

Swallowing threshold parameters of subjects with complete dentures and overdentures

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ABSTRACT

Aim: To compare the chewing process and swallowing threshold parameters of subjects with complete dentures and overdentures with data obtained from subjects with complete natural dentitions. **Methodology:** The chewing process in terms of swallowing threshold parameters of four groups of subjects with complete dentures (all females) was quantified by sieving particles after chewing of an artificial test 'food' and compared with that of subjects with complete natural dentitions as a reference group (33 subjects). All subjects (except those of the reference group) had a complete denture in the upper jaw. Regarding the lower jaw two groups with complete dentures (with high (24 subjects), respectively low mandible (12 subjects)) and two groups with overdentures (implant-retained (22 subjects), respectively natural root supported (19 subjects)) were composed. **Results:** The 'overdenture-implants' group needed significantly more chewing cycles and time (mean: 45 cycles in 32 seconds) until 'swallowing' compared to the group with complete natural dentitions (mean: 26 cycles in 19 seconds until 'swallowing'). Also the 'complete denture-low mandible' group needed significantly more cycles and time (mean: 52 cycles in 44 seconds) until 'swallowing' than the complete dentition group. In the 'overdenture-natural roots' group these outcomes (33 cycles in 24 seconds) were not significantly different compared with the complete dentition group. The 'complete denture-high mandible' group (32 cycles in 26 seconds) needed not significantly more cycles until 'swallowing', however time until 'swallowing' was significantly longer compared to the complete dentition group. All denture groups had significantly larger mean particle sizes when 'swallowing' (sizes in the order of 3 mm) than the natural dentition group (about 2 mm). **Conclusion:** Despite efforts to compensate for a reduced chewing efficiency, subjects with complete dentures

(including overdentures) had 50% larger median particle sizes when 'swallowing' compared to subjects with complete natural dentitions.

Keywords: Swallowing Threshold; Chewing Efficiency; Complete Denture; Overdenture; Oral Implant

1. INTRODUCTION

Chewing efficiency can be defined as the capacity to pulverize food particles during a given number of chewing cycles, for instance to half of the original particle size [1]. Regarding particle size reduction during chewing, it has been stated that "denture wearers reach only 25% of dentate chewing performance" [2], and "chewing efficiency of denture wearers is less than one-sixth that of subjects with a dentition" [3]. However, chewing efficiency is only one parameter in the chewing process and depends of variables such as bite force, salivary flow and dental status including prosthodontic status. In order to describe the chewing process as a whole, the number of chewing cycles and the time needed until swallowing are also relevant parameters together with the result of the chewing process, *i.e.* the particle size reduction until subjects feel the urge to swallow. These parameters have been referred as swallowing threshold parameters [4,5].

Swallowing threshold parameters together with the chewing frequency as derived from the number of chewing cycles and the time until swallowing are considered appropriate to describe how people manage their chewing process [4,5]. Therefore, swallowing threshold parameters outcomes can be used to indicate to what extent people adapt to loss of teeth or prosthodontic devices, *e.g.* by more chewing cycles until swallowing or by swallowing larger food particles.

Bite force, chewing efficiency and their relationship were previously analyzed for subjects with complete (over) denture prostheses and for natural dentitions [1].

Also, swallowing threshold parameters were previously analyzed, however, only for subjects with implant-retained overdentures after chewing variable portion sizes [4].

A direct comparison of swallowing parameters for subjects with different denture prostheses status and subjects with complete natural dentitions has not been published so far. This paper aims to quantify the swallowing threshold parameters of subjects with complete dentures on low and high mandibles, of subjects with implant-retained overdentures and of subjects with natural roots-supported overdentures, and to compare the outcomes with those of subjects with complete natural dentitions as a reference.

2. MATERIALS AND METHODS

2.1. Subjects

The study sample (n = 110) was partially drawn from participants in a longitudinal clinical trial on implant-retained mandibular overdentures and partially from patients of the Nijmegen dental school [1,4]. Because a gender effect has been demonstrated for chewing efficiency and only few males were included in the clinical trial [4] and analyzed for bite force and chewing efficiency [1], the present study only comprised females.

Four denture groups were defined (**Table 2**). All participants of the denture groups had a complete denture in the upper jaw. Subjects in the ‘complete denture-*low mandible*’ group (n = 12) and subjects in the ‘overdenture-*implants*’ group (n = 22) all fulfilled the clinical trial criteria for inclusion as described elsewhere [1,4] and therefore had a mandibular symphyseal bone height between 8 and 15 mm as measured on a standardized

lateral cephalogram. Subjects of the ‘complete denture-*high mandible*’ group (n = 24) had a mandibular symphyseal bone height of 16 mm or more. Subjects in the ‘overdenture-*implants*’ group had two bar-connected cylindrical IMZ implants in the interforaminal region [1,4]. Subjects in the ‘overdenture-*natural roots*’ group (n = 19) had two functional natural roots without additional attachments. All subjects of the denture groups had their appliances for periods that made habituation or adaptation plausible. The complete dentition group as a reference comprised of 33 subjects with complete natural dentitions with or without 3rd molars. In this group 2 subgroups were defined (an older (n = 14) and younger group (n = 19; **Table 1**) in order to detect possible age-effects.

No participant indicated to suffer from pain related to temporomandibular disorders. The ethics committee of the Nijmegen University Medical Centre had given approval for the study and informed consent was obtained from all participants.

2.2. Swallowing Threshold Tests

Swallowing threshold tests were performed with cubic (edges 5.6 mm) silicone particles (Optocal Plus based upon the silicone component Optosil[®] Plus (Bayer Dental, Leverkusen, Germany)) [1,4]. Subjects were asked to chew portions of 17 particles (approximately 3 cm³) in “a way they normally do”, and to spit out the chewed particles when they felt the urge to swallow. Number of chewing strokes until ‘swallowing’ as well as time (in seconds) until swallowing were registered. Particles

Table 1. Swallowing threshold parameters (means (s.d.)) of the older and younger complete natural dentition sub-samples.

Complete natural dentition sub-samples	n	Age Mean (SD) (yrs)	No. of chewing cycles until swallowing	Time until swallowing (sec)	Chewing frequency (cycles/min)	Median particle size (X _{50swal}) [*] (mm)
Older	14	54.1 (6.4)	26.5 (11.2)	19.1 (8.0)	84.5 (13.2)	2.0 (0.9)
Younger	19	22.7 (1.5)	26.4 (10.8)	18.7 (7.4)	84.8 (12.1)	2.1 (0.8)

(X_{50swal})^{*} is the aperture (mm) of a theoretical sieve through which 50% of the weight of the particles pass when ‘swallowing’.

Table 2. Swallowing threshold parameters (mean (s.d.)) of the dental groups; denture groups had a complete denture in the upper jaw.

Denture groups	n	Age (y)	No. of chewing cycles until swallowing	Time until swallowing (sec)	Chewing frequency (cycles/min)	Median particle size (X _{50swal}) [*] (mm)
Complete denture- <i>low mandible</i>	12	57.8 (6.6)	51.6 (31.8) ^a	44.5 (33.0) ^a	74.0 (13.4) ^a	3.8 (1.4) ^a
Overdenture- <i>implants</i>	22	56.7 (7.1)	45.0 (17.1) ^a	32.0 (12.0) ^a	84.4 (12.1) ^b	2.8 (0.8) ^a
Complete denture- <i>high mandible</i>	24	58.3 (8.8)	32.3 (12.6) ^b	25.7 (12.0) ^b	77.3 (10.6) ^b	3.2 (1.1) ^a
Overdenture- <i>natural roots</i>	19	59.9 (8.5)	33.3 (18.2) ^b	24.4 (14.0) ^{bc}	84.6 (15.3) ^b	3.0 (1.1) ^a
Complete natural dentition	33	36.0 (16.3)	26.5 (10.8) ^b	18.9 (7.5) ^c	84.7 (12.4) ^b	2.1 (0.8) ^b

^{abc}: same characters indicate no significant difference (Mann-Whitney tests comparing the subsequent dental groups); (X_{50swal})^{*} is the aperture (mm) of a theoretical sieve through which 50% of the weight of the particles pass when ‘swallowing’.

were air-dried for at least one week and sieved for 20 minutes in a stack up to 12 sieves, with square meshes decreasing from 5.6 mm at the top to 0.5 mm at the bottom and a bottom plate (Laboratory Sieving machine VS1000; F. Kurt Retsch, Haan, Germany). Frequent intermittent eccentric movements of the sieves gave irregularly shaped particles (as after chewing) opportunities for favorable positions to fall through the square meshes. After the drying period, the sizes of the chewed particles were assessed by determining the aperture of a theoretical sieve through which 50% of the weight of the particles can pass and this was expressed as the median particle size ($X_{50\text{swal}}$) [4, 5].

Tests were carried out twice.

2.3. Statistical Analyses

To determine the added value for repeating the chewing tests, Spearman's correlation coefficient was used to assess the relation between the two measurements in each subject. All correlations (for the number of chewing cycles, the time until 'swallowing', $X_{50\text{swal}}$, and chewing frequency) were 0.85 or higher. This indicates a very high correlation between the first and second test. In the main analysis, the number of chewing cycles, and the time until 'swallowing', and $X_{50\text{swal}}$ were averaged. The chewing frequency was calculated from these mean values as the number of chewing cycles per minute.

The two subgroups 'complete dentition-older' and 'complete dentition-younger' were compared in order to detect possible age effects (Mann-Whitney tests). For reason of irregular distributions of the outcomes, non-parametric tests were used: Kruskal-Wallis tests to detect group effects comparing all five dental groups. If the groups differed significantly according to the Kruskal-Wallis test, Mann-Whitney tests were used to analyze differences between the five subsequent dental groups with the following sequence: complete denture-*low mandible*, overdenture-*implants*, complete denture-*high mandible*, overdenture-*natural roots*, and complete natural dentition. Next, the relation between the number of chewing cycles until 'swallowing', the time until 'swallowing', and $X_{50\text{swal}}$ was assessed (Spearman's Rho).

For the analyses, SPSS program, version 16.0 was used. P -values ≤ 0.05 were considered significant.

3. RESULTS

Swallowing threshold parameters of the older and younger complete natural dentition sub-samples did not differ significantly (Table 1; all 4 tests: $P \geq 0.392$). Therefore, the sub-samples were combined to the complete natural dentition group for statistical analyses ($n = 33$; Table 2).

Descriptive statistics and presence of statistical significant differences between the groups regarding the four outcome variables are given in Table 2.

Concerning the number of chewing cycles until 'swallowing' the Kruskal-Wallis test revealed a significant difference ($P < 0.001$). Amongst the denture groups a dichotomy can be observed: a high number of chewing cycles for the 'complete denture-*low mandible*' and the 'overdenture-*implants*' groups compared to the other two denture groups ('high mandible' and 'natural-roots') and the control group.

Regarding the time until 'swallowing', the Kruskal-Wallis test again revealed a significant difference ($P < 0.001$). An analogous dichotomy for the denture groups can be distinguished: the 'complete denture-*low mandible*' and 'overdenture-*implants*' groups chewed longer than the other two denture groups. However, all denture groups with the exception of the 'overdenture-*natural roots*' group used significantly longer time until 'swallowing' than the complete natural dentition group (control).

For chewing frequency, the Kruskal-Wallis test again showed a significant difference, but this outcome was less clear ($P = 0.046$). The frequency was significantly lowest in the 'complete denture-*low mandible*' group, without a significant difference between the other (subsequent) groups.

For $X_{50\text{swal}}$, the Kruskal-Wallis test showed a clear cut significant difference ($P < 0.001$). All denture groups had similar $X_{50\text{swal}}$ scores in the order of 3 mm while the complete natural dentition group showed a $X_{50\text{swal}}$ of approximately 2 mm.

Within all dental groups, the number of chewing cycles until 'swallowing' was highly significant correlated with time until 'swallowing' (Spearman's Rho's ranged from 0.87 to 0.95; all P -values < 0.001). As a consequence the chewing frequency was more or less constant within each group. Moreover, for all five groups the number of chewing cycles until 'swallowing' was significant negatively correlated with $X_{50\text{swal}}$ (Spearman's Rho's ranged between -0.45 and -0.87 ; all P -values 0.037 or lower).

4. DISCUSSION

4.1. Study Design

The dental groups of this study were convenient samples of subjects participating in other studies of the Nijmegen dental school, and selected on the basis of availability. As only a small number of males was included in the clinical trial on implant-retained overdentures [4], males were eventually not included in this study. It has been demonstrated in that clinical trial that males chewed their food more efficiently than females, as they achieved

greater particle size reduction using the same number of chewing cycles [4]. Although gender was found to have a small indirect effect on chewing function because of bite force [6], it is plausible that the relationships found in the present study also apply to males.

The criterion of a symphyseal bone height of 16 mm as applied in this study originates from the inclusion criteria of the original clinical trial [4]. This cut-off corresponds with Cawood Class V: "a flat ridge form, inadequate in height and width" [7], which might compromise complete denture function and thus gives relevance for using implants.

In the previous study investigating chewing efficiency and bite force [1], subjects with complete dentitions were slightly younger than those of the denture groups. Therefore, a group of young adults was included in order to detect possible age effects. In the present study age effects were not found (**Table 1**), which is in accordance with findings of others [6,8]. Therefore, both age groups were combined for further analyses.

Analyses revealed a very high correlation between the repeated measurements within each subject. This implies a marginal added value of the second test. Consequently, in similar studies a restriction to one test only can be advised.

In cases the Kruskal-Wallis test showed an overall difference between groups, the Mann-Whitney was applied. This test was chosen to minimize the number of post-hoc tests. However, this test only compares subsequent (adjacent) groups in a more or less logical sequence, for instance starting from 'poor' to 'good' outcomes as expected beforehand. For the three primary outcomes this appeared to be an appropriate approach because the outcomes coincided with the sequence of the groups. However, for chewing frequency this was not the case. Here two groups not being subsequent groups, i.e. the 'complete denture-low mandible' and the 'complete denture-high mandible' groups were found to deviate from the other groups. Consequently, for chewing frequency the labeling of the groups (**Table 2**) to indicate differences or similarities amongst non-adjacent groups is too crude.

4.2. Chewing Test Outcomes

The relative similarity between the outcomes of the first and the second test indicates that the chewing process until 'swallowing' is fairly constant within a subject for a specific type of food. On the other hand, the large differences in outcomes together with large standard deviations (**Table 2**) indicate wide variations among subjects. This implies that the chewing process is an individually determined and adapted process e.g. to denture function [9,10].

It can be subject of debate whether chewing just a single type of artificial test 'food' represents 'real life' chewing function. The difference in particle size reduction between 'good' and 'bad' chewers in such a test depends partly on food consistency, and the firm artificial test 'food' as used in the present study might have magnified differences between 'good' and 'bad' chewers [5,11]. Moreover, it has been shown that larger portions to chew until 'swallowing' increase $X_{50\text{swal}}$, and the number of chewing cycles until 'swallowing' increases linearly with the volume [4,12], but it is unknown whether this increase is proportionally amongst dental groups. Despite these shortcomings the outcomes of this study are considered to be indicative for clinically relevant swallowing parameters when comparing groups with different dental or prosthodontic status.

4.3. Compensation for Impaired Chewing Capacity

It has been stated that chewing efficiency of complete denture wearers is substantially inefficient compared to subjects with complete natural dentitions: less than one-sixth [3], or even one-seventh [13].

The present study on the other hand, focusing on chewing until 'swallowing' reveals a less dramatic picture. Compensation for the reduced chewing efficiency by more chewing cycles and longer time until 'swallowing' in the denture groups resulted overall in a 40% to 50% larger $X_{50\text{swal}}$ than in the complete dentition group, however subjects with 'complete denture-low mandible' had approximately twice larger $X_{50\text{swal}}$ (**Table 2**).

When people use more chewing cycles until 'swallowing' and chew with lower frequency, however swallow larger particles, this reflects the effectiveness of their chewing process. Compared to the controls, subjects in the 'complete denture-low mandible' group used a higher number of chewing cycles until 'swallowing' (factor 1.9), had lower chewing frequency (factor 1.1), and had larger outcome $X_{50\text{swal}}$ (factor 1.8). Although these are dependent variables, these figures can be interpreted as that the chewing effectiveness is 1.9 (higher number of chewing cycles) \times 1.1 (lower chewing frequency) \times 1.8 (larger $X_{50\text{swal}}$) = 3.8 times lower than that of the controls. Following this interpretation, in the 'complete denture-high mandible' group the chewing effectiveness was $1.2 \times 1.1 \times 1.5 = 2.0$ times lower; in the 'overdenture-implants' group $1.7 \times 1.0 \times 1.3 = 2.2$ lower, and in the 'overdenture-natural roots' group $1.3 \times 1.0 \times 1.4 = 1.8$ times lower than that of subjects with complete natural dentitions.

With respect to interventions aiming to achieve a more acceptable chewing process, the application of implants (mostly in low mandibles) or the preservation

of natural roots are considered valid interventions. However, improvement of chewing effectiveness is limited to the level of the 'complete denture-high mandible' group. This indicates that mandibular implant-retained overdenture treatment is most effective in terms of improved masticatory performance in persons with a less than adequate mandibular ridge. This suggestion has been stated also by others [14], irrespective different mesostructure modalities including bar-clip (as in this study), ball or magnet attachments [15].

As stated previously, the relatively large standard deviations in $X_{50\text{swal}}$ denote substantial individual variation within groups. In other words, the differences *within* groups are large compared to the mean differences *amongst* groups. Just as an illustration, the subject with the lowest number of chewing cycles before 'swallowing' was found in the 'complete denture-low mandible' group. It should be noted that denture status is just one of the chewing efficiency determinants. Other determinants are saliva, muscles (influencing bite force), and cultural habits and personality. In other words, also cultural and personality traits determine 'slow' and 'fast' swallows [9,10,16-18]. The multifactorial nature of the chewing process undoubtedly explains the large individual differences in the outcomes of this study on swallowing threshold parameters. This individual variation is considered unproblematic since the assumed link between chewing function and deficient dietary intake is based only on relatively weak correlations and cannot confer a causal relationship [19], as it is not clear to what extent human digestion depends on chewing [20].

5. CONCLUSIONS

1) Despite efforts to compensate for their reduced chewing efficiency by a larger number of chewing cycles until 'swallowing', subjects with mandibular (over)dentures and maxillary complete dentures had approximately 40% - 80% larger $X_{50\text{swal}}$ than subjects with complete natural dentitions.

2) The outcomes of swallowing threshold parameters of subjects with overdentures retained by implants or natural roots were on average comparable to those of subjects with complete dentures on a 'high' mandible.

3) Apart from dental and denture status, large individual differences in outcomes of swallowing threshold parameters were observed indicating 'slow' and 'fast' swallows.

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