Influence of altered tongue contour and position on deglutitive pharyngeal and UES function

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Ali, G. N., I. J. Cook, T. M. Laundl, K. L. Wallace, and D. J. de Carle. Influence of altered tongue contour and position on deglutitive pharyngeal and UES function. Am. J. Physiol. 273 (Gastrointest. Liver Physiol. 36): G1071–G1076, 1997.—The potential influence of altered lingual position and contour during the bolus loading phase of the swallow in mediating the swallowed bolus volume-dependent regulation of upper esophageal sphincter (UES) relaxation and opening was studied in 15 healthy volunteers using simultaneous videoradiography and manometry. A maxillary dental splint modulated tongue deformity during the early oral phase of deglutition. We examined the effect of the splint and swallowed bolus density on bolus volume-dependent changes in the timing of events in the swallow sequence and on hypopharyngeal intrabolus and midpharyngeal pressures. Peak mid-pharyngeal pressure (P = 0.001) and hypopharyngeal intrabolus pressure (P = 0.04) were significantly reduced by the splint. The normal volume-dependent earlier onset of sphincter relaxation and opening was preserved with the splint in situ. The splint significantly delayed the onset of hyoid motion and UES relaxation and opening without influencing transit times or total swallow duration. Alterations in tongue contour and position reduce intrabolus pressure and pharyngeal contraction without influencing normal bolus volume-dependent regulation of timing of UES relaxation and opening. Afferent input from oral and pharyngeal receptors may be important in regulating the temporal relationships among motor events during the oral-pharyngeal swallow. The sequence of motor events is not stereotyped, and the timing of hyoid motion and upper esophageal sphincter (UES) relaxation and opening can be modified by alterations in the characteristics of the swallowed bolus such as volume or viscosity (7, 8, 14). Blockade of all oral-pharyngeal mucosal receptors by topical anesthesia does not influence the temporal relationships among the deglutitive oral-pharyngeal motor events, suggesting that these volume- and viscosity-dependent temporal shifts are not mediated by tactile mucosal sensory receptors (2). It is possible that other receptors deep to the mucosa, such as mechanoreceptors, might mediate the observed temporal shifts. Alterations in tongue contour and position have been shown to serve important functions of bolus containment and loading before bolus propulsion (15). These processes involve deformation of the tongue at swallow initiation and are to an extent dependent on bolus volume (16). It is possible that a sensory cue that is modified by bolus variables might emanate from lingual mechanoreceptors at swallow initiation. We hypothesized that modification of bolus forces on the tongue, at or shortly after swallow initiation, influences bolus volume-dependent temporal events and that lingual mechanoreceptor activity is likely to be involved in this process. The aim of this study was to determine whether experimental modulation of tongue contour and position and thus lingual mechanoreceptor activity mediates volume-dependent changes in swallow coordination. We used this experimental procedure on the premise that it is likely to alter mechanoreceptor activity. Hence a positive finding would support the hypothesis that mechanoreceptor activity is involved in volume-dependent changes in swallow coordination.

METHODS

Subjects. We studied two groups of healthy volunteers recruited by advertisement from the community. Group 1 consisted of 6 healthy subjects (mean age 27.2 ± 6.3 yr) in whom we confirmed that the maxillary splint caused lingual deformity and group 2 consisted of 15 healthy volunteers (mean age 30 ± 11 yr) in whom the physiological effects of dental splints were examined. All were carefully screened, and none had swallowing difficulties, medical illnesses, or were taking any medications. Ethical approval was granted by Southern Sydney Area Health Service Ethics Committee, and all subjects gave written informed consent.

Videoradiography. Subjects were studied by simultaneous videoradiography and manometry as previously described (7). Briefly, subjects were studied seated, and images of bolus swallows were recorded in the lateral projections using a 9-in. Toshiba (Kawasaki, Japan) image intensifier. Fluoroscopic images were recorded on videotape at 25 frames/s by a VHS video recorder (Panasonic, AG6500, Osaka, Japan) for later analysis. The correction factor for magnification was determined before each study by placing two metallic markers set 3 cm apart in the field of the image intensifier, above the subject's head but in the plane of the UES. Subjects swallowed duplicate 5- and 10-ml boluses of two different densities: 1) high-density liquid barium suspension [250% (wt/vol), E-Z-HD, E-Z EM, Westbury, NY] and 2) a low-density water-soluble iodinated radiopaque contrast MD-Gastroview (Mallinckrodt Medical, St. Louis, MO). The rationale for using two densities was to examine the effect of bolus weight on the tongue. All boluses were delivered to the mouth by a syringe. Included in the field of view were the incisor teeth anteriorly, hard palate superiorly, cervical spine posteriorly, and proximal cervical esophagus inferiorly.

Manometry. Pharyngeal pressures were measured with a catheter combining three solid-state transducers (Gaeltec, Dunvegan, Isle of Skye, Scotland) measuring pharyngeal pressures and a 6-cm perfused sleeve assembly (Dentsleeve, Belair, South Australia) measuring UES pressure. The solid-state catheter (OD 2.3 mm) was inlaid into a six-lumen silcon rubber-polyvinyl chloride perfused manometric catheter (ID each lumen 0.51 mm). The overall catheter diameter was 6 mm, and the sleeve assembly distal to the transducers had a 5 × 3 mm oval cross section to maintain its anteroposterior orientation within the UES (13). The manometric assembly...
was passed transnasally, and the transducers and the sleeve were orientated posteriorly with the sleeve straddling the UES. The posterior orientation of the transducers was readily verified radiographically. The solid-state transducers were spaced 3 cm apart with the middle transducer lying at the level of the valleculae in the midpharynx and the distal transducer lying at the upper margin of the sleeve in the hypopharynx, just proximal to the UES at the time of maximal sphincter ascent during swallowing. Four perfused side holes, spaced at 1.5-cm intervals in the pharynx with the distal side hole located at the midsleeve position, were used to aid in positioning the sleeve such that its midpoint was in the center of the UES high-pressure zone at rest. The sleeve assembly and side holes were perfused by a low-compliance pneumohydraulic perfusion system at 0.6 ml/min, and UES pressures were registered by external transducers (Spectramed Medical Products), and all signals were amplified and digitized at 200 Hz by preamplifiers (Neomedix Systems, Sydney, Australia) and recorded on a Macintosh computer (Apple, Cupertino, CA) using Gastromac software (Neomedix Systems). The height-adjustable perfusion pump was positioned so that the external transducers were level with the midsleeve position. All pressures were referenced to basal hypopharyngeal (atmospheric) pressure. A purpose-built, video-digital timer unit (Practel Sales, Holden Hill, South Australia) imprinted simultaneously the elapsed time on the video images in hundredths of seconds and a signal on the pressure tracing each whole second, to permit precise temporal correlation of video images with pressure.

Validation experiment. A validation experiment was conducted in the six group 1 subjects in whom we examined radiologically the tongue surface contour relative to the palate to confirm that a maxillary splint did exaggerate tongue deformity for a given bolus volume. In these six subjects we applied three tantalum markers (3-mm diam) to the ventral surface of the tongue in the midsagittal plane.

Fig. 1. Effect of maxillary splint on tongue surface contour relative to palate before and during tongue action for 5-ml water bolus swallow. A: rays from reference marker on hard palate were traced to each of 3 tantalum markers applied to ventral surface of tongue in midsagittal plane. Distances along these rays were measured at 3 time points: T1 (rest position), T2 (swallow onset, or initial movement of tongue tip against posterior surface of maxillary incisors), and T3 (mid oral phase, or T2 + 200 ms). At T1 with maxillary splint in situ, distance between reference and middle and posterior tongue markers was greater than would be predicted by thickness of splint. This increased palatolingual separation was significantly more pronounced posteriorly at rest (*) \( P = 0.02 \) and at T2 \( (*) P = 0.02 \). Effect of splint on deformity of posterior tongue had diminished at middle oral phase T3 \( (P = 0.08) \).
with denture adhesive (Poly-grip, Stafford-Miller, New South Wales, Australia). The anterior tantalum marker was placed 0.5 cm from the tongue tip, the posterior marker was positioned adjacent to the last lower molar tooth, and the middle marker was placed midway between the other two. A reference marker was placed on the hard palate in the midline (Fig. 1A). We then recorded lateral videoradiographic images of duplicate 5- and 10-ml water swallows to determine splint-induced alteration in tongue contour at rest and during oral bolus delivery. Rays from the hard palate reference marker were traced to each tongue marker, and distances along these rays were measured at three time points: preswallow rest position (T1); at swallow onset (T2), defined as the initial movement of the tongue tip against the posterior surface of the maxillary incisors; and at the mid oral phase (T3), 200 ms after swallow onset.

Experimental protocol. Swallows in each of the 15 group 2 subjects were recorded under control conditions (no oral splint) and separately under two experimental conditions, after insertion of either a mandibular splint or a maxillary splint. Full arch mandibular and maxillary splints were made from Hydroplastic (Tak Systems, Boston, MA), a custom formulated plastic that softened in hot water to enable molding. A “U-shaped” mandibular splint of uniform thickness covered the occlusal, lingual, and labial surfaces of the lower teeth. The maxillary splint covered the mucosa of the hard palate in addition to covering the upper teeth. The maxillary splint served to reduce the supralingual, subpalatal space, thereby exaggerating bolus forces on the tongue for a given bolus volume and altering tongue contour. Because the maxillary splint had the potential to influence extralingual mechanoreceptors (e.g., periodontal and temporomandibular joint proprioceptors) and increase salivation, the purpose of making the same measurements with the mandibular splint was to control for these potential nonlingual confounders, as the mandibular splint has the same mechanical influences on the mouth as the maxillary splint without influencing the supralingual, subpalatal space.

Data analysis. The timing of swallow events was referenced to the swallow onset, defined as the initial movement of the tongue tip against the posterior surface of the maxillary incisors. All these temporal measures have been defined previously (7). UES opening, closure, and duration of UES flow were defined fluoroscopically (6). UES relaxation onset was defined as the time point when the basal UES pressure began to fall abruptly. Maximum UES relaxation was defined as the point in time when the UES relaxation profile ceased to fall rapidly and leveled off. Because the proximal sleeve margin projects into the hypopharynx, the sleeve registers prematurely the apparent termination of UES relaxation (14). Accordingly, termination of UES relaxation was measured from the tracing recorded by the side hole 1.5 cm distal to the proximal sleeve margin, which was seen fluoroscopically to lie within the UES at the time of sphincter closure. We measured the onset of superior and anterior motion of the hyoid and larynx as well as timing of peak anterosuperior motion of these structures. Total swallow duration was defined as the interval between swallow onset and UES relaxation. Peak pharyngeal pressure was measured at the two distal solid-state transducers positioned in the hypopharynx and the midpharynx. Hyopharyngeal intrabolus pressure measured at the side hole immediately proximal to the UES represents the pressure within the bolus as it traverses the sphincter (7).

Duplicate values for each subject were averaged before calculation of group mean data for each volume swallowed. Statistical inferences were made regarding the bolus volume effect, splint effect, and splint-volume interaction using a two-way mixed design analysis of variance for repeated measures (3). All values, both numeric and graphic, are represented as means ± SE unless stated otherwise.

RESULTS

The lingual marker study confirmed that, with maxillary splint in situ, the distance between the reference and tongue markers was greater than what would be predicted by the thickness of the splint. This increased palatal lingual separation was more pronounced posteriorly and at rest (P = 0.02). This effect was also significant at swallow onset T2 (P = 0.02) but diminished as the oral phase progressed (Fig. 1). The effects were comparable for 5- and 10-ml water boluses.

With the mandibular splint in situ the timing of swallow events did not differ from that under control

### Table 1. Timing of swallow events referenced to swallow onset

<table>
<thead>
<tr>
<th>Variable</th>
<th>Density</th>
<th>Volume, ml</th>
<th>Control</th>
<th>Splint</th>
<th>Mandibular</th>
<th>Maxillary</th>
<th>P Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior hyoid onset</td>
<td>High</td>
<td>2</td>
<td>0.34 ± 0.05</td>
<td>0.33 ± 0.04</td>
<td>0.30 ± 0.04</td>
<td>0.003 NS</td>
<td>NS NS NS</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>10</td>
<td>0.15 ± 0.04</td>
<td>0.19 ± 0.05</td>
<td>0.22 ± 0.05</td>
<td>NS NS</td>
<td>0.001 0.001</td>
</tr>
<tr>
<td>UES relaxation onset</td>
<td>High</td>
<td>2</td>
<td>0.46 ± 0.05</td>
<td>0.43 ± 0.06</td>
<td>0.42 ± 0.04</td>
<td>0.003 NS</td>
<td>NS 0.03 NS</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>10</td>
<td>0.24 ± 0.04</td>
<td>0.28 ± 0.06</td>
<td>0.34 ± 0.05</td>
<td>NS NS</td>
<td>0.002 0.003</td>
</tr>
<tr>
<td>UES opening</td>
<td>High</td>
<td>2</td>
<td>0.21 ± 0.05</td>
<td>0.22 ± 0.04</td>
<td>0.28 ± 0.06</td>
<td>0.02 NS</td>
<td>NS 0.002 NS</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>10</td>
<td>0.63 ± 0.05</td>
<td>0.62 ± 0.05</td>
<td>0.58 ± 0.04</td>
<td>0.0001 NS</td>
<td>NS 0.002 NS</td>
</tr>
<tr>
<td>UES closure</td>
<td>High</td>
<td>2</td>
<td>0.33 ± 0.08</td>
<td>0.34 ± 0.04</td>
<td>0.38 ± 0.06</td>
<td>0.01 NS</td>
<td>NS 0.0003 0.0001</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>10</td>
<td>1.03 ± 0.05</td>
<td>1.01 ± 0.05</td>
<td>0.97 ± 0.03</td>
<td>NS NS</td>
<td>NS NS NS</td>
</tr>
</tbody>
</table>

Values are means ± SE in seconds; n = 15 subjects. UES, upper esophageal sphincter; high, high-density bolus (barium); low, low-density bolus (Gastroview); NS, not significant.
conditions. Hence all subsequent comparisons were made between control state (i.e., no splint) and maxillary splint in situ. Under control conditions the timing of UES relaxation onset and UES opening relative to the swallow onset occurred earlier with increasing swallowed bolus volume (Table 1), and this effect was preserved with the maxillary splint in place (Fig. 2). However, for any given bolus volume the maxillary splint caused a delay in the onset of hyoid motion, the onset and termination of UES relaxation, and UES opening and closure (Fig. 3). This effect was statistically significant with low-density bolus swallows ($P < 0.006$) but was less marked and did not reach statistical significance with high-density bolus swallows. Hence the volume-dependent earlier timing of UES relaxation and opening was preserved for both bolus densities, whereas for low-density boluses, the maxillary splint causes a rightward temporal shift in these variables. The timing of UES relaxation onset, maximum relaxation, and opening did not differ significantly between high- and low-density swallowed boluses, indicating that density per se did not influence coordination (Fig. 4).

Oral and pharyngeal transit times, total swallow duration, and pharyngeal clearance times were not significantly influenced by the maxillary splint (Fig. 5). Because the splints occupied space within the oral cavity, we examined whether this effect might cause earlier entry of the bolus head into the pharynx. The timing of the arrival of the bolus head into the pharynx was not significantly influenced by either splint.

Bolus volume did not influence peak pharyngeal pressure. Midpharyngeal, but not hypopharyngeal, peak pressure was significantly reduced by both splints during high-density barium bolus swallows ($P < 0.01$; Table 2). Hypopharyngeal intrabolus pressure was also significantly reduced by both maxillary and mandibular splints during high-density barium boluses ($P < 0.05$; Table 2) but not during low-density boluses.

**DISCUSSION**

In this study we hypothesized that modification of bolus forces on the tongue, at or shortly after swallow initiation, influences bolus volume-dependent temporal events and that lingual mechanoreceptor activity is likely to be involved in this process. We demonstrated that the presence of a maxillary splint during the swallow alters tongue contour during the early stages of the swallow. The maxillary splint delays the onset of anterior hyoid motion, UES relaxation, and UES opening without influencing bolus transit times or total swallow duration. However, contrary to our initial hypothesis, the maxillary splint did not influence the normal bolus volume-dependent earlier onset of anterior hyoid motion, UES relaxation, or UES opening.
Influence of oral splints on pharyngeal pressures (1, 24). In this study we manipulated bolus density and 23, 26), as have tongue and periodontal proprioceptors have been identified histologically (11, 17, 18, 23). These observations suggest that mechanoreceptors are likely to mediate volume-dependent regulation of UES timing. Oral and pharyngeal mechanoreceptors have been identified histologically (11, 17, 18, 23, 26), as have tongue and periodontal proprioceptors (1, 24). In this study we manipulated bolus density and supralingual capacity to modulate the extent of tongue deformation independent of bolus volume. We hypothesized that either increased bolus density or the maxillary splint, or both, would result in earlier onset of temporal swallow events because of increased lingual deformity or bolus forces on the tongue for a given volume. Contrary to our prediction, bolus density had no effect. Furthermore, the maxillary splint did delay UES relaxation and opening, despite the total swallow duration remaining unchanged, but had no effect on the normal volume-dependent earlier onset of anterior hyoid motion, UES relaxation, or UES opening. The former finding may reflect inadequate differences in density between bolus type. We were able to confirm that the maxillary splint did exaggerate anterior and middle tongue deformity without influencing bolus transit and that the splint did delay the onset of UES relaxation and UES opening. However, our results do not permit us to conclude whether this response is simply due to mechanical effects or to reflex modulation by lingual or other mechanoreceptors because we had no way of quantifying mechanoreceptor stimulation. Hence our findings do not support the hypothesis that modulation of tongue contour and position, and thereby lingual mechanoreceptor activity, mediates volume-dependent changes in UES relaxation and opening. The possibility that receptors distal to the faucial pillars might be implicated cannot be ruled out, but this is an unlikely explanation because the response seems to be mediated very early in the swallow sequence (7, 14). If it were dependent on stimulation of pharyngeal receptors by the bolus, it is doubtful whether there would be sufficient time for this to take place because the bolus head enters the oropharynx before onset of anterior hyoid motion for bolus volumes > 5 ml.

An alternative explanation is that the observed effects, such as delayed hyoid motion and delayed UES relaxation, might not be reflexive but rather mechanically mediated. The possibility exists that the new tongue position at swallow onset might alter the tension on the hyoid exerted by the hyoglossus thereby delaying anterior hyoid motion effected by genioglossus and anterior belly of digastic muscle. Hyoglossal traction force does contribute to UES opening (7, 12) and delay in the onset of this force or reduction of its magnitude could possibly delay the timing of manometric UES relaxation and sphincter opening.

With either maxillary or mandibular splint in situ, we showed a significant reduction in peak midpharyngeal pressures. We showed a significant reduction in peak midpharyngeal pressures. We showed a significant reduction in peak midpharyngeal pressures. We showed a significant reduction in peak midpharyngeal pressures.

Hence the splint is capable of modifying neuromuscular coordination, and this effect is not a result of altered bolus transit. We have also shown that both maxillary and mandibular splints reduce pharyngeal pressures.

The normal control of swallowing involves afferent and efferent pathways. The medullary swallow center is responsible for the coordination and sequencing of the entire swallow (21, 22). The timing of onset of hyoid motion, an event occurring early in the swallow sequence when the bolus is still in the mouth, is bolus volume dependent (7, 8, 14). This observation suggests that lingual afferents are likely to be mediating this effect. The mouth is not merely a motor organ but is densely innervated by afferent receptors sensitive to tactile and pressure stimuli (9). We have recently shown that neither the ability of the individual to initiate a normal pharyngeal swallow response nor temporal relationship among swallow events are dependent on the integrity of oral-pharyngeal mucosal tactile receptors (2). These observations suggest that mechanoreceptors are likely to mediate volume-dependent regulation of UES timing. Oral and pharyngeal mechanoreceptors have been identified histologically (11, 17, 18, 23, 26), as have tongue and periodontal proprioceptors (1, 24). In this study we manipulated bolus density and supralingual capacity to modulate the extent of tongue deformation independent of bolus volume. We hypothesized that either increased bolus density or the maxillary splint, or both, would result in earlier onset of temporal swallow events because of increased lingual deformity or bolus forces on the tongue for a given volume. Contrary to our prediction, bolus density had no effect. Furthermore, the maxillary splint did delay UES relaxation and opening, despite the total swallow duration remaining unchanged, but had no effect on the normal volume-dependent earlier onset of anterior hyoid motion, UES relaxation, or UES opening. The former finding may reflect inadequate differences in density between bolus type. We were able to confirm that the maxillary splint did exaggerate anterior and middle tongue deformity without influencing bolus transit and that the splint did delay the onset of UES relaxation and UES opening. However, our results do not permit us to conclude whether this response is simply due to mechanical effects or to reflex modulation by lingual or other mechanoreceptors because we had no way of quantifying mechanoreceptor stimulation. Hence our findings do not support the hypothesis that modulation of tongue contour and position, and thereby lingual mechanoreceptor activity, mediates volume-dependent changes in UES relaxation and opening. The possibility that receptors distal to the faucial pillars might be implicated cannot be ruled out, but this is an unlikely explanation because the response seems to be mediated very early in the swallow sequence (7, 14). If it were dependent on stimulation of pharyngeal receptors by the bolus, it is doubtful whether there would be sufficient time for this to take place because the bolus head enters the oropharynx before onset of anterior hyoid motion for bolus volumes > 5 ml.

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Fig. 5. Effect of mandibular and maxillary splints on regional transit times and pharyngeal clearance time. Data for 10-ml barium bolus swallows shown. Neither total swallow duration, oral and pharyngeal transit times, nor pharyngeal clearance time were influenced by splints. Presence of oral splints did not result in premature entry of bolus head into pharynx.

Table 2. Influence of oral splints on pharyngeal pressures

<table>
<thead>
<tr>
<th>Splint</th>
<th>Variable</th>
<th>P Values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Volume, ml</td>
<td>Control</td>
</tr>
<tr>
<td>Midpharyngeal peak pressure</td>
<td>2</td>
<td>100 ± 7</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>90 ± 9</td>
</tr>
<tr>
<td>Hypopharyngeal peak pressure</td>
<td>2</td>
<td>147 ± 11</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>149 ± 13</td>
</tr>
<tr>
<td>Intrabolus pressure</td>
<td>2</td>
<td>6.7 ± 1.6</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>8.95 ± 2</td>
</tr>
</tbody>
</table>

Values are means ± SE in mmHg; n = 15 subjects. Data only shown for high-density barium boluses.
tongue but not hypopharyngeal contraction amplitude during swallowing. Unlike UES relaxation and opening pharyngeal peristaltic velocity, contraction duration, and maximal contraction amplitude are stereotyped among swallow volumes (16). As distinct from the hypopharynx the midpharyngeal chamber is bound anteriorly by the tongue base. Augmentation of supralingual, retrolingual, and hypopharyngeal peak pressures by bolus viscosity suggests that bolus propulsion is a function of both tongue and pharyngeal constrictor activity (10, 25). Alterations in mandibular position by a maxillary splint can influence tongue function (5), and electromyographic recordings confirm that changes in the mandibular position have a definite effect on tongue activity (19). These observations indicate that alterations in mandibular position, with or without altered tongue activity, may influence pharyngeal propulsive forces.

The finding of reduced hypopharyngeal intrabolus pressure is also likely to be due to modification of lingual forces by the splint. During pharyngeal bolus propulsion the initial phase of the intrabolus pressure domain is generated by tongue forces, whereas the later segment is due to a combination of tongue and pharyngeal constrictor forces (4, 20). The intrabolus pressure domain is similar in the retrolingual and hypopharyngeal regions (10). The reduction of the intrabolus pressure domain in our study was uniform and therefore not delineating the exact contribution of the tongue in the generation of this pressure domain.

Although both splints reduced hypopharyngeal intrabolus and midpharyngeal peak pressures, the pressures observed under experimental conditions still lay within the normal range. It is likely that the magnitude of change was insufficient to influence bolus transit time. Alternatively, the absence of any effect on transit time might reflect activation of nonlingual mechanoreceptors. The changes in propulsive forces demonstrated in our study may have implications for bolus transport in patients with oral prostheses and dentures, because, although unknown, it is highly likely that maxillary dentures may have similar effects. Therefore any attenuation of propulsive forces during deglutition with such devices might further impair bolus transport in the context of preexisting compromise of pharyngeal function.

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