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Impact of lingual plates on the interocclusal free way space: a pilot study

C. BARBEZAT*, M. SRINIVASAN*, M. SCHIMMEL*, K. HORI§, K. TAMINE†, T. ONO†1 & F. MÜLLER*‡1 *Division of Gerodontology and Removable Prosthodontics, University of Geneva, Geneva, Switzerland, †Division of Oro-maxillofacial Regeneration, Osaka University Graduate School of Dentistry, Suita, Japan, ‡Department of Rehabilitation and Geriatrics, University Hospitals of Geneva, Geneva, Switzerland and §Division of Dysphagia Rehabilitation, Niigata University Graduate School of Medical and Dental Sciences, Niigata, Japan

SUMMARY **Palatal augmentation prostheses are commonly used in the treatment for dysphagia. By lowering the palatal contours, the tongue contact is increased and thus the bolus propulsion facilitated. However, the unfavourable weight of such appliances may be avoided when using lingual plates. Hence, the aim of this study is to investigate the effect of two different types of lingual plates on the vertical dimension in rest position. Eleven healthy dentate subjects with an average age of 35·5 years (26–60 years) volunteered in this pilot study. The vertical overbites were measured on plaster models. Two different designs of the experimental lingual plates were tested in this pilot study (P-type & D-type). The inter-occlusal freeway space was measured using the electromagnetic K7 jaw-tracking system (Myotronics, USA), while the subjects were seated in an upright position. They were asked to close from rest position into maximum intercuspation for about 2 s. Recordings were performed without the plates and subsequently with each of the two plate designs *in situ*. All recordings were performed three times and the second closing movement of each recording was used for the analysis. After averaging the repetitions without experimental lingual plates, with P-type and D-type plates, the differences were analysed using a Kruskall–Wallis test. The results showed no significantly increased freeway space while using both types of lingual plates. Hence, it can be concluded that any altered tongue pressure during swallowing with lingual plates is not related to an increase in vertical dimension.**

KEYWORDS: **lingual plates, palatal lift prosthesis, dysphagia, vertical dimension, freeway space**

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Introduction

Dysphagia or swallowing dysfunction is a very common disorder in frail elderly individuals. Dysphagia increases the risk of aspiration whereby potentiating the risk of pneumonia and possibly death (1). Swallowing function is of primary importance for masticatory function and nutrition and in compromised individuals it is an important reflex to prevent food and saliva aspiration. The role of the tongue and its pressure during swallowing has often been studied in dysphagic and non-dysphagic subjects (2). Videofluorographic investigations and more recently, newly developed pressure sensors have provided comprehensive evidences to reveal the coordination of the tongue with other associated structures in swallowing (3).

Palatal augmentation prostheses lower the contours of the palate in regions where the dysfunctional tongue has a reduced contact (4, 5). Palatal plates have demonstrated to improve oral functions including deglutition, depending on their thickness and the extent of palatal coverage (6–8). Measurements of the tongue pressure evinced a correlation to the thickness

[1]Equal contribution as senior authors.

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of the palatal resin plate. Another important factor influencing the tongue pressure during swallowing is the occlusal vertical dimension; an increase in the occlusal vertical dimension reduced the tongue pressure on the palate (9). Head posture is also known to affect swallowing and can be used in preventing aspiration in dysphagic patients (10, 11). In particular, the use of chin down posture is frequently employed to reduce and prevent aspiration during swallowing, although this posture requires more effort in performing the oropharyngeal swallow (10).

Although the palatal augmentation prostheses are commonly used and somewhat successful in the treatment for dysphagia, their major shortcoming is their weight, which may diminish denture retention, especially when no residual abutment teeth are present to retain the appliance. The thick resin palatal plate may further cause discomfort and diminish patient compliance.

These inconveniences could be avoided by using lingual plates as an alternative to the conventional palatal lift prosthesis. The mechanical support of the tongue tissue by means of the lingual plates would help to raise the tongue by reducing the available space for the tissues and enhance contact of the dorsum of the tongue to the natural palate during swallowing. Lingual tongue-lifting plates have been used in children with Down syndrome as well as tumour patients with partial resection of the tongue, yet their scientific evaluation for both indications is still missing.

The efficacy of the lingual plates as a swallowing aid in the treatment for dysphagia has not been tested nor has it been experimentally verified whether such devices would provide adequate tongue lift and tongue pressure on the palate to aid in swallowing. However, the additional volume in the oral cavity may increase the occlusal vertical dimension, which in turn might extinct the therapeutic effect of the plates. Hence, the purpose of this study was to experimentally confirm whether the use of lingual plates for the treatment for swallowing disorders would have any influence on the interocclusal freeway space or the occlusal vertical dimension.

Materials and methods

The ethical committee of the University of Geneva, Switzerland, approved the study protocol. Written informed consent was obtained from all participants.

Subjects

The subjects included in this experimental *in-vivo* pilot study were 11 healthy dentate volunteers (four women and seven men; mean age 35·5 ± 10·5 years; range 26–60 years; Angle class I $n = 7$, Angle class II/2 $n = 4$) with no history of masticatory, swallowing, occlusal and TMJ disturbances. They were recruited from the staff of the dental school. Alginate impressions were taken, and the overbite was measured from the poured plaster casts.

Experimental lingual plate design

Two different types of the experimental lingual plates were fabricated for the purpose of this study (Fig. 1). First a plateau design (P-type) shaped to extend the occlusal plane lingually for half of the adjacent tooth's width. Posteriorily the plateau was rounded off in a semi-circle and in the anterior region, it was 3–4 mm wide. Secondly a drop-shaped design (D-type) that bulked in the lingual sulcus and tapered to the occlusal plane. At their thickest point, they were on average 7·5 ± 1·1 mm (D-type) and 7·6 ± 1·3 mm (P-type) thick. The experimental lingual plates were fabricated with heat-polymerised resin and attached to the dentition with bent wire clasps. Care was taken to avoid occlusal interference from the clasps.

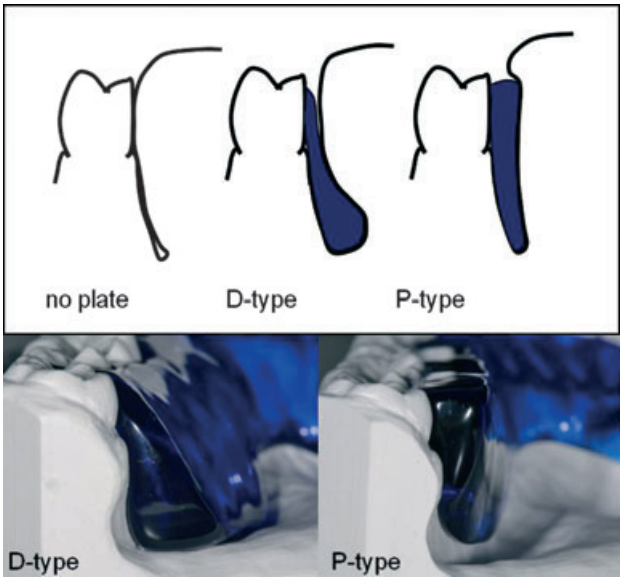

Fig. 1. Two different lingual plates were fabricated: a drop-shaped one which flattens towards the occlusal plane and a p-shaped one which extends the occlusal table lingually.

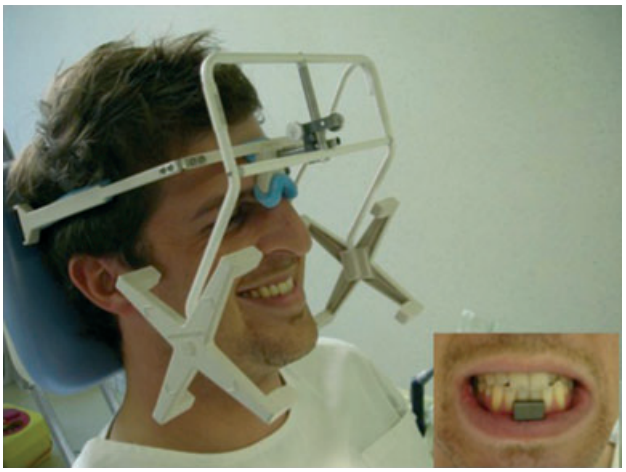

Fig. 2. Electromagnetic jaw tracking was used to record mandibular movement (K7 system). Inset photograph shows an affixed intra-oral magnet in place.

Measurement of the interocclusal freeway space

The freeway space was measured using an electromagnetic K7 jaw-tracking system* (Fig. 2). The K7 system is a computer-based system for three-dimensional jaw tracking comprising of a light (225 g) headset with eight hallway-transducers, which monitor the position of a small permanent magnet, attached to the lower incisors at a frequency of 60 Hz. The magnet has a size of $4 \times 8 \times 12$ mm and was affixed with the double-sided adhesive material (Stomahesive strips*). Within a distance of 8 mm from occlusion, the system has a maximum measuring error of 0·5 mm.

Study protocol

The protocol was explained to the participants, and the plates were checked for comfort, fit and occlusal clearance. The permanent magnet was attached parallel to the eye-line and clear from the upper incisors in occlusion. Then the K7 aerial was placed on the head parallel to the magnet, the central position of which was verified by means of the K7 software. The subjects were comfortably seated upright on a dental chair with the occlusal plane horizontal. They were instructed to lick their lips and then rest their mandible with the moistened lips un-forcefully closed. After the recording started, they were asked to close down in maximum intercuspation for about 2 s and then return to the rest position several times (Fig. 3). The recordings were repeated twice so that a total of three recordings were available for the analysis. The second closing movement from rest position into maximum intercuspation from each sequence was measured using the K7 software. The freeway space was first recorded without any plates in the mouth and subsequently repeated with the P-type and D-type appliances *in situ*. The same two operators performed all the experiments.

Statistical analysis

The repeated measurements of the freeway space were averaged per subject and each of the three experimental situations: without plate, P-type and D-type appliances *in situ*. Furthermore, the difference in freeway space was calculated for every patient. The calculated values were then compared by means of a Kruskall–Wallis Test with the level of significance set at $P < 0{\cdot}05$. In addition, the freeway spaces were compared with a non-parametric Wilcoxon test for paired data. The freeway spaces of the participants with different Angle's classes (I and II/2) were compared with the non-parametric Mann–Whitney test for unpaired data. The correlation between incisal overbite and increase in freeway space with the plates were analysed by a simple regression analysis. STATVIEW 5·0† was used for these tests. In addition post hoc power analysis was carried out using G*Power 3·1 (12).

Results

An average vertical mandibular displacement from rest position to maximum intercuspation of $1{\cdot}4 \pm 0{\cdot}8$, $1{\cdot}6 \pm 0{\cdot}9$ and $1{\cdot}6 \pm 0{\cdot}9$ mm was measured without plates, with P-type and D-type plates, respectively (Fig. 4). The differences calculated per participant indicated an average increase in the freeway space of $0{\cdot}2 \pm 0{\cdot}8$ and $0{\cdot}2 \pm 0{\cdot}9$ mm for type P and type D, respectively (Fig. 5). None of the differences were statistically significant (Kruskall–Wallis $P = 0{\cdot}8635$; Wilcoxon: no plate versus P-type $P = 0{\cdot}8939$ ($1-\beta = 0{\cdot}98$), no plate versus D-type $P = 0{\cdot}9594$ ($1-\beta = 0{\cdot}99$), P-type versus D-type $P = 0{\cdot}9645$ ($1-\beta = 0{\cdot}96$). Subjects with an Angle's classification of Class II division 2 ($n = 4/11$) exhibited a non-significant tendency to larger freeway space with or without the lingual plates. They also tended to show an increase in freeway space with

*Myotronics, Kent, WA, USA.

†SAS Institute Inc, Cary, NC, USA.

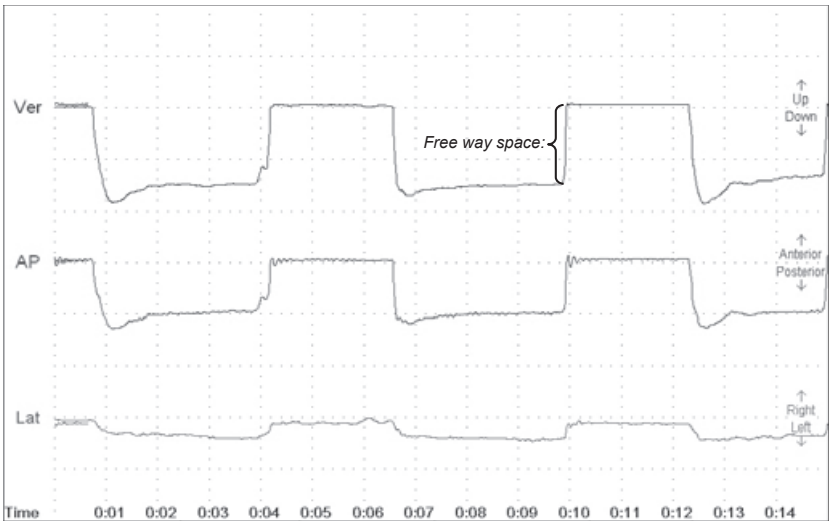

Fig. 3. Example of a 3D-tracking of repeated mandibular closure from rest position into maximum intercuspation. The second closing movement was used for the analysis.

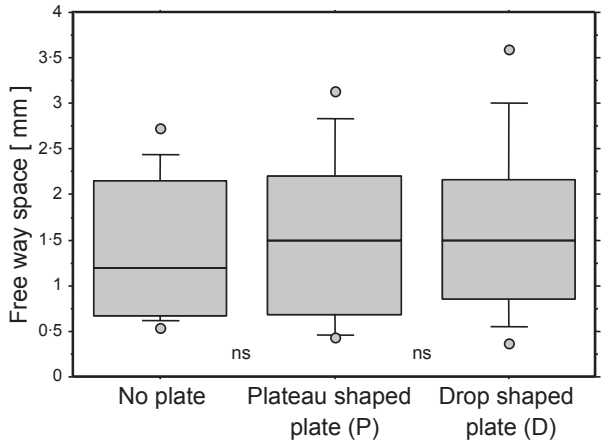

Fig. 4. Box-plot of the freeway space without lingual plate, with the P-type and the D-type lingual plates (minimum, 5%, 25%, median, 75% and 95%, maximum). None of the interocclusal distances in rest position were statistically different.

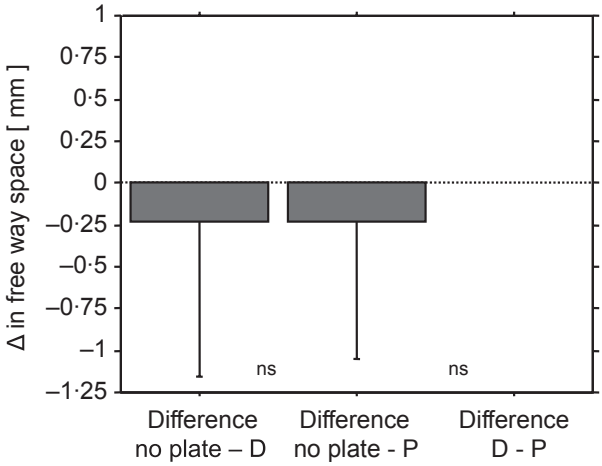

Fig. 5. Box-plot showing a non-significant (n.s.) increase in freeway space with the P-type and the D-type lingual plates per patient.

D-type and P-type appliances in place (Mann–Whitney no plate versus P-type $P = 0{\cdot}2459$, no plate versus D-type $P = 0{\cdot}1518$, P-type versus D-type $P = 0{\cdot}2601$). The increase in the freeway space vaguely correlated to the participants' vertical overbite (P-type, $r = -0{\cdot}27$ and D-type, $r = -0{\cdot}32$).

Discussion

The results from the present pilot experiments have to be interpreted with caution. The sample size was small, yet given the high power revealed by the *post hoc* power analysis, it can be concluded the sample size was large enough to avoid type II errors. Earlier studies have shown that the freeway space changes with emotional stress (13–15). Hence, the experimental set up might have influenced the participant's rest position, not only because of the voluminous head-set, but also because of the permanent magnet that was attached to their lower incisors. Furthermore, the mandibular rest position is likely to vary in a circadian rhythm. Although the present experiments were not all carried out at the same time of the day, but they all took place during the morning. A further methodological shortcoming might be an insufficient time to adapt to the lingual plates.

Various methods have been employed in studies evaluating mandibular movements such as graphical,

electromagnetical, optical, ultrasound and radiological techniques (16–21). The advantages and the disadvantages of these methods have been extensively reviewed (22, 23). Amongst the available techniques, the opto-electronical devices were reported to be the least interfering with the individual's chewing patterns but they track reference points on the skin (23). In contrast, the electromagnetic K7 jaw-tracking system measures the movements of the incisal point which is more relevant to the analysis of mandibular movement than the skin. Despite the inconvenience of the additional volume of the magnet, using an electromagnetic measuring device was ideal because, for measuring the rest position, it is absolutely essential to allow an 'unforced' lip closure. Furthermore, the K7 system is particularly precise for measurements close to occlusion.

The rationale behind this study on the freeway space with two different types of lingual plates is their potential use in patients with dysphagia. Palatal augmentation appliances facilitate a more positive and resourceful tongue contact during swallowing in dysphagic patients. The basic rationale, applied in the construction of these swallowing aids, is to provide adequate tongue lift and pressure against the palate during swallowing. Tongue pressure during swallowing has been proven to be higher on the appliance plates than on an uncovered palate (24). The increased tongue pressure caused by wearing swallowing aids is hypothesised to reproduce similar conditions as with effortful swallowing and the food bolus is propelled through the pharynx more efficiently (25). However, the possible disadvantages of these appliances comprise of loss of retention as its weight might exceed the physical suction, especially in unfavourable anatomical and functional conditions. The additional volume might furthermore trigger a gag-reflex or a continuing velvopharyngeal insufficiency (26). Hence, the use of the lingual plate appliance as an alternative might avoid the above-mentioned problems. However, such a lingual appliance could only be efficient in the absence of a compensatory increase in the freeway space.

The rationale behind the suggestion of using lingual plates is the assumption that an increased tongue pressure on the palate during swallowing is because of a reduced volume available in the oral cavity. However, a physical space limitation may be achieved by either a palatal or lingual limitation of the tongue space. Complete denture wearers are known to lower their vertical dimension at rest whilst not wearing their lower denture as the tongue spreads laterally in the absence of the support of the lingual denture flange (27).

It has been suggested that an increase in the resin thickness in complete dentures may lead to a compensatory increase in the vertical dimension. The resin thickness limits existing tongue space resulting in an increased tongue pressure (5). However, it has never been investigated whether the mandibular rest position is increased to create more volume for the restricted tongue. As a consequence, the vertical dimension at rest may be altered. If such a compensatory raise in vertical dimension would happen, the plates would not affect the tongue contact and its pressure during swallowing. Hence, such restriction in tongue volume would not be a valuable treatment option for dysphagia.

The question arises which should be the optimum shape of the suggested lingual plates. As there is no background literature delivering a prototype design, we opted for the P-type and D-type shape as logically they were both decreasing the sublingual volume, but in distinctly different manners. The D-type 'voluminously' fills the sublingual space by confirming to the contours of the tongue, whereas the P-type would provide a raised platform to shift the tongue more forcefully upwards. Both designs are preliminary suggestions and have to be considered prototypes for future development. The results of this study confirm that there were no significant increases in the vertical dimension on wearing the two different designs of the experimental lingual plates. Hence, the restriction in volume by the experimental plates may be efficient to increase the tongue pressure during swallowing. Previous studies have suggested the deleterious effects on swallowing by changes in the vertical dimension (9). If the lingual plates would have increased the vertical dimension, not only would they be inefficient, their use would even deteriorate the existing condition.

The findings of our pilot study confirm that the added volume by the lingual plates was well tolerated and most importantly did not hinder swallowing. Also, it may be accepted as a better appliance in terms of patient comfort and patient compliance, when compared with the disadvantages of the palatal augmentation prostheses. However, the amount of tongue contact on the palate or the magnitude of tongue pressure brought about by these lingual plates remains to be confirmed and is a prerequisite to ascertain the efficacy of these experimental lingual plates as a viable option in the treatment for dysphagia in frail elderly individuals.

Conclusion

Despite the limits of this pilot study, it can be concluded that both designs of lingual plates did not significantly increase the freeway space. This is important when evaluating these plates as swallowing aids in dysphagic patients. Further evaluation of the effects of these experimental lingual plates on the tongue lift and its pressure during swallowing is needed.

Conflicts of interest

The authors wish to declare that they have no conflicts of interests and no external funding was received for the completion of this study.

References

1. Schmidt J, Holas M, Halvorson K, Reding M. Videofluoroscopic evidence of aspiration predicts pneumonia and death but not dehydration following stroke. Dysphagia. 1994;9:7–11.
2. Hirota N, Konaka K, Ono T, Tamine K, Kondo J, Hori K *et al.* Reduced tongue pressure against the hard palate on the paralyzed side during swallowing predicts Dysphagia in patients with acute stroke. Stroke. 2010;41:2982–2984.
3. Hori K, Ono T, Tamine K, Kondo J, Hamanaka S, Maeda Y *et al.* Newly developed sensor sheet for measuring tongue pressure during swallowing. J Prosthodont Res. 2009;53:28–32.
4. Makihara E, Masumi S, Arita M, Kakigawa H, Kozono Y. Use of a tongue-pressure measurement system to assist fabrication of palatal augmentation prostheses. Int J Prosthodont. 2005;18:471–474.
5. Toyoshita Y, Koshino H, Hirai T, Matsumi T. Effect of wearing a palatal plate on swallowing function. J Prosthodont Res. 2009;53:172–175.
6. Kaiba Y, Hirano S, Hayakawa I. Palatal coverage disturbance in masticatory function. J Med Dent Sci. 2006;53:1–6.
7. Schierano G, Mozzati M, Bassi F, Preti G. Influence of the thickness of the resin palatal vault on the closest speaking space with complete dentures. J Oral Rehabil. 2001;28:903–908.
8. Yoshinaka M, Yoshinaka MF, Ikebe K, Shimanuki Y, Nokubi T. Factors associated with taste dissatisfaction in the elderly. J Oral Rehabil. 2007;34:497–502.
9. Nagao K, Kitaoka N, Kawano F, Komoda J, Ichikawa T. Influence of changes in occlusal vertical dimension on tongue pressure to palate during swallowing. Prosthodont Res Pract. 2002;1:16–23.
10. Hori K, Tamine K, Barbezat C, Maeda Y, Yamori M, Muller F *et al.* Influence of chin-down posture on tongue pressure during dry swallow and bolus swallows in healthy subjects. Dysphagia. 2011;26:238–245.
11. Ayuse T, Ishitobi S, Kurata S, Sakamoto E, Okayasu I, Oi K. Effect of reclining and chin-tuck position on the coordination between respiration and swallowing. J Oral Rehabil. 2006;33:402–408.
12. Faul F, Erdfelder E, Buchner A, Lang AG. Statistical power analyses using G*Power 3.1: tests for correlation and regression analyses. Behav Res Methods. 2009;41:1149–1160.
13. Turrell AJ. Clinical assessment of vertical dimension. 1972. J Prosthet Dent. 2006;96:79–83.
14. Thompson JR. Concepts regarding function of the stomatognathic system. J Am Dent Assoc. 1954;48:626–637.
15. Atwood DA. A Critique of the research of rest position of the mandible. J Prosthet Dent. 1966;16:848–854.
16. Lewin A, van Rensburg LB, Lemmer J. A method of recording the movement of a point on the jaws. J Dent Assoc S Afr. 1974;29:395–397.
17. Lemmer J, Lewin A, van Rensburg LB. The measurement of jaw movement. Part I. J Prosthet Dent. 1976;36:211–218.
18. Lewin A, Lemmer J, van Rensburg LB. The measurement of jaw movement. Part II. J Prosthet Dent. 1976;36:312–318.
19. Lewin A, Nickel B. The full description of jaw movement. J Dent Assoc S Afr. 1978;33:261–267.
20. Karlsson S. Recording of mandibular movements by intraorally placed light emitting diodes. Acta Odontol Scand. 1977;35:111–117.
21. Mesqui F, Palla S. Real-time non-invasive recording and display of functional jaw movements. J Oral Rehabil. 1985;12:541–542.
22. Soboleva U, Laurina L, Slaidina A. Jaw tracking devices – historical review of methods development Part I. Stomatologija. 2005;7:67–71.
23. Soboleva U, Laurina L, Slaidina A. Jaw tracking devices – historical reviews of methods development. Part II. Stomatologija. 2005;7:72–76.
24. Saito Y, Motoyoshi M, Arimoto M, Itoi K, Shimazaki T, Namura S. Tongue pressure on palate during deglutition. Orthod Waves. 1999;58:303–308.
25. Steele CM, Huckabee ML. The influence of orolingual pressure on the timing of pharyngeal pressure events. Dysphagia. 2007;22:30–36.
26. Light J, Edelman SB, Alba A. The dental prosthesis used for intraoral muscle therapy in the rehabilitation of the stroke patient. A preliminary research study. N Y State Dent J. 2001;67:22–27.
27. Basker RM, Davenport JC, Tomlin HR. Jaw relations – theoretical considerations. Prosthetic treatment of the edentulous patient. 5th ed. Oxford: Wiley-Blackwell; 2011:68–76.

Correspondence: Frauke Müller, Division of Gerodontology and Removable Prosthodontics, School of Dental Medicine, 19 Rue Barthelémy-Menn, Geneva 1205, Switzerland.
E-mail: frauke.mueller@unige.ch