

## Research Article

# Establishment Method of Retention Force of Mandibular Complete Dentures and Examination of Factors Related to Retention Force

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- Mandibular complete denture
- Mouth opening
- Residual ridge
- Retention

**Abstract**

**Purpose:** Various aspects of the retention of mandibular complete dentures are unclear, as no evaluation method has been established to date. This study aimed to clarify the effect of suitable mouth opening, the shape of the residual ridge, and the form of the denture on retention when measuring retention of mandibular complete dentures.

**Methods:** The subjects were 37 individuals wearing mandibular complete dentures. The central incisor was loaded 45° downward toward the occlusal plane. The force needed to dislodge the denture was measured using a digital force gauge. The size of the mouth opening was defined as 1, 2, and 3 cm, and was measured four times. Retention forces were compared based on the shape of the molar residual ridge and the relative position of the anterior residual ridge crest.

**Results:** As the size of the mouth opening increased, the retention decreased ( $P < .05$ ). The variation index was the lowest when the mouth was opened to 1 cm. Denture retention increased as the viscosity of the oral moisturizer increased ( $P < .05$ ). Retention decreased when the residual ridge in the anterior mandibular region was positioned relatively backward ( $r = -0.608$ ,  $P < .01$ ). There was a significant relationship between the height of the residual ridge in the molar region and denture retention.

**Conclusions:** As the viscosity of the oral moisturizer increased, denture retention increased. The size of mouth opening needs to be defined when measuring retention. The size of mouth opening is stable at 1 cm; therefore, this is the optimal size. Retention was associated with the height of the molar region residual ridge and the relative position of the crest of the anterior residual ridge.

**ABBREVIATIONS**

QOL: Quality of Life

**INTRODUCTION**

Japan is facing a super-aged society: the number of the elderly people has increased markedly, and such prolonged survival increases the number of denture wearers. Additionally, it is predicted that the number of incurable edentulous cases will increase because of the marked resorption of the jawbone and changes in the chin bone with aging [1-3], and the onset of dry mouth [1,4-6]. These factors reduce denture retention and greatly affect the quality of life (QOL) of elderly individuals [1,2,7-10]. Therefore, the quality of complete dentures will need to be improved in the future. Many previous studies have investigated factors that affect denture retention. According to

Östlund [11,12], denture retention may vary, depending on the layer of liquid between the residual ridge and the mucosal side of the denture base. Furthermore, there are many reports of the effect of saliva and oral moisturizer on denture retention [13-17].

Therefore, we performed previous studies focusing on the retention of maxillary complete dentures; we developed a new device for measuring retention objectively [18], and reported an optimal site for measuring denture retention at the chairside, as well as for measuring load [19]. We found that, although denture retention increased with the viscosity of an oral moisturizer, the relative position of the anterior residual ridge crest was not involved in retention [20].

Thus, the retention of the maxillary complete denture has been well studied; however, there have been few studies on mandibular complete dentures. There is currently no

established gold standard for the measurement of the retention force in mandibular complete dentures. In a previous study, we first examined the measurement method and optimal site for establishing such a measurement method for retention of complete mandibular dentures, using a model. In the current study, we examined whether the loading site and the method for evaluating the residual ridge that we established in the previous study are useful *in vivo*, in an actual oral cavity, and determined the effect of the residual ridge of the mandibular complete denture and denture form on retention.

## MATERIALS AND METHODS

The usefulness of a measurement method involving application of force to the central incisor with loading 45° downward toward the occlusal plane was confirmed in our previous study [21], and was again applied in this study.

### Retention force measuring equipment

As in the previous study, a digital force gauge (Digital Force gauge RX Series®; AIKOH ENGINEERING, Tokyo, Japan) was used as the retention measuring device. As the pressing jig, we used a fabricated hook-shaped component. Scales of 1, 2, and 3 cm were attached to each jig at an angle of 45° to define the size of the mouth opening (Figure 1).

### Measuring the retention force of mandibular complete dentures

**Subjects:** The subjects were 37 recall patients wearing mandibular complete dentures that did not require basal surface adjustment (14 men, 23 women; average age, 83.3 ± 6.7 years). Individuals with residual dental roots or mucosal abnormalities were excluded. Before participation, the subjects received a complete explanation of the purpose of the study and consented to participation. In the research they are not specially used for medication. There is no regulation of the pairing. The dentures were made by this department doctor member in accordance with the ordinance and shall be within 5 years after production. This study was approved by the Examining Committee of Clinical Study of the Dentistry Hospital at Showa University (Approval number: 2015-005).

**Mediating fluids:** Kawazoe et al. [14], reported that mediating fluids are present between the oral mucosa and the basal surface of mandibular complete dentures worn by individuals. Yamagaki et al. [15], have reported that stable retention force readings were obtained when the entire surface of a model was covered with such mediating fluids. Given that there is no defined optimal volume of mediating fluid, the volume that fully covered the basal surface of the denture was chosen for use in this study. As a mediating fluid, the artificial saliva (Saliveht®; Teijin Pharma) used in our previous study and an oral moisturizer gel (Biotene Oral Balance Jell®; T&K) were used.

**Retention force measurement method:** The patient posture used for performing measurements was the seated position. The measurement point and direction were based on the previous study, and a force was applied to the central incisor with loading 45° downward toward the occlusal plane (Figure 2).

The force required to dislodge the denture was considered the retention force.

The mouth opening in the absence of any interposing liquid was set at 1 cm and measured once. The purpose was to confirm whether measurement could be performed without pain, and to assess the normal value of retention. Using artificial saliva, mouth opening was set at 1, 2, and 3 cm, and measured four times each. Furthermore, mouth opening while the using oral moisturizer gel was set at 1 cm and was measured four times (Table 1). We performed measurements with dentures to which mediating fluid had been applied, after occluding for 10 s.

Measurement was discontinued when the measured value exceeded 20 N, as preliminary research has indicated that this level of pressure can cause pain and impede measurement, or when the subject complained of pain. If the aforementioned impediments to measurement occurred twice, subsequent measurements were discontinued.

### Measurement of the residual ridge shape

**Dental impression and casting of duplicate dentures:** To analyze the effect of the shape of the residual ridge on retention force, dental impressions of the polished surfaces and basal surfaces of the mandibular complete dentures were obtained using a silicone impression material (Examixfine® Putty type and Injection type; GC). A duplicate denture was then cast by pouring a denture impression using tray resin (Tray resin®, Shofu Inc.) onto the impression (Figure 3).

**Measuring the molar region residual ridge height and shape:** The measurement procedure was based on the method of Ishibashi et al. [22,23]. Using a supporting tissue scale (Figure 4), the height of and the residual ridge area corresponding to the central fossa of the right and left first molar (15 mm forward of



Figure 1 A scale of 1, 2, or 3 cm is attached to each jig at a 45° angle.

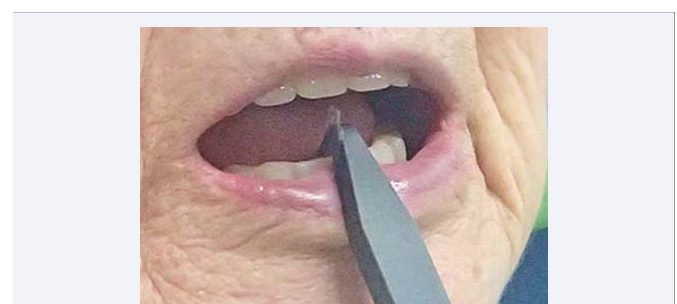
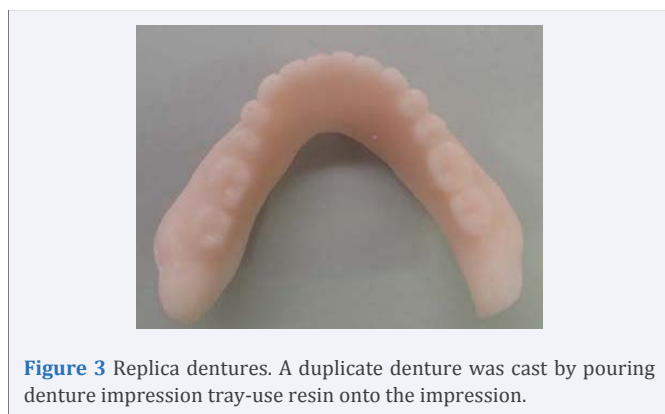


Figure 2 Loading site. The loading site is loaded 45° downward toward the occlusal plane.

**Table 1:** Number of measurements.

Conditions	Mouth opening	Number of measurements
Subject's saliva	1 cm	1
	1 cm	4
Artificial saliva	2 cm	4
	3 cm	4
Oral moisturizers	1 cm	4



**Figure 3** Replica dentures. A duplicate denture was cast by pouring denture impression tray-use resin onto the impression.

the leading edge of the retromolar pad) were measured on the impression of the mucous membrane surface of the mandibular complete denture (Figure 5). The height of the residual ridge was classified into three categories: high ( $\geq 5$  mm), medium ( $\geq 0$  mm, but  $<5$  mm), and low ( $<0$  mm). The residual ridge shape was categorized as follows: U, UV (middle), V, and flat. In cases where the residual ridge height was deemed to be low, the residual ridge shape was considered flat. A shape with a width of 7 mm or more was defined as U-shaped. If the ridge had a width of 5 mm or more, but was less than 7 mm, it was defined as UV-shaped. The height thus deteriorated in the order of high, middle, and low. The shape deteriorated in the order U, UV, V, and flat. Based on these values, the influence of residual ridge height and residual ridge shape on retention force was analyzed.

### Measuring the relative positions of the central incisor edge, anterior residual ridge crest, and posterior border of dentures

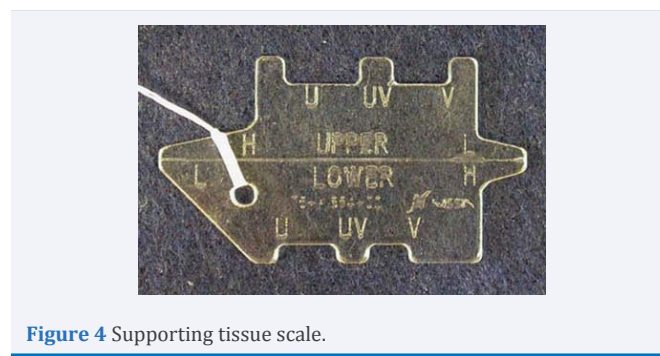
When measuring the force applied to the cutting edge of the midline between the right and left central incisors, a force is applied to the posterior border of the dentures to dislodge the denture, by using the residual ridge in the anterior mandibular region as a fulcrum point. Hence, the relative positions of the central incisor edge, anterior residual ridge crest, and posterior denture border were measured.

Using the duplicated denture, we performed these measurements using the following procedures. We measured the distance from the central incisor to the anterior residual ridge (Distance A). The cutting edge of the central incisor and the right and left posterior borders of the denture were plotted on graph paper. The middle point linking the posterior borders and the distance to the cutting edge of the central incisor (Distance B) were measured (Figure 6). The position of the anterior residual

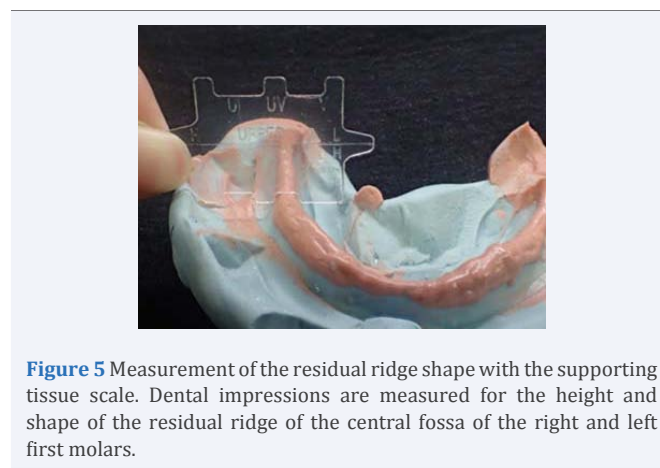
ridge crest relative to the distance of the posterior border of the duplicated dentures from the central incisor edge was examined.

### Statistical analysis

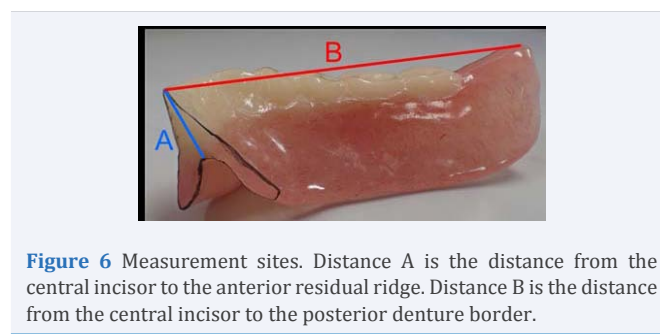
The Shapiro-Wilk test of normality was used for all measured values. After Friedman analysis of variance was used for the mean retention under the five conditions, the data were analyzed with the Bonferroni multiple comparison test. For assessing the differences in the height and shape of the molar region residual ridge, Levene's test and one-way analysis of variance (ANOVA) or the Kruskal-Wallis tests were performed. To evaluate the relationship between position and retention among the cutting edge of the central incisor, the residual ridge in the anterior mandibular region, and the posterior border of the denture, Spearman's rank correlation coefficient was used. All statistical analyses were performed in SPSS ver. 19.0 (SPAW Statistics Base 19®, IBM).



**Figure 4** Supporting tissue scale.



**Figure 5** Measurement of the residual ridge shape with the supporting tissue scale. Dental impressions are measured for the height and shape of the residual ridge of the central fossa of the right and left first molars.



**Figure 6** Measurement sites. Distance A is the distance from the central incisor to the anterior residual ridge. Distance B is the distance from the central incisor to the posterior denture border.

## RESULTS

### Retention according to the residual ridge condition

Of the 37 subjects, 6 showed a measured value of more than 20 N, depending on the size of the mouth opening. Subjects who showed more than 20 N were excluded. The reason is that when the retention force exceeds 20 N, the denture is strongly detached and there is a danger of breakage. And 6 subjects exceeded 20 N, all of them appealed for pain. In addition, although 1 was less than 20 N, he got up with the measurement because he was fatigued by the elderly. The data obtained from 30 subjects were consequently included in the analysis. When the mouth opening was increased to 2 or 3 cm in comparison to 1 cm, the retention significantly decreased ( $P < .05$ ). In addition, the oral moisturizer gel, which had a higher viscosity than the artificial saliva, showed significantly greater retention ( $P < .05$ ; Figure 7). The mean variation indexes of 30 subjects, measured four times, are shown in Figure 8. When using artificial saliva as the mediating fluid, the data showing the lowest variation index and the smallest error with repeated measurement were found when the size of the mouth opening was 1 cm.

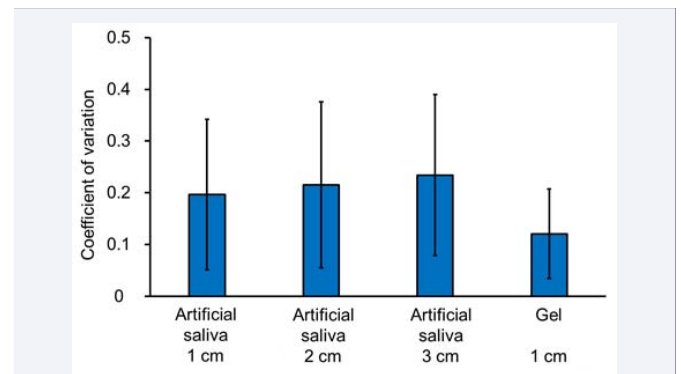
### Relation of the retention according to the height of and form of the molar residual ridge

The residual ridge height was classified as high in five subjects, medium in 20 subjects, and low in five subjects. When artificial saliva was used as mediating fluid, and when the size of the mouth opening was 1 cm, the retention increased significantly as the height of the residual ridge increased ( $P < .05$ ; Figure 9).

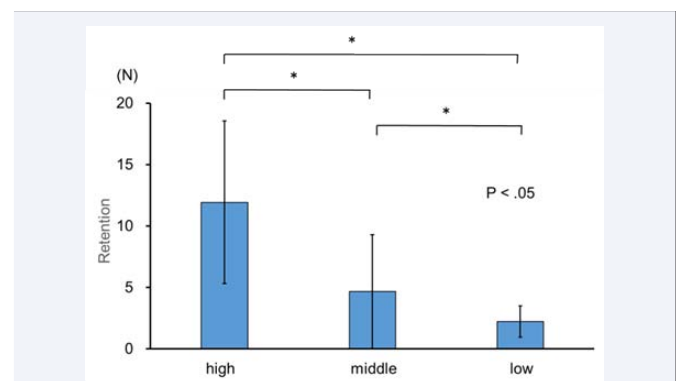
Four, 14, seven, and five subjects had a U-shaped, UV-shaped, V-shaped, and flat residual ridge, respectively. When artificial saliva was used as the mediating fluid, there was no relation with retention when the size of the mouth opening was 1 cm ( $P < .05$ ; Figure 10).

### Correlation between retention force and the relative positions of the central incisor edge, anterior residual ridge crest, and posterior denture border

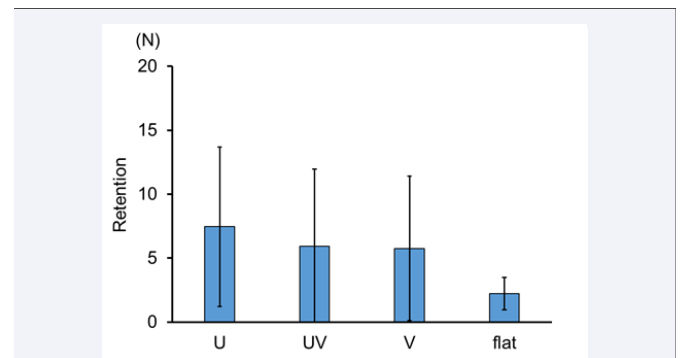
Spearman's rank correlation coefficient was used to assess the relationship between retention and the position along the cutting edge of the central incisor, the residual ridge in the anterior



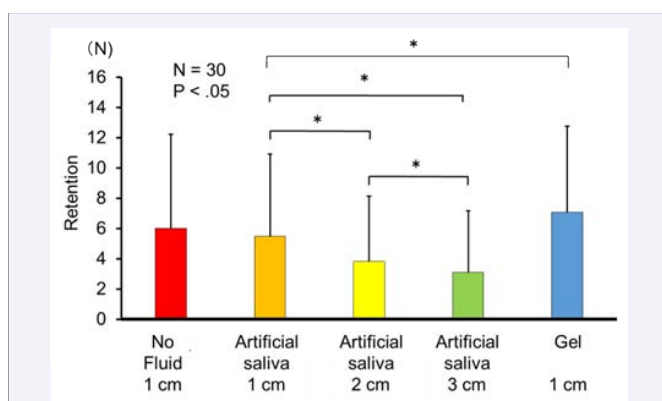
**Figure 8** Coefficient of variation. The smallest coefficient of variation is associated with 1-cm mouth opening size.



**Figure 9** Effect of residual ridge height in the molar region. The retention force decreases as the height of the residual ridge in the molar region decreases.

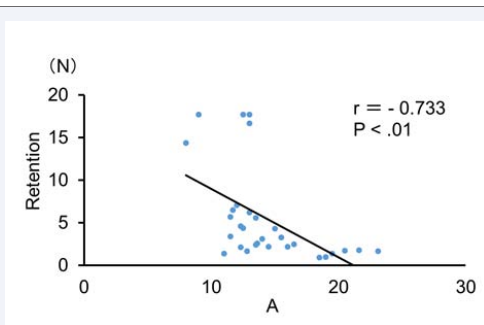


**Figure 10** The effect of the shape of molar region residual ridge. No correlation exists between the shape of the molar region residual ridge and retention force.

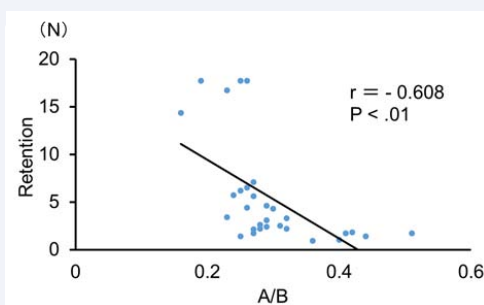


**Figure 7** Effect of mediation fluids and mouth opening. A gel type of oral moisturizer shows greater retention compared to that of artificial saliva. Retention force decreases with larger mouth opening size.

mandibular region, and the middle point of the posterior borders of denture when the mouth opening level was 1 cm. There was a significant negative correlation between retention and Distance A ( $P < .01$ ; Figure 11). There was also a significant negative correlation between retention and the ratio of the distance of the anterior residual ridge crest from the central incisor edge to the distance of the posterior border of the denture from the central incisor edge (Distance A/Distance B;  $P < .01$ ; Figure 12).



**Figure 11** Effect of the relative position of the anterior residual ridge. Retention force decreases as the distance (A) from the cutting edge of the central incisor to the anterior residual ridge crest increases.



**Figure 12** Effect of the relative position of the anterior residual ridge. Retention force decreases as the ratio of the distance (A) from the central incisor to the anterior residual ridge and the distance (B) from the central incisor to the posterior denture border increases.

## DISCUSSION

### Retention according to the condition

According to a report by Yamagaki et al. [15], there is a positive correlation between retention and the viscosity of mediating fluid. We found that retention increased as the viscosity of the oral moisturizer increased when used with mandibular complete dentures, similar to that of maxillary complete dentures, indicating that the use of oral moisturizer may increase denture retention in the oral cavity. When using artificial saliva as the mediating fluid, the lowest variation index and the smallest error on repeated measurement were achieved with the 1 cm mouth opening size, which appeared to be the most stable. Thus, opening the mouth to 1 cm was preferable for the measurement of retention.

### Height and shape of the molar region residual ridge

Since there is no established method for evaluating the height and shape of the molar residual ridge [24,25], we developed a scale and used it for measurement. When we compared the retention of maxillary complete dentures according to the height and shape of the molar residual ridge, we found no significant difference [22]. In this study, no significant difference was found between the residual ridge shape and retention, although there was a significant difference between the height of the residual ridge and retention. Retention was measured by applying a force to the cutting edge of the central incisor, and the fulcrum

point was the residual ridge in the anterior mandibular region. Moreover, the residual ridge in the anterior mandibular region might affect retention. However, in the present study, the number of the subjects was too small to analyze the effect of the height and shape of the molar region residual ridge on retention, and various other factors may influence denture retention [9]. Further investigations are therefore necessary.

### Relative positions of the central incisor edge, anterior residual ridge crest, and posterior border of the denture

It has been reported that the form of the pad is important for the retention of mandibular complete dentures [26]. However, no previous studies have compared retention based on the residual ridge shape and the denture form [22,27,28]. When measuring the force applied to the cutting edge of the midline between the right and left central incisors, a force is applied to the posterior border of the denture to dislodge the denture by using the residual ridge in the anterior mandibular region as a fulcrum point. Therefore, we measured the effect of position, including the cutting edge of the central incisor, the residual ridge in the anterior mandibular region, and the posterior border of the denture.

We found a negative correlation between retention and the distance from the cutting edge of the central incisor to the anterior residual ridge crest, and demonstrated that retention decreases as the distance from the residual ridge to the cutting edge of the central incisor increases. There was similarly a negative correlation between retention and the ratio of the distance of the anterior residual ridge crest from the central incisor edge to the distance of the posterior border of the denture from the central incisor edge. This may be related to the actual resorption of the mandibular bone of the residual ridge in the anterior mandibular region (resorption in the inside, upper, lower, and anteroposterior directions) in the living body.

We showed that the measurement of retention using the central incisor edge is greatly influenced by the relative position of the anterior residual ridge crest in terms of the distance from the central incisor edge to the middle point linking the central incisor edge to the posterior border of the denture. This result suggests that the retention force of mandibular complete dentures depends on the position of the posterior border of the denture and on the relative positions of the central incisor edge, anterior residual ridge crest, and posterior border of the denture. Hence, these positions should be considered.

### Future research

This study was conducted on only 30 recall patients; thus, it is difficult to generalize our findings. These findings may vary if we include patients with a fault in their denture or oral cavity. In future, it is necessary to conduct studies with more patients in different study locations in order to assess the generalizability of our findings. In the future, the relationship between retention and the effect of the lips, buccal mucosa, and tongue should be investigated by measuring denture retention in a greater number of subjects wearing complete dentures. Moreover, the effect of xerostomia on denture retention force and the relationship between objective assessment of retention force and the patients'

satisfaction with each mediating fluid should be clarified. This would allow improved dental care of patients requiring complete dentures, which would contribute to the improvement of the QOL of the elderly.

## CONCLUSIONS

As the viscosity of the oral moisturizer increased, denture retention increased. Opening the mouth to a size of 1 cm allowed stable measurements. Retention was associated with the height of the residual molar ridge and with the relative position of the anterior residual ridge crest.

## ACKNOWLEDGEMENTS

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