment should be considered after 1-year of surgical treatment due to a high rate of recurrence/metastasis (35%). Survival of implants in native bone in maxilla and mandible was 79.8% and 100%, respectively, after 3 years. For implants placed in the native bone, there was a higher likelihood of failure in the maxilla compared to the mandible and there was also a tendency for implants placed in the posterior region to fail compared to those placed in the anterior region.^[52] With regard to the preparation of the fixture hole, a 2Æ85 mm twist drill was used instead of a 3 mm drill, and drilling was done very gently and without tapping because grafted iliac

bone is very soft.^[53] Exclusively, implant-supported telescopic prostheses seem to avoid prosthesis related soft tissue ulcers and appear to be favorable, especially in the case of difficult anatomic conditions and following irradiation.^[54] Gürlek *et al.* concluded that implants enhance dental restoration in selected patients, and micro-vascular bone flaps, including the fibula and iliac crest, are well suited for dental implant restoration.^[27]

Further scope of research

Results also indicate that preservation of the hypoglossal nerve is the main determinant of whether postoperative tumor patients could achieve the same level of mastication as nontumor patients. Use of sensate flaps might be helpful.^[55,40] If a patient has compromised tongue function and cannot selectively manipulate a bolus to the occlusal platform or consolidate a bolus prior to swallowing, even a stable and retentive mandibular prosthesis will not benefit the patient. Curtis *et al.* found that occlusal force was poorly correlated with function, whereas measurement of tongue function strongly correlated with successful mastication.^[40] Model simulations which exactly duplicate exact anatomic deficits of these patients could be developed.^[40] Stem cells along with xenograft and bone morphogenic protein attains new bone formation with sufficient quantity and quality to allow for implant placement, with decreased patient morbidity and surgical time compared to conventional reconstructive methods.^[56] A multi-site clinical trial could provide sufficient samples to address problems related to specific defects and adaptation.

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How to cite this article: Vijayaraghavan NV, Ramesh G, Thareja A, Patil S. Masticatory efficiency after rehabilitation of acquired maxillary and mandibular defects. *Indian J Dent* 2015;6:139-46.

Source of Support: Nil. **Conflict of Interest:** None declared.