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# The vibratory characteristics of obturators with different bulb height and form designs

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SUMMARY **The aim of the present study was to investigate whether the vibratory characteristics of obturator prostheses are affected by bulb design, i.e.: the hollow or buccal flange type, and different lateral and medial bulb heights. Buccal flange and hollow bulb obturator prostheses were fabricated with two different lateral bulb wall heights and two different medial bulb wall heights. Ultimately, eight obturator prostheses were prepared for evaluation of their vibratory characteristics. The frequency–response functions were recorded on an FFT analyzer to identify their vibratory characteristics. A transient response simulation was carried out in which an impact was applied to the non-defect side. The decay rate, damping time and maximum amplitude of the retainers were statistically analysed by ANOVA with Scheffé's test ($P < 0{\cdot}05$). The decay rate of every buccal flange type was higher and damping time was shorter than those of every hollow type, except between a pair with low lateral and low medial bulb walls. The maximum amplitude values of four obturators with low medial bulb walls were significantly lower than those of four obturators with high medial walls. The buccal flange obturator prosthesis with high lateral and low medial walls showed the maximum decay rate and the minimum amplitude of the retainers on molars. Vibration analysis suggests that a buccal flange obturator prosthesis with high lateral and low medial walls is preferable.**

KEYWORDS: **maxillectomy patients, maxillofacial prosthetics, obturator prosthesis, modal analysis, bulb designs**

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## Introduction

Prosthetic rehabilitation of the maxillofacial region has played an important role in improving the quality of life of patients with acquired maxillary defects (1, 2). Obturators extend into nasal defects to various degrees and contribute to the effectiveness of oronasal separation and the retention and the stability of the prosthesis, thereby improving the patients' speech and aesthetics. The degree of maxillofacial prosthetic treatment depends on various factors, such as the size and location of the defect, the absence or presence of natural teeth, and availability of tissue undercuts around the defect cavity. In patients with extensive maxillary defects, the form and weight of the bulb is important, as the weight of the obturator exerts dislodging and rotational forces on the abutment teeth (2–4). Concerning the nasal extension, Brown (5) and Desjardins (6) have suggested that the lateral wall of the bulb should be extended higher geometrically. However, bulb height is occasionally limited, such as in cases with trismus. Sharry (7) felt that it is not necessary to fill the entire defect. Adisman (8) stated that if the defect is limited to the hard palate area, it is sufficient to cover the defect and create a seal by engaging a minimal amount of undercuts. Aramany and Drane (9) indicated that the use of small nasal extension sections in hollow obturators in patients with large palatal defects tends to improve voice quality, but with smaller defects, the size of the nasal extension

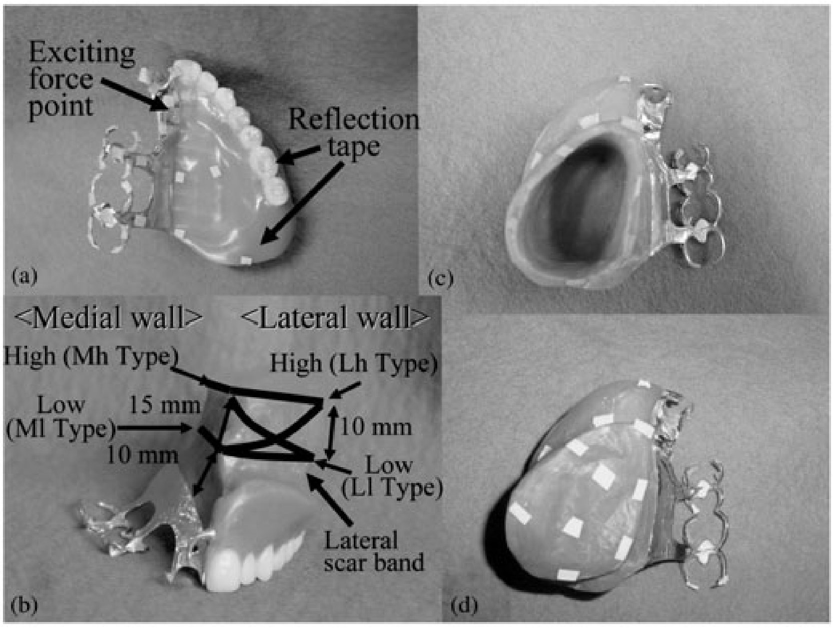


**Fig. 1.** Test subjects. (a) Occlusal view of obturator. The metal framework had a hole for the impact force using a screw rod. Reflection tapes were placed on all measurement points. (b) The types of obturator prostheses: the height of the obturator bulb was varied. There were two different lateral heights, such as, high (Lh) or low (Ll), and two different medial heights, high (Mh) or low (Ml). Consequently, eight bulb types of obturator prostheses such as HoLhMh, BuLhMh, HoLlMh, BuLlMh, HoLhMl, BuLhMl, HoLlMl and BuLlMl were prepared. (c) Mucosal view of the buccal flange type obturator (Bu). (d) Mucosal view of the hollow type obturator (Ho).

section has little effect on voice quality. Oral *et al.* (10) reported that buccal flange obturators showed statistically significant superiority to hollow obturators as the preferred condition only in the live and tape-recorded evaluation of speech.

Modal analysis (11) has come to be applied in the dental research field, and is used to establish a rationale for designing metal frameworks (12–14). Masticatory force causes vibration of the teeth or prostheses during function. Concerning the application of modal analysis to maxillofacial prosthetics, Oki *et al.* (15) evaluated the vibratory characteristics of a solid, a buccal flange, and a hollow-type obturator prosthesis, and revealed that a hollow obturator showed rapidly stopping vibration and minimized displacement of the retainers. Kobayashi *et al.* (16, 17) evaluated hollow obturators (16) and buccal flange obturators (17) with different lateral bulb heights. They suggested that the decay rate was higher when the lateral wall of the obturator was lower. To date, however, there have been no studies clarifying the relationship among the height of the lateral and medial wall of obturator prostheses, the type of bulb, and the vibratory characteristics of the retainers.

The purpose of the present study was to investigate the effect of height of the lateral and medial wall and both hollow and buccal flange bulbs on the vibratory characteristics of a cast obturator prosthesis classified as Aramany Class I (18–20). Eight samples, in which the bulb parts were formed into two different heights of the lateral wall and two different heights of the medial wall of buccal flange and hollow types, were evaluated according to decay rate, damping time and maximum amplitude of the retainers *in vitro*.

## Materials and methods

### *Experimental subjects*

A model cast categorized as Aramany Class I (18–20) was selected in the present study. The teeth from the right central incisor to the right second molar remained on the non-defect side. The defect size was 50 mm medial-distally, 30 mm buccal-palatally and 45 mm in height. A metal framework was fabricated of Chrome–Cobalt alloy (Biosil-l®)* (Fig. 1). The framework had two embrasure clasps on the first and second molar and on the first and second premolar, and an RPI system (rest, proximal plate, I-bar clasp) on the central incisor. The framework was threaded at the middle of the metal base for fixation onto the exciting rod. The buccal flange type of obturator, which had a wall thickness of approximately 2 mm, was processed in the standard manner, using heat-polymerizing acrylic resin (Acron)†. To fabricate a hollow-type obturator, an impression of the top of the bulb was taken to act as a

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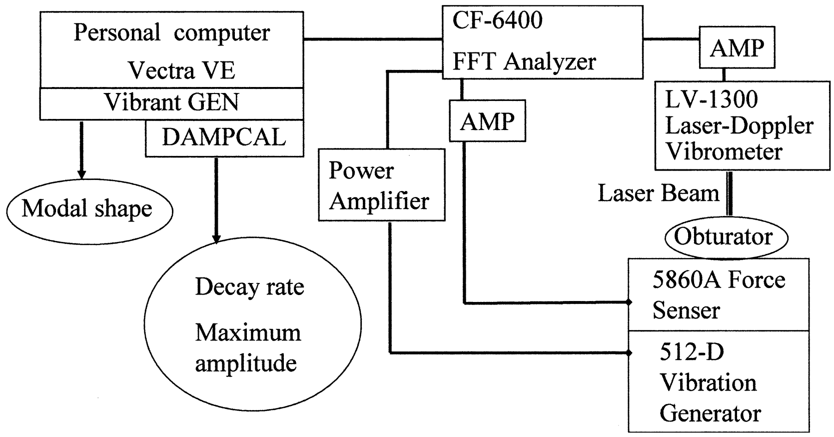


**Fig. 2.** Diagram of the experimental setup.

lid. The lid was processed with heat-polymerizing acrylic resin and fixed to the bulb with auto-polymerizing acrylic resin (Unifast-II)†, to complete the first obturator, with a high lateral and high medial wall and a hollow bulb (HoLhMh). The top of the lateral wall was about 15 mm above the lateral scar band. After HoLhMh was measured for vibration analyses, the lid was cut off. A buccal flange type was then fabricated at the same bulb height (BuLhMh). After BuLhMh was measured, 10 mm of the height of the lateral wall of the bulb was removed but the medial wall was retained, and the anterior and posterior walls between them were trimmed transitionally. By attaching a new lid, a lateral low hollow type was made (HoLlMh). After HoLlMh was measured, the lid was cut off, and a buccal flange type was prepared with the same bulb height (BuLlMh). After measuring BuLlMh, the medial wall of the bulb was removed to 10 mm up to the metal-resin finishing line, the lateral wall was restored to the same height as in BuLhMh, and the other wall parts were modified. Thus, by attaching a new lid, a medial low hollow type was made (HoLhMl). After HoLhMl was measured, the lid was trimmed. The buccal flange type was fabricated at the same bulb height (BuLhMl). HoLlMl and BuLlMl were made in the same manner (Fig. 1).

The weights of HoLhMh, BuLhMh, HoLlMh, BuLlMh, HoLhMl, BuLhMl, HoLlMl and BuLlMl were 41·50, 38·22, 38·97, 36·01, 38·04, 35·44, 36·28 and 33·92 g, respectively.

*Measurement points*

In the present study, 53 measurement points were placed on each hollow type obturator (HoLhMh, HoLlMh, HoLhMl and HoLlMl) including two points on the lid part, 51 points on each buccal flange type (BuLhMh, BuLlMh, BuLhMl and BuLlMl) (Fig. 1). Forty-seven measurement points were located at the same points of the eight obturators except for two points on the lid part and four changeable points on the rim of the bulb part.

The coordinate value of each measurement point was measured using SURFLACER, a non-contact, high-speed 3-D Shape Measurement System‡. The 3-D data were computed on a workstation (Indigo2)§ using SURFACER 3-D surface data management-conversion-analysis software¶. The coordinate values of each point were input into Vibrant GEN** to draw the wire-frame shape.

*Measurement system*

Figure 2 shows overall system diagram. A 512-D Vibration Generator†† and a 5-Axis Stage‡‡ were set up on an AYN-1007K4 Vibration Isolator Table‡‡. A 5860A Force Sensor§§ connected to the Vibration Generator was applied to measure the excitation force signals. The response force signals were picked up by a LV-1300 Laser-Doppler Vibrometer¶¶ whose sensor head was supported by the 5-Axis Stage. The excitation signals and the response signals were led through

‡UNISN Inc., Osaka, Japan.
§Silicon Graphics Inc., Mountain View, CA, USA.
¶Imageware Inc., Ann Arbor, MI, USA.
**Marubeni Solutions Co., Tokyo, Japan.
††EMIC Co., Tokyo, Japan.
‡‡Meiritsu Seiki Co., Yokohama, Japan.
§§Dytran Instruments Inc., Chatsworth, CA, USA.
¶¶Ono Sokki Co. Ltd., Yokohama, Japan.

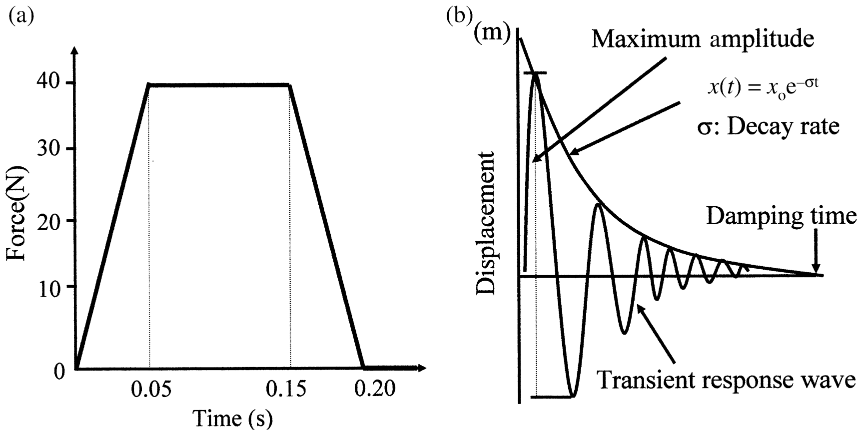


**Fig. 3.** Transient response simulation. (a) Simulation conditions: the force of 40 N in the vertical direction impacted simultaneously on the two rests of each embrasure clasps on the non-defect side. (b) Transient response diagram: decay rate, damping time and maximum amplitude were calculated using this wave.

respective charge preamplifier (AMP) into a CF-6400 FFT analyzer¶¶ to calculate the frequency–response functions at each measurement point. All frequency response functions were input into a Vectra VE personal computer*** and analysed using Vibrant GEN modal analysis software.

*Measurement procedure*

The experiment was performed in a laboratory at 24 °C and 40% humidity.

The test subject was screwed onto a rod connected to the vibration generator. The occlusal plane was set parallel to the horizontal plane. The reflection tapes were placed on the measurement points, as far as possible perpendicular to the vertical axis to enhance laser beam detection. The He-Ne laser beam was aimed parallel to the vertical axis and the vibration direction.

Periodic random excitation was selected as the exciting force signal. The frequency range in this examination was 0–3200 Hz. The frequency–response function of each measurement point was calculated as the summed average of eight measurements by FFT analyzer. The frequency–response functions at all measurement points were transferred to Vibrant GEN and adjusted using the curve-fitting function in the frequency range from 200 to 2800 Hz with an error convergence rate of curve-fitting kept at >99·90%.

*Procedure transient response Simulation*

Using all the curve-fitted frequency–response functions, the transient response waves were produced at 18 points established on two embrasure clasps of each obturator by Vibrant GEN transient response simulation. In this simulation, the models were impacted under the same conditions (Fig. 3a) as in Simulation 1 of Kobayashi *et al.*'s study (16).

Decay rate, damping time and maximum amplitude were used to evaluate the waves. For the decay rate and damping time, the wave peaks of each measurement point were carefully selected and plotted on a computer display. The decay rate and damping time were then calculated using the method of least squares and DAMPCAL software**. The plots were repeated four times to prevent measurement errors, after which the mean decay rate and damping time of the point were obtained. The maximum amplitude value of each measurement point was automatically calculated using DAMPCAL software (Fig. 3b).

Statistical analysis was performed according to the One-way analysis of variance (ANOVA) with Scheffé's test ($P < 0{\cdot}05$) to compare the decay rate, damping time and maximum amplitude results among eight samples.

## Results

The results of the curve-fitted frequency–response functions of eight obturators within the range of investigation between 200 and 2800 Hz are shown in Fig. 4. Table 1 presents the natural frequencies of eight obturator prostheses. The natural frequency–response peaks remained constant for all measurement points in each sample.

The results of transient response simulations (Fig. 5) revealed an inclination of the damping curve at the tip of the clasp at the second molar. The mean ± s.d. of the decay rate of HoLhMh, BuLhMh, HoLlMh, BuLlMh,

***Hewlett-Packard Co., Grenoble Cedex, France.

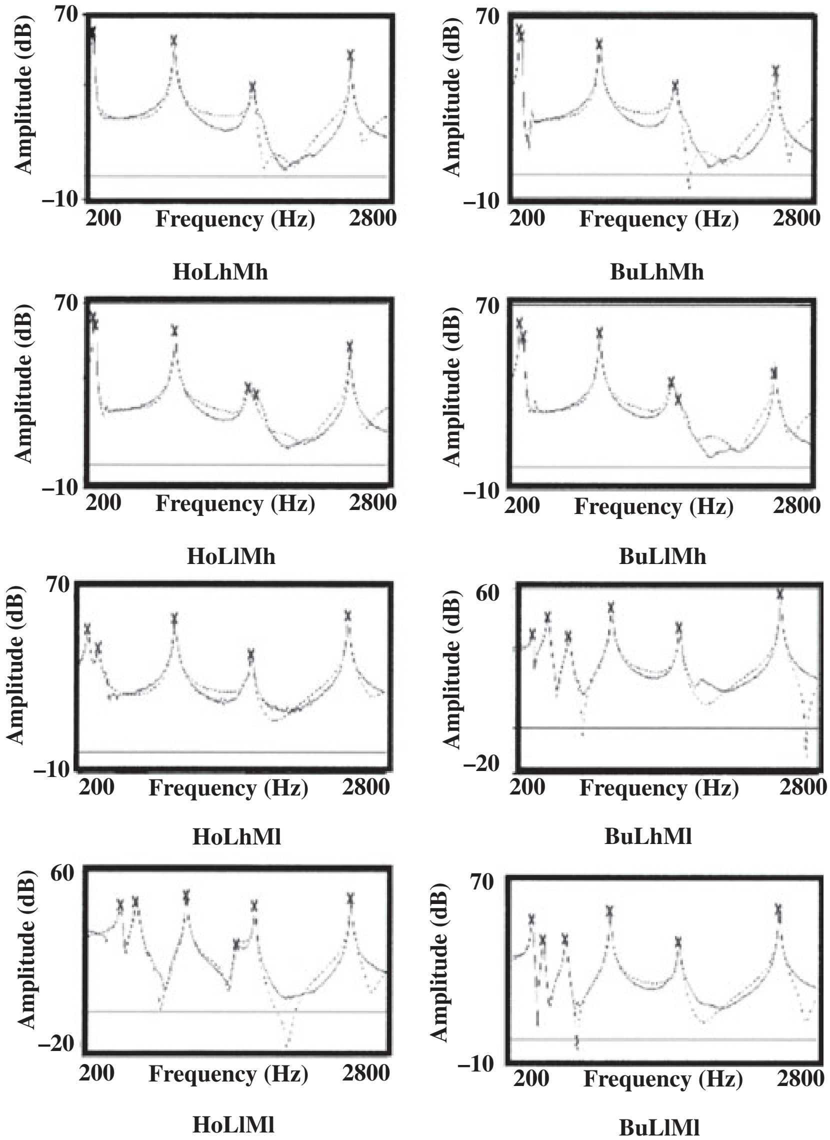


**Fig. 4.** The curve-fitted frequency–response functions at the tip of the clasps on the second molar.

HoLhMl, BuLhMl, HoLlMl and BuLlMl were 18·62 ± 0·84, 20·96 ± 0·58, 22·26 ± 0·83, 24·82 ± 0·69, 41·80 ± 8·71, 48·06 ± 2·49, 45·08 ± 8·78 and 33·57 ± 2·80 $s^{-1}$, respectively. Significant differences were found in all pairs among eight prostheses, except between HoLhMh and BuLhMh, HoLhMh and HoLlMh, BuLhMh and HoLlMh, BuLhMh and BuLlMh, HoLlMh and BuLlMh, HoLhMl and HoLlMl and BuLhMl and HoLlMl (Fig. 6) ($P < 0{\cdot}05$).

The mean ± s.d. of the damping time of HoLhMh, BuLhMh, HoLlMh, BuLlMh, HoLhMl, BuLhMl, HoLlMl and BuLlMl were, respectively, 0·85 ± 0·02, 0·81 ± 0·01, 0·78 ± 0·02, 0·70 ± 0·01, 0·40 ± 0·05, 0·39 ± 0·01, 0·38 ± 0·04 and 0·45 ± 0·02 s. Significant differences were found in all pairs among eight prostheses, except between BuLhMh and HoLlMh, HoLhMl and BuLhMl, HoLhMl and HoLlMl, and BuLhMl and HoLlMl (Fig. 7) ($P < 0{\cdot}05$).

Figure 8 shows that the mean ± s.d. of the maximum amplitude of HoLhMh, BuLhMh, HoLlMh, BuLlMh, HoLhMl, BuLhMl, HoLlMl and BuLlMl were 1·165 ± 0.381, 1·656 ± 0·507, 1·019 ± 0·554, 1·633 ± 0·483, 0·043 ± 0·038, 0·026 ± 0·011, 0·098 ± 0·074 and 0·064 ± 0·040 $\times 10^{-3}$mm, respectively. A comparison of these eight obturators revealed the maximum amplitude of BuLhMl to be the smallest, but no

**Table 1.** Natural frequencies of eight obturator prostheses (Hz)

| Type | HoLhMh | BuLhMh | HoLlMh | BuLlMh | HoLhMl | BuLhMl | HoLlMl | BuLlMl |
|---|---|---|---|---|---|---|---|---|
| Mode |  |  |  |  |  |  |  |  |
| 1 | 280 | 290 | 290 | 310 | 280 | 370 | 520 | 380 |
| 2 | 290 | 310 | 310 | 340 | 370 | 500 | 650 | 480 |
| 3 | 980 | 980 | 990 | 990 | 1020 | 680 | 1080 | 660 |
| 4 | 1650 | 1620 | 1620 | 1610 | 1670 | 1040 | 1510 | 1050 |
| 5 | | | 1690 | 1670 | | 1630 | 1670 | 1630 |
| 6 | 2490 | 2490 | 2490 | 2480 | 2490 | 2490 | 2490 | 2490 |

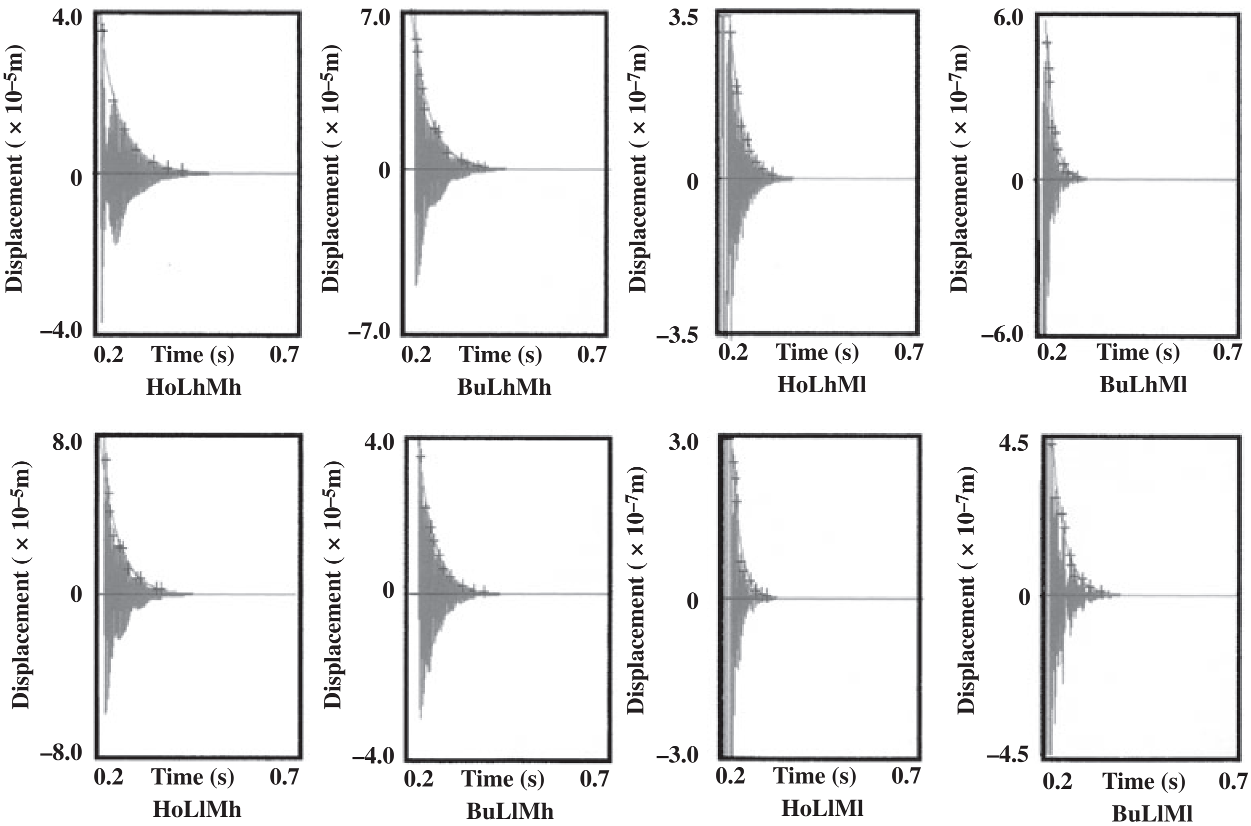


**Fig. 5.** Transient response simulation waves at the tip of the clasp on the second molar.

significant differences were found between HoLhMh and HoLlMh, BuLhMh and BuLlMh, HoLhMl and BuLhMl, HoLhMl and HoLlMl, HoLhMl and BuLlMl, BuLhMl and HoLlMl, BuLhMl and BuLlMl, or HoLlMl and BuLlMl (Fig. 8) ($P < 0{\cdot}05$).

## Discussion

Designs of maxillary obturator bulb are affected by the size and location of the defect and availability of tissue undercuts around the defect cavity. We fabricated four different bulb height designs, of types used in many clinical cases, but with different lateral wall and different medial wall heights. If trismus is very severe, upward extension is limited. The medial wall should not be as high as the lateral wall, where the height of the medial wall may be limited by the turbinates, which should not come into contact with the prosthesis. However, it is considered that satisfactory retention and stability of obturator during function are provided

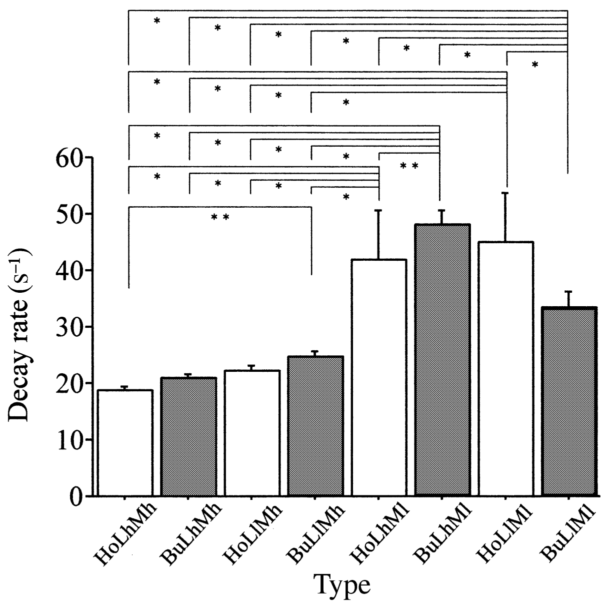


**Fig. 6.** Decay rates of eight obturator prostheses (*$P < 0{\cdot}01$, **$P < 0{\cdot}05$).

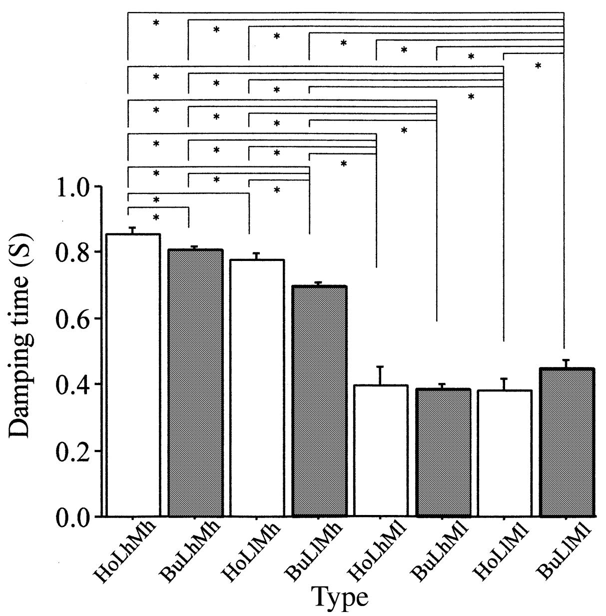


**Fig. 7.** Damping time of eight obturator prostheses (*$P < 0{\cdot}01$).

when the bulb wall is as high as possible beyond the scar band (5, 6). In addition, it is suggested that the size and bulb type, the buccal flange type or the hollow type, affects voice quality (9, 10).

The most frequent maxillary defect is the case classified as Aramany's Class I (18–20). This group has a large unilaterally maxillary defect with the teeth along one side of the arch. The abutment teeth are

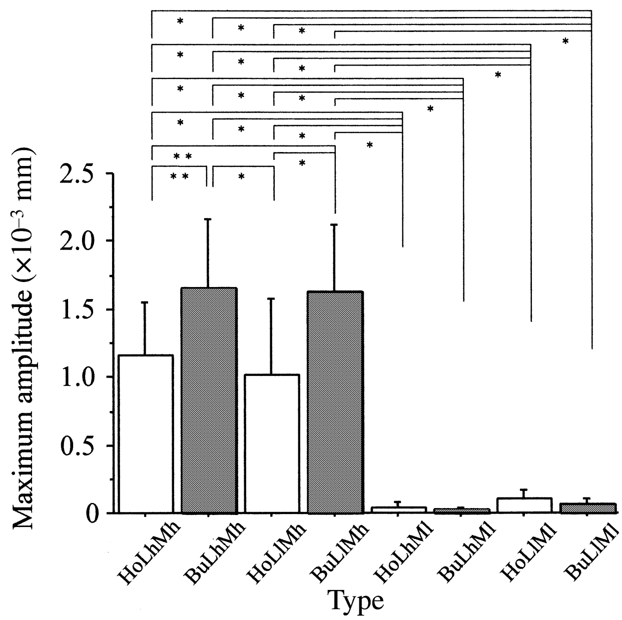


**Fig. 8.** Maximum amplitudes of eight obturator prostheses (*$P < 0{\cdot}01$, **$P < 0{\cdot}05$).

exposed to the rotational and dislodging forces caused by a heavy bulb. To increase the longevity of the abutment teeth, it is useful to investigate the dynamic characteristics of the retentive clasps of the obturator.

Theoretically, the high decay rate and short damping time mean that, after an impact has been applied, the subject can stop the vibrations quickly and rapidly absorb the energy of impact. Kobayashi *et al.* (16) claimed that the hollow type obturator with a lower lateral bulb had a higher decay rate. Kobayashi *et al.* (17) also indicated that a buccal flange obturator with a lower lateral bulb had a higher decay rate. Oki *et al.* (15) reported that, when an obturator classified as Aramany's class II (18–20) impacted on the rest parts of metal framework under almost the same conditions as in the present study, the decay rates of the hollow type were significantly higher than those of the solid and the buccal flange types. In the present study, our simulation showed that the decay rate of every buccal flange type was higher than those of every hollow type, except between HoLlMl and BuLlMl, in which the decay rate of the hollow type was higher than that of the buccal flange type. The results for damping time were identical to those for decay rate: every buccal flange type obturator had a shorter damping time than that of every hollow type, except between HoLlMl and BuLlMl. These results indicated that a buccal flange type obturator was superior if a sufficiently high lateral wall could be obtained, but that if the obturator had only a low lateral and low medial wall, for instance, the patient had a condition such as severe trismus, that the hollow obturator might be more suitable. Brown (5) and Desjardins (6) suggested the importance of extending the lateral wall of the bulb higher. Bummer *et al.* (2) reported that the superior height of medial palatal extension should terminate at the junction of the oral and respiratory mucosa, or at the level of the nasal floor, as further extension medially would only serve to impede nasal airflow. For reason of rapidly stopping vibration at retainers, BuLhMl would be the optimal obturator design as it showed the best decay rate values.

Concerning maximum amplitude, the obturator with the best properties for minimizing maximum amplitude would be preferable. The obturator should be designed to share the stress sustained by abutment teeth and thus increase their longevity. Clinically, the movement of abutment teeth should be within the range of physiologic tooth movement. Miura *et al.* (21) reported that the displacement of a maxillary molar in the palatal direction during mastication varied between $68 \times 10^{-3}$ and $79 \times 10^{-3}$ mm. The mean values of maximum amplitude of all obturators were shown to be under the normal physical range (21). The maximum amplitude of BuLhMh and BuLlMh were significantly larger than those of the others, and the maximum amplitude values of four obturators with low medial bulb walls were significantly better than those of four obturators with high medial walls. The mean values of maximum amplitude in retainers of obturators with high medial walls thus showed much movement. No significant differences among hollow obturators were observed. These findings support that the medial wall of the nasal extension of the medial wall into the defect did not require the maximum height (2).

In conclusion, the BuLhMl obturator was less movable and the decay rate was higher. The results of vibratory characteristics are another rationale for keeping the medial wall at a modest height but keeping lateral walls as high as possible. Mouth opening training may be necessary to avoid trismus during maxillofacial prosthetic rehabilitation. It should lead to better conditions to make the obturator with a high lateral and low medial wall, and to distribute the stress sustained by the abutment teeth and thus increase their longevity.

We are aware that our test conditions do not completely reproduce the clinical situation; however, they did simulate actual clinical variability reasonably accurately, even though the resultant variance was somewhat large. The results yield useful basic information on the principles of the bulb structure of obturator prostheses.

## Acknowledgments

We would like to thank Dr Makio Kobayashi, Dr Shogo Ozawa and Dr Takaaki Inoue for their kind advices in this study. A part of this study was presented at the 6th ISMR Maxillofacial Conference in 17 June 2004, Maastricht, The Netherlands.

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