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Clinical Test of Masticatory Efficacy in Patients with Maxillary/Mandibular Defects Due to Tumors

Bernd Reitemeier[a] Michael Unger[a] Gert Richter[a]
Barbara Ender[b] Ursula Range[c] Jutta Markwardt[d]

[a]Poliklinik für Zahnärztliche Prothetik, Universitätsklinikum, Technische Universität Dresden,
[b]Deutsche Gesellschaft für Ernährung e.V., Sektion Sachsen,
[c]Medizinische Fakultät Carl Gustav Carus, Institut für Medizinische Informatik und Biometrie,
[d]Klinik und Poliklinik für Mund-, Kiefer- und Gesichtschirurgie, Universitätsklinikum, Technische Universität Dresden, Germany

Keywords

Masticatory efficacy · Resection prosthesis · Tumor patient · Nutrition guideline

Schlüsselwörter

Kaueffektivität · Resektionsprothese · Tumorpatient · Ernährungsrichtlinie

Summary

Background: The goal of the study was to evaluate the masticatory efficacy in patients who had been provided with resection prostheses after tumor removal in the maxillary/mandibular region. These patients complained of impairment of masticatory function. **Patients and Methods:** 3 groups of patients were compared under clinical-experimental conditions. A uniform chewing material was masticated by the participants under standardized conditions. A sieving procedure was used to evaluate the masticatory efficacy. Analysis of the particle sizes and particle masses obtained was performed with the aid of computers. **Results:** The results showed that the masticatory efficacy of the patients with resection prostheses was the lowest of the 3 groups compared. The number of existing supporting zones and the location of the defect were found to be important influencing factors. Recording of the dietary habits of all patients was performed using a standardized dietary questionnaire. These data were analyzed using the corresponding software of the German Nutrition Society. With regard to the patients with resection prostheses, it was revealed that they often switched to food that did not require mastication. **Conclusions:** A nutritional guideline for patients with resection prostheses was developed, which is available for downloading free of charge on the Internet.

Zusammenfassung

Hintergrund: Ziel der Untersuchung war die Prüfung der Kaueffektivität bei Patienten, die mit Resektionsprothesen nach Tumorentfernung im Kieferbereich versorgt worden waren. Diese Patienten klagten über eine Einschränkung der mastikatorischen Funktion. **Patienten und Methoden:** Unter klinisch experimentellen Bedingungen erfolgte der Vergleich von 3 Patientengruppen. Unter standardisierten Bedingungen zerkleinerten die Patienten einheitliches Kaugut. Zur Bewertung der Kaueffektivität wurde ein Siebverfahren eingesetzt. Die Auswertung der ermittelten Partikelgrößen und Partikelmassen erfolgte computergestützt. **Ergebnisse:** Die Ergebnisse zeigten, dass im Vergleich der 3 Gruppen die Kaueffektivität der Patienten mit Resektionsprothesen am geringsten war. Die Zahl der vorhandenen Stützzonen des Restgebisses und die Defektlokalisation wurden als bedeutsame Einflussfaktoren ermittelt. Die Erfassung der Ernährungsgewohnheiten aller Patienten erfolgte mittels eines standardisierten Ernährungsfragebogens. Diese Daten wurden mit der zugehörigen Software der Deutschen Gesellschaft für Ernährung ausgewertet. Bei den Patienten mit Resektionsprothesen zeigte sich, dass diese auf Nahrungsmittel ausweichen, die kein Kauen erfordern. **Schlussfolgerungen:** Es wurde eine Ernährungsrichtlinie für Patienten mit Resektionsprothesen abgeleitet, die zum kostenfreien Herunterladen im Internet zur Verfügung steht.

Background and Goal

Patients who were provided with a resection prosthesis after tumor removal in the upper and/or lower jaw subjectively complained of a massive impairment in their masticatory function. Therefore, the primary goal of the study was the objective documentation of masticatory efficacy.

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Prof. Dr. Bernd Reitemeier
Poliklinik für Zahnärztliche Prothetik
Universitätsklinikum an der Technischen Universität Dresden
Fetscherstraße 74, 01307 Dresden, Germany
Tel. +49 351 458-2193, Fax -4368
bernd.reitemeier@uniklinikum-dresden.de

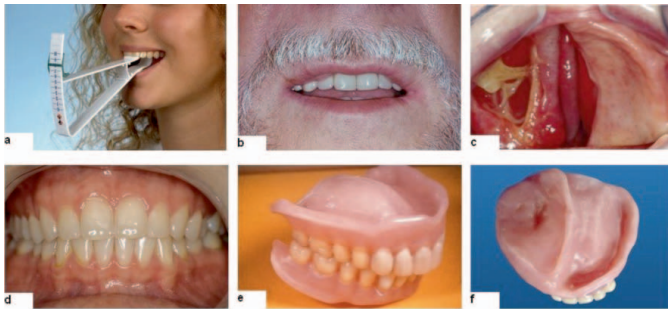

Fig. 1. (Left) Female patient with complete dentition (**a**) and her intraoral situation (**d**). (Middle) Patient with complete denture (**b**) and the prostheses removed from the mouth (**e**). (Right) Patient with a half-side resection in the upper jaw (**c**); in addition, the basal view of the resection prosthesis is shown (**f**).

The subgoals represented multiple aspects involved in this issue. The primary focus was on the objective testing of masticatory efficacy in patients with resection prostheses. Patients with complete dentition and patients with complete denture served as comparison groups. In addition, the individual dietary habits of all patients were documented. The final subgoal concerned the drafting of a nutritional guideline for patients with maxillary/mandibular defects and resection prostheses.

Patients and Methods

The patients were divided into 3 groups of 20 persons each:

- Group 1 consisted of persons with complete dentition and no impairments of the occlusal relationships. The average age of the group members was 27 years. The group consisted of 18 women and 2 men. These were students of the Medical Faculty of Dresden who voluntarily participated in this study. They were chosen at random. This group is designated below as 'patients with complete dentition'.
- Group 2 consisted of toothless patients who had complete denture in the upper and lower jaws. Only patients who had been wearing fully functional prostheses for at least 1 year without pain were included. The average age of this group was 72 years. The group consisted of 9 women and 11 men. These people were patients who had been treated in the clinic for prosthodontics. They were also chosen at random. This group is referred to below as 'patients with complete denture'.
- Group 3 consisted of patients who were treated with resection prostheses after the removal of tumors in the upper or lower jaw. This group included 10 patients with resection prostheses after hemimaxillectomy. The other 10 patients were provided with resection prostheses after partial mandibulectomy (without disruption of the mandibular continuity). The defects in the groups were comparable. In this 3rd group, the prostheses had been worn without pain for at least 1 year as well. The average age of this group was 62 years. The group consisted of 11 women and 9 men. Surgical and prosthetic treatment was carried out at the University Hospital Dresden. This group is designated hereafter as 'surgical prosthetic patients'.

Figure 1a–f shows typical examples. Patients with implant-based prostheses were intentionally excluded. The situation of patients with implant-based prostheses varies greatly depending on the number and arrangement of the implants, so that the conditions would not have been comparable at all. The group of the surgical prosthetic patients represents the worst-case situation in the study.

Table 1. Composition of the chewing test masses

Designation	Chemical characterization	Masses, %
Water	H_2O	63.9
Gelatin	polypeptide	25.5
Glycerin	$C_3H_5(OH)_3$	10.2
Gelan	polysaccharide	0.3
Sorbic acid	$C_6H_8O_2$	0.1

The patients with complete dentition or residual dentition were assigned to groups according to the Eichner classification [1]. The basic criterion for this classification is the number of existing supporting zones. Occlusal areas are antagonistic dentition contacts in the left and right molar regions. There is a maximum of 4 supporting zones per patient.

Gelatin-based chewing test masses were created for the study. Their composition is listed in table 1. The materials used are approved as foodstuffs and/or foodstuff additives and are thus toxicologically safe [2]. Furthermore, sufficient gel stability, neutral taste, ease of production and adequate shelf life were important requirements.

The liquid material was poured bubble free into a plastic plate with uniform bore holes. First, it was cooled down to room temperature. In order to form the gel, the entire plate with the test masses was placed in a separate laboratory refrigerator at a temperature between +4 and +6 °C. Then, the plates were stored in disposable freezer bags in the refrigerator at the same temperature. The cylindrical chewing test masses had the following dimensions: height 20 mm, diameter 16 mm. The average weight of a test mass was 6.1 g.

The process of comminuting the chewing test masses took place under standardized conditions, e.g. exclusively in the morning. Each patient had to complete 30 chewing cycles per test mass. Each patient had to comminute 10 test masses. The break between 2 test masses was 1 min each. The patients were instructed not to swallow any pieces of the chewing test mass. The patients rinsed their mouths before starting a new test. The times required for the 30 chewing cycles per test chewing mass were recorded using a stopwatch for orientation purposes only.

After the chewing mass was subjected to a specified drying process (brief rinsing under tap water and drying for 20 min under a suction device), the analysis for each individual subtest was performed using fractionated sieving with regard to particle weight and particle size. A device of the type Analysette 3 pro (Fritsch Laborgerätebau, Idar-Oberstein, Germany) was used for this purpose. The mesh width ranged from 0 to 16.00 mm. Because only particles larger than 1.0 mm were found, the results for the particle size ranged from 1.0 to 16.0 mm. After the uniform sieving process lasting 2 min at an amplitude of 1.5 mm and a frequency of 50 Hz, the sieved product was weighed using a computerized scale of the type O-haus Explorer (Ohaus, New Jersey, USA) (fig. 2a, b). The analysis was performed using the corresponding software of the type Autosieb (Fritsch Laborgerätebau).

Statistical analysis was carried out by means of the software package PASW Statistics 18. Contingency table analysis with the chi-square test as well as the Kruskal-Wallis test and the Mann-Whitney-U test were used. The significance level was set at $\alpha = 0.05$. Bonferroni correction was effected on multiple testing.

Additionally, the individual dietary habits of the patients were documented for 7 consecutive days using a standardized questionnaire (type: VEGETA2) from the German Nutrition Society [3]. The analysis was carried out using the nutrition software of the type DGE-PC professional (GEO-Software, Linden, Germany).

For orientation purposes, the occlusal forces were determined using a gnathometer (Blend-a-med Forschung, Schwalbach, Germany) in the right and left molar regions and in the front region. A new gnathometer was used for each measurement [4].

The ethics committee of the Faculty of Medicine of Dresden University of Technology approved this study (no. EK 82042004). Informed written consent was obtained from each patient for inclusion in the study.

Table 2. Chewing times in the 3 groups of patients

Group	Chewing time[a], s
Patients with complete dentition	21.0 ± 4.0
Patients with complete denture	29.2 ± 10.0
Surgical prosthetic patients	36.5 ± 12.7

[a]Mean value ± standard deviation.

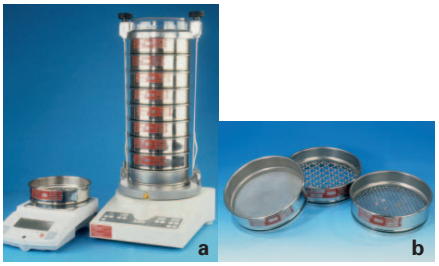

Fig. 2. Sieve tower with scales (**a**), individual sieves with different mesh widths (**b**).

Results

Figure 3 shows an overview of the results of the chewing efficacy analysis. The various particle sizes resulted from the sizes of the holes in the sieves used. In particular, the fact that the share of larger particles increased from the patients with complete dentition to the complete denture wearers to the patients with surgical prostheses is noteworthy. In a comparison of the 3 groups, the last-mentioned group had the smallest degree of comminution and thus the least masticatory efficacy. This is shown by the following situations in figure 3: The percentage of smaller particles up to a maximum size of 8 mm declined from the test subjects with complete dentition to the complete denture wearers to the surgical prosthetic patients. These results are shown by the yellow, orange and light blue columns.

On the other hand, the share of larger particles increases in the fractions in the same sequence. These results are shown by the gray and red columns.

The ranking for the test groups with decreasing masticatory efficacy is as follows:
– patients with complete dentition,
– patients with complete denture,
– surgical prosthetic patients.
Significant differences were obvious between the group of the test persons with full dentition and both patient groups ($p < 0.001$), which could have been expected. Significant differences were also detected between the groups of patients with total prostheses and the surgical prosthetic patients ($p < 0.001$).

The influence of age was evaluated. All patient groups were significantly different regarding their age ($p < 0.001$). The results for the patients with complete dentition clearly differed from the results for all other patients.

Table 2 shows the average mastication times. All patient groups showed significant differences regarding the mastication time ($p < 0.001$). Further to the analysis of the weight distribution density, it was noted that not only the degree of comminution in the form described above declined between the group of patients with complete dentition and the group of surgical prosthetic patients but the mastication time increased as well.

The number of supporting zones was also reviewed as another possible influencing factor. As expected, the masticatory efficacy increased with increasing number of the patients' own supporting zones (fig. 4). To visualize this, colored columns similar to those described in figure 3 were used.

Considering the masticatory efficacy in connection with the defect localization within a patient group with resection prostheses, patients with maxillary defects achieve a higher masticatory efficacy in comparison to patients with mandibular defects (fig. 5). Particle sizes < 11.2 mm appear significantly more often in patients with maxillary defects; larger particles predominate in patients with mandibular defects ($p < 0.001$). Colored columns like those already used for evaluation were also used in this case.

The occlusal forces were documented for orientation purposes. For the test patients with complete dentition, the measured data in both molar regions exceeded the display possibilities of the gnathometer. As with the masticatory efficacy, the values declined from the group of patients with complete dentition to the patients with complete denture to the surgical prosthetic patients (table 3).

The documentation of the dietary habits revealed insufficient fluid intake and often a diet excessively high in fat, in all groups of patients. Furthermore, a very one-sided choice of diet only appeared in the group of patients with surgical prostheses, who tended to prefer food that did not require any mastication.

Discussion

The comparability of the masticatory efficacy measurements presented in the literature is very low because, e.g., use of the mastication time or the number of mastication cycles as parameters and the various analytical methods applied differ greatly.

Artificially produced mastication material is preferred over 'natural foodstuffs' [5, 6]. The mastication material used in this study met the requirements of Dahlberg [7], which are still valid today. The use of silicone molding materials [5] did not prove useful in practice due to their consistency. Gunne et al. [8] hardened the gelatin test masses using formalin, which is unacceptable today. Thus, gellan gum was added as a stabilizing additive to the gelatin used in the study [2]. In a modification of this method, no flavoring was used because the sense of taste in surgical prosthetic patients and patients with complete denture is reduced. This is observed simply with increasing age alone [9].

The specification of the parameter for the uniform number of mastication cycles proved favorable in this study. The mas-

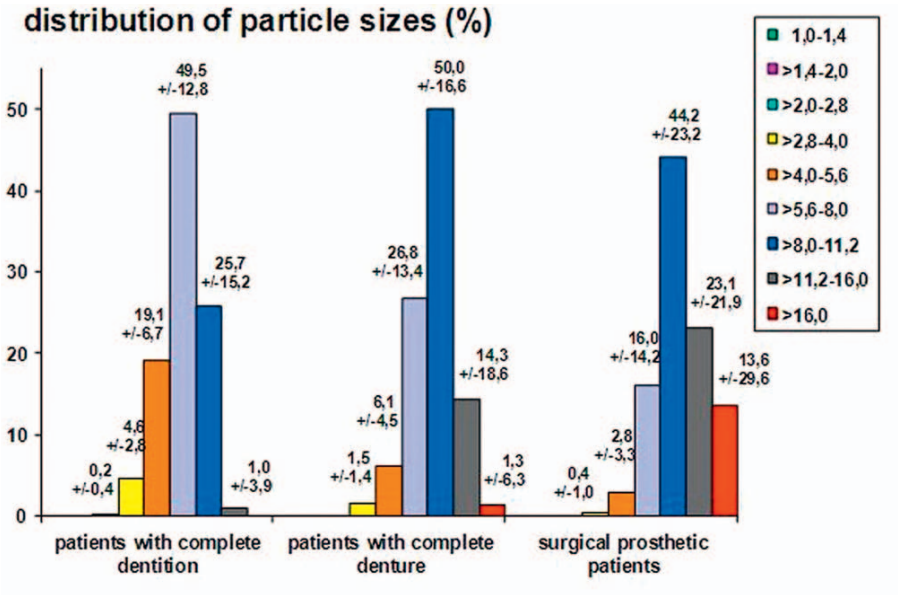

Fig. 3. Comparison of the average values of the proportional shares of the mass distribution density (sieve residues) of the patient groups as a function of the particle size. The ordinate indicates the proportional shares.

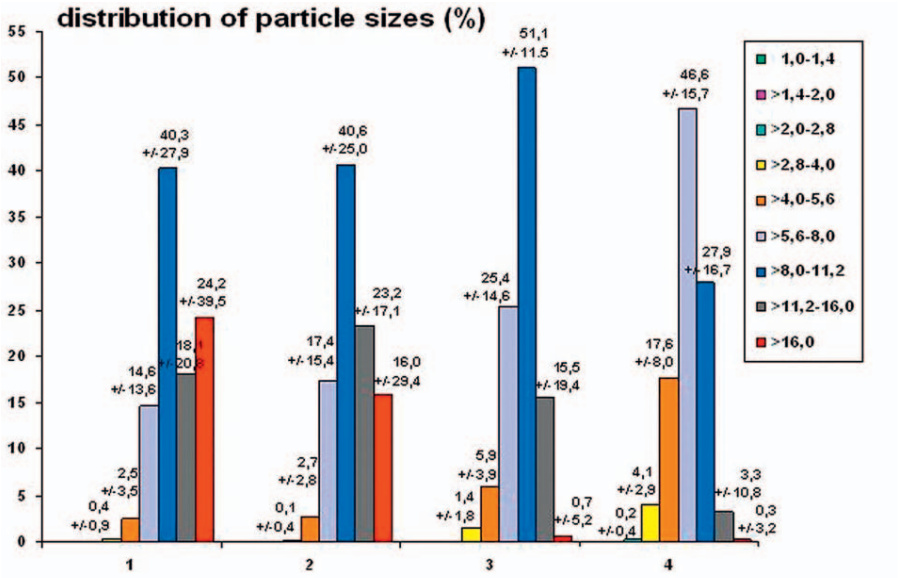

Fig. 4. Comparison of the average values of the proportional shares of the mass distribution density (sieve residues) for the number of supporting zones (1–4) as a function of the particle size. The ordinate indicates the proportional shares.

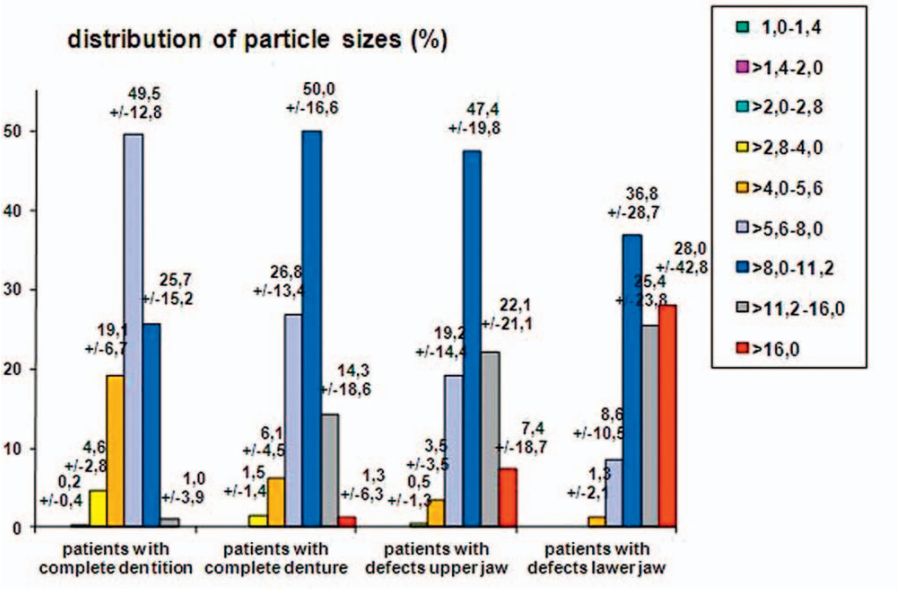

Fig. 5. Comparison of the mass distribution density as a function of the defect localization (upper jaw, lower jaw). For reasons of direct comparability, the data of the patients with complete dentition and of the patients with complete denture were included in the diagram.

Table 3. Comparison of the average values of the cursory determination of the masticatory forces

Determination area	Masticatory forces, N		
	Patients with complete dentition	Patients with complete denture	Surgical prosthetic patients
Right molar region	> 98	43.4	21.8
Left molar region	> 98	48.6	26.2
Front region	> 87	26.7	23.1

tication times differed by 50 and 75% compared to the group of patients with complete dentition. Massive differences were also found with regard to the analytical methods used. In addition to the fractionated sieve procedures, methods using computer programs for the direct measurement of particle surfaces were employed for analysis [10, 11]. The latter method is very expensive and time consuming.

The markedly higher masticatory efficacy of patients with complete dentition compared to patients with complete denture was already described back in 1965 [12]. According to this study, tongue movements have a large influence on the masticatory efficacy because, when the tongue movement is unrestricted, patients can keep the chewing test mass between their teeth and can much better move it back to a location between their teeth. In the present study, this is especially true for the patients who had mandibular defects caused by tumors. The tumors of these patients also involved the tongue.

Marshall et al. [13] showed that the stability of the complete denture in the lower jaw also influenced the choice of food. As an alternative to the removable prostheses, which transmit masticatory forces exclusively via the mucosa, implant-retained and implant-based prostheses are now available. Bakke et al. [14] found a significant improvement in masticatory efficacy in patients with complete prostheses when 2 implants were placed in the mandible.

Huber and Terezhalmy [15] described the special situation of patients with tumors. For patients with defects due to tumors in the jaw, provision of securely anchored dental prostheses is important [16, 17]. The relationship between the restoration of functionality of the orofacial system and the quality of life for tumor patients was emphasized [18].

Conclusions

The masticatory efficacy of the surgical prosthetic patients is lower than that of the patients with complete denture and the patients with complete dentition. Masticatory efficacy is influenced by the number of supporting zones of the patients' own residual dentition and the site of the defect. Secure anchoring of the removable prostheses is an important prerequisite.

A balanced diet is especially important for patients with surgical prostheses. The dietary guideline for patients with jaw defects derived from the results of this study is to be used for individual patient instruction. The entire guideline is available for downloading free of charge, in English and German, at *www.uniklinikum-dresden.de/das-klinikum/kliniken-polikliniken-institute/zap/downloads/Eating%20Guideline.pdf* and *www.uniklinikum-dresden.de/das-klinikum/kliniken-polikliniken-institute/zap/downloads/Ernaehrungsrichtlinie_de.pdf*.

Disclosure Statement

The authors hereby disclose any conflict of interest.

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