Retention of complete maxillary dentures measured as resistance against unilateral occlusal loading

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Fløystrand, F. & Ørstavik, J. S. Retention of complete maxillary dentures measured as resistance against unilateral occlusal loading. *Acta Odontol. Scand.* 1984, 42, 29–36. Oslo. ISSN 0001-6357.

Complete maxillary dentures were tested for their ability to remain in place when subjected to unilateral occlusal loads. The test material comprised five persons, each supplied with three identical dentures. The denture design was based on the principles of 1) functionally determined filling-in of the vestibular sulcus, 2) palatal coverage to the vibration line without post dam, 3) aesthetically governed positioning of the front teeth, and 4) positioning of the lateral teeth in the plane connecting the top of the residual ridge with the central part of the occlusal surface of the antagonizing natural teeth. Resistance to unilateral occlusal loads was measured by means of a miniature bite force sensor. In the pooled material, an average load of 70 N was tolerated before the dentures were dislodged. For a given participant/denture combination, the resistance against dislodgment varied considerably when tested on different days. Marked differences were also found among three identical dentures in one person. The tolerance against unilateral occlusal loads could feasibly be quantified. However, the influence of specific clinical and/or technological factors on denture retention during function should be studied only if strict definitions as to the test conditions are given. These conditions must include the time, person, and denture tested. □ *Denture retention; metric measurements; prosthesis*

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One of the aims of denture construction is balanced occlusion and articulation. This ensures that the denture on occlusion is pressed evenly against its total supporting area (3, 8). When chewing, however, a denture will be subjected to unilateral occlusal loads until the teeth on the working side have penetrated the bolus—that is, until the teeth on the opposite side have established balancing contact. If the unilateral loads exceed the counteracting retentive forces, the denture will come loose.

The aim of this study was to investigate the ability of complete maxillary dentures to withstand unilateral occlusal loading under defined experimental conditions.

Materials and methods

Participants. Five persons participated voluntarily in the study. All had an edentulous upper jaw and a natural dentition in the lower jaw with at least all incisors, canines and bicuspids present. Table 1 shows the age, sex and previous denture experience of the participants.

Denture design. The semi-dynamic impression technique as advocated by Brill et al. (5) was used to achieve functionally determined denture borders. The palate was covered to the vibration line, but without post dam. The front teeth were orientated in the horizontal plane so as to achieve aesthetically acceptable lip support without overlapping the antagonizing teeth vertically. In the lateral segments two bicuspids and one molar were orientated in the plane connecting the top of the residual ridge and the central part of the occlusal surface of the antagonizing teeth. Occlusal contact in the retruded position (RP) was determined by passive registration (5, 13). Selective occlusal grinding was done to ensure even bilateral contacts in the bicuspid areas (8, 17). A single tooth balancing contact was established for lateral excursions up to 3 mm in the canine area, and bilateral posterior balancing

Table 1. Age, sex, and previous denture experience of the participants

Patient	Age, years	Sex	Previous complete denture experience	
			Years	No. of dentures
T	83	M	36	3
C	68	F	3	2
S	75	M	15	2
W	68	F	9	2
H	58	F	2	1

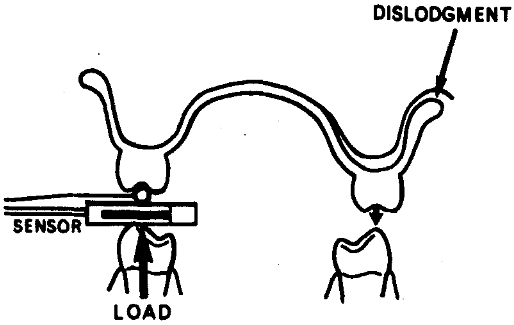

Fig. 1. Schematic drawing of denture dislodgment provocation. Transverse section in the bicuspid area.

contacts were ensured for protrusive movements.

Cusped acrylic teeth (Durablend®, Myerson Tooth Corp., Cambridge, Mass., USA) were used throughout. The denture base was made from heat-cured polymethyl-methacrylate (Stellon®, Amalgamated Dental Trade Distributors, Ltd., London), processed by compression polymerization in a flask in accordance with the manufacturer's instructions. All dentures were designed by the same operator, and all laboratory procedures were carried out by the same dental technician.

When the denture was accepted by the patient, two copies were made, using the following technique: Molds were made in hydrocolloid (Perflex®, Howmedica AG, Cologne, FRG), into which was injected pour-type polymethyl-methacrylate (Sweflow®, Swedia Dental Industry, Enköping, Sweden). Polymerization was then carried out at 4.5 kp pressure and 45°C for 30 min. Control linear measurements included total sagittal and transversal denture dimensions and denture border thickness in labeled areas, using a graded caliper (Tesa®, Switzerland). The copies were accepted if differences from the original denture were 0.1 mm or smaller.

Thus, each participant was supplied with three closely identical dentures. The three dentures were worn alternately by the patient for a period of 2–4 weeks before the dislodgment studies started. Dentures not in use were stored in water.

Dislodgment experiments. Occlusal loads were measured by means of a miniature bite-force recorder (9), modified by introducing a small steel roller bearing ball (diameter, 3 mm) as the loading point instead of the original disk. This modification reduced the error of measurement inherent in the apparatus to ±1 N (unpublished data). A guiding pit for positioning the steel ball had been ground into the occlusal surface of the right first bicuspid of the master denture before duplication, thus ensuring that the loading point could be accurately located and reproduced in successive loadings (Fig. 1).

The procedure for each recording was as follows: After firm contact between the den-

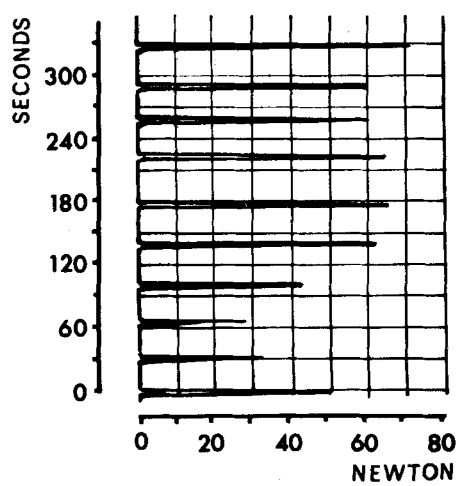

Fig. 2. Graphic chart showing 10 successive dislodging loads for the same denture.

ture and its supporting area had been established by occluding, the participant opened his jaws moderately to enable insertion of the bite-force sensor, as shown in Fig. 1, and after 30 sec he was asked to close firmly. The load was recorded on a graphic chart. It increased up to a maximum and then fell abruptly to zero, coinciding in time with a sudden loosening of the denture on the opposite side (Fig. 2).

Thirty recordings were performed at 30-sec intervals for each denture. The resistance against dislodgment was measured for all 15 dentures on 2 different days. The mean and standard deviation of these values were calculated and used as a measure of denture retention.

Results

Pooled material

Fig. 3 shows the distribution of dislodgment values in the pooled material. The loads causing dislodgment of the dentures varied considerably. In extreme cases, the dentures were dislodged almost spontaneously on contact. In about 5% of the various participant/denture combinations, less than 20 N sufficed to cause dislodgment. On the other hand, in about 7% of the tests, loads exceeding 120 N were required to cause dislodgment. However, in some 70% of the recordings the resistance against dislodgment was broken by loads ranging from 40 to 100 N.

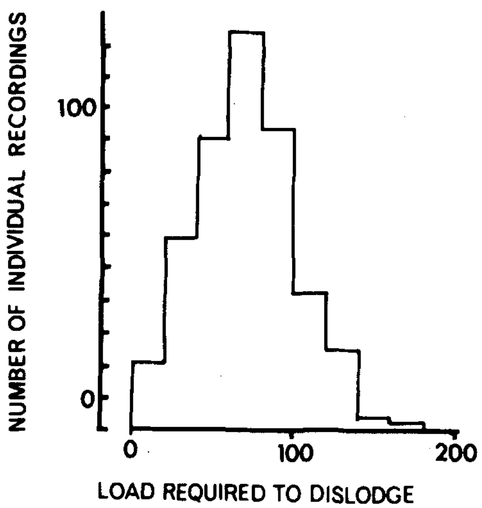

Fig. 3. Individual unilateral occlusal loads causing dislodgment of complete upper dentures. The material comprised five persons each supplied with three dentures. For each denture 30 individual loads were recorded.

Separate test series

In series of 30 single tests the individual dislodgment values were fairly normally distributed. Fig. 4 shows the distribution pattern of four test series, representing dentures with high, medium, and low retention.

The coefficient of variation (CV) was calculated for 30 test series, and the distribution of this value is shown in Fig. 5. For the entire material, the mean CV was 28.4%, with a standard deviation of 12.7%.

The results further indicate that separate loads causing dislodgment remained relatively stable during a test series of 30 loadings. Fig. 6 shows how 30 consecutive recordings appeared chronologically in 4 different series. No trend towards improved or impaired dislodgment resistance can be seen. This impression was further strengthened by analysis of the pooled material. Thus, the average resistance values for a selected early recording (no. 5), for the middle recording

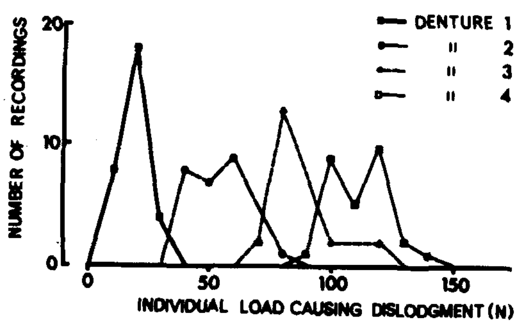

Fig. 4. Distribution pattern of individual loads causing denture dislodgment in 4 separate series, each consisting of 30 consecutive single loads. The dentures represent high, medium, and low dislodgment resistance.

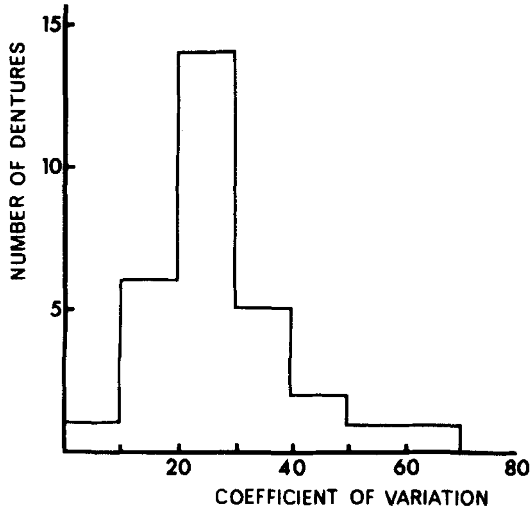

Fig. 5. Coefficient of variation (CV) for dislodgment resistance of complete upper dentures. Mean and SD of dislodgment resistance for each denture were calculated from 30 consecutive individual tests.

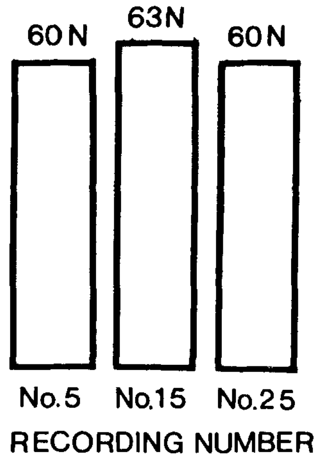

Fig. 7. Mean dislodgment-provoking loads for an early, the middle, and a late observation in 30 different test series. Each series consisted of 30 consecutive single loads.

(no. 15), and for a selected late recording (no. 25) were all virtually the same (Fig. 7).

On the basis of these observations, retention of a denture was defined as the mean of 30 dislodgment values.

Time-dependent differences

Each denture was tested on 2 separate days. It can be seen from Table 2 that most dentures showed different retention on the two occasions. For a given denture, the day-to-day difference varied from 2 to 57 N. For the total material, the mean difference was 21.4 N.

There was a tendency towards improved resistance against dislodgment on the 2nd test day as compared with the 1st day. On the average, the resistance value increased by 10 N. The trend was, however, not valid for all dentures.

Thus, 10 dentures showed higher dislodgment resistance values, whereas the other 5 dentures showed lower values on the 2nd test day.

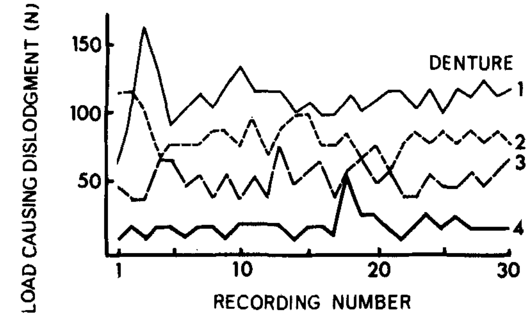

Fig. 6. Chronological recording of 30 consecutive dislodgment-provoking loads for 4 different complete upper dentures.

Denture-dependent differences

Comparison of the retention of denture copies was based on measurements performed on the same day. For each participant the closely identical dentures were tested on two separate occasions. The results are presented in Table 3.

The differences in retention between the identical dentures varied from 1 to 67 N, with a mean difference of 24.5 N. No conspicuous deviation from the general trend was found for any of the participants.

Table 2. Differences in dislodgment resistance of 15 complete upper dentures as measured on 2 separate days

Denture no.	Dislodgment resistance (N) Day 1 x̄ SD	Day 2 x̄ SD	Difference (N)	Level of significance
1	66 ± 15	113 ± 18	57	0.001
2	50 ± 15	85 ± 24	35	0.001
3	42 ± 12	69 ± 17	27	0.001
4	34 ± 9	58 ± 22	24	0.001
5	55 ± 12	79 ± 23	24	0.001
6	45 ± 2	68 ± 16	23	0.001
7	40 ± 13	62 ± 32	22	0.001
8	43 ± 11	60 ± 10	17	0.001
9	29 ± 12	34 ± 13	5	n.s.
10	43 ± 12	46 ± 26	3	n.s.
11	94 ± 13	92 ± 26	−2	n.s.
12	67 ± 16	65 ± 18	−2	n.s.
13	85 ± 15	76 ± 21	−9	n.s.
14	86 ± 15	53 ± 20	−33	0.001
15	64 ± 8	26 ± 16	−38	0.001
			x̄ 21.4	

Interindividual variations

Fig. 8 shows the mean and standard deviation of the denture retention calculated for each of the five participants. The values are based on measurements performed on 2 separate days for all identical dentures. The dislodgment resistance varied from 48 to 72 N. For comparison, the mean resistance value in the pooled material was 62 N. However, interindividual differences were not statistically significant ($p < 0.05$).

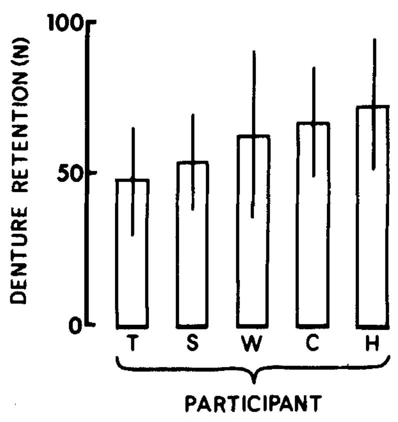

Fig. 8. Dislodgment resistance for five different test persons. Mean and SD of six separate tests performed for each person indicated.

Discussion

Dislodgment of a denture occurs when the dislocating forces exceed the counteracting retentive forces. The present experiments can be regarded as a method to assess the retention of complete maxillary dentures.

Our experimental approach seems to fit the broad clinical concept of denture retention as expressed by Brill et al. (4). In contrast, most previous studies of denture retention (6, 7, 14, 16, 19) have dealt with the far more restricted definition of denture retention as 'resistance of a denture towards removal in a direction opposite to its insertion' (2). The authors of these reports have chosen experimental models limiting the influence of muscular retentitive forces. Therefore, the present findings should not be directly compared with previous numerical data on denture retention.

The experimental design aimed at imitating denture retention as it is experienced

Table 3. Differences in dislodgment resistance between paired copies of complete upper dentures. Measurements were performed on the same occasion for both copies

Pair no.	Dislodgment resistance (N) Copy 1 x̄ S.D.	Copy 2 x̄ S.D.	Difference (N)	Level of significance
1	113 ± 18	46 ± 27	67	0.001
2	94 ± 13	45 ± 2	49	0.001
3	86 ± 15	40 ± 13	46	0.001
4	85 ± 15	40 ± 13	45	0.001
5	79 ± 23	34 ± 13	45	0.001
6	113 ± 18	69 ± 17	44	0.001
7	94 ± 13	50 ± 15	44	0.001
8	65 ± 18	26 ± 16	39	0.001
9	60 ± 10	26 ± 16	34	0.001
10	55 ± 12	29 ± 12	26	0.001
11	58 ± 22	34 ± 13	24	0.001
12	67 ± 16	43 ± 11	24	0.001
13	66 ± 15	42 ± 12	24	0.001
14	92 ± 26	68 ± 16	24	0.001
15	69 ± 17	46 ± 27	23	0.001
16	66 ± 15	43 ± 12	23	0.001
17	76 ± 21	53 ± 20	23	0.001
18	79 ± 23	58 ± 22	21	0.001
19	64 ± 8	43 ± 11	21	0.001
20	55 ± 12	34 ± 9	21	0.001
21	85 ± 24	68 ± 16	17	0.01
22	76 ± 21	62 ± 32	14	0.05
23	62 ± 32	53 ± 20	9	n.s.
24	92 ± 26	85 ± 24	7	n.s.
25	50 ± 15	45 ± 2	5	n.s.
26	34 ± 9	29 ± 12	5	n.s.
27	65 ± 18	60 ± 10	5	n.s.
28	67 ± 16	64 ± 8	3	n.s.
29	86 ± 15	85 ± 15	1	n.s.
30	43 ± 12	42 ± 12	1	n.s.
			x̄ 24.5	

during chewing, allowing physiological retentive forces to act freely. With this in mind, a wide range of dislodgment-provoking load values, even when testing the same denture repeatedly (Fig. 4), was not unexpected.

Several factors may have contributed to these variations among individual dislodgment load values. For instance, the conditions for efficient physical retention on the basis of a close adaptation of the denture base to the supporting mucosa probably varied. It has been claimed that patient-governed occlusion as a method of seating the denture does not favor good reproducibility of denture retention values (15). Furthermore, the nature of the experimentally introduced dislocating force was not thoroughly defined. True enough, the point of application of the occlusal load was standardized and could be exactly reproduced in consecutive tests. Similarly, the duration of the applied force, which is also known to influence the load tolerated (1), was roughly the same in all consecutive tests. However, the velocity and the direction of the dislodging force may have an impact on the final result (1, 14), and these factors were not equally well controlled.

Finally, the participants might activate the retentive potential of the tongue and of the vestibular soft tissues to various degrees. It has been shown that the soft tissues represent an efficient retentitive power (1, 3, 4), and it has been reported that variations in cheek muscle activity may profoundly influence the retention of complete maxillary dentures (4, 11).

Fairly stable dislodgment resistance values during a series of 30 consecutive tests (Fig. 6) may indicate that clinical factors governing retention did not vary to any great extent within this limited period. In contrast, marked day-to-day differences in denture retention (Table 2) show that the retention factors cannot be expected to act equally efficiently on different days. All factors contributing to the variations discussed above might obviously also contribute to the day-to-day variations. In addition, differences might also be due to fluctuations in saliva qualities (1, 6, 12, 14) and to daily variations in the volume and resilience of the supporting soft tissue (3).

It might seem surprising that, although meticulous care was taken to produce identical dentures, their ability to resist unilateral occlusal loads varied considerably (Table 3). Thus, although it was attempted to eliminate technological factors known to have an impact on denture retention (7, 10, 11, 15, 18), the results did not overthrow the bold statement that 'From the viewpoint of retention, exact duplication of a denture appears to be an impossibility' (7). Differences in dislodgment resistance between closely identical dentures were apparently not caused by denture-inherent properties alone, since tests performed on different days gave different ranking among copies within a given triplet (Table 3). Considering the fact that the retention of complete maxillary dentures improves during the early stages of wearing (16), one possible explanation of the present findings might be that the physiological retentive elements could adapt to minute details in denture design. This possibility was not further explored, as the data did not include information on which copy had been in use during the last period before the actual tests.

The daily variation in the ability of a denture to remain seated indicated that multiple tests performed on different occasions will be required to produce a retention value of general validity.

It was therefore not surprising that differences among participants based on two tests only (Fig. 8) were not statistically significant. This finding does not, however, exclude the possibility that such interindividual differences existed.

In conclusion, the results of the present study indicate that the ability of a complete maxillary denture to withstand unilateral occlusal loads can be determined quantitatively in terms of a mean retention value. Since this ability is influenced by several physiological factors, it seems pertinent to supplement the retention value with a description of the distribution pattern of the results obtained by repeated individual provocations.

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Received for publication 11 November 1982