Introduction
Swallowing, a stomatognathic function, is characterized by a complex mechanism that requires the involvement of many structures that must be coordinated to occur effectively. The main functional condition that needs to be considered is the ability to protect the lower airway through elevation, laryngeal closure and protective reflexes, such as coughing. When starting the pharyngeal phase of swallowing, three events occur: laryngeal elevation through the contraction of the suprahyoid muscles; lowering of the epiglottis, which reduces the space of the laryngeal inlet; and vocal fold adduction, operating in glottal closure, which is an additional mechanism that reduces exposure of the lower airway.1–3

The main diagnostic method to evaluate swallowing dynamics is videofluoroscopy, also known as “videodeglutogram” or dynamic examination of swallowing. Considered the reference standard for evaluation and diagnosis of changes in this function, it consists of swallowing food with barium, allowing the visualization of the process by dynamic X-ray machine.
which shows the path traversed by the material swallowed. In
this exam, the exact course taken by the food can be precisely
identified, as well as the areas where the process does not occur
efficiently; it is possible to view a deposit of contrasted material
in places with changes in motility.4,5

Although videofluoroscopy is the standard for diagnosis, it
is not easy to access for patients with swallowing disorders,
because having restrictions on its indication. Therefore, clini-
cal evaluation is routinely used for detection of swallowing
disorders and determination of treatment.6,7 This method
consists of several steps that, when taken together, describe
the swallowing changes according to the characteristics
presented by the patient, thus allowing the determination of
therapeutics.5,7,8

One of the aspects considered in the clinical evaluation is
laryngeal function, which requires assessment of the ana-
tomical conditions of the region, evaluated by palpation and
aspects of mobility and its functional capacity, evaluated by
changes in vocal production after swallowing. Altered vocal
production after swallowing has been considered a leading
indicator of inefficiency of the process, because stasis of food
in the laryngeal-pharyngeal cavity during swallowing is
commonly observed in patients with dysphagia.9,10 The
presence of food in this region can alter the space of the
vocal tract, modifying voice quality.11 Although this param-
ter is routinely evaluated in clinical protocols, few studies
have analyzed its reliability for detection of dysphagia, indi-
cating possible bias of this method when indicating a change
in swallowing. Moreover, studies do not compare voices of
individuals with and without swallowing disorders, which
could determine whether this modification can actually be
attributed to a disturbance of this function or it occurs for all
subjects immediately after swallowing.

This study aimed to: (1) investigate the reliability of the
protocol used; (2) check whether significant change occurs in
the perceptual assessment of voice after swallowing in indi-
viduals with oropharyngeal dysphagia; and (3) compare
significant changes related to voice quality in the group
with dysphagia compared with the control group.

Methods

Design and Sample
This study presents a descriptive cross-sectional prospective
comparison between subjects with and subjects without
oropharyngeal dysphagia aiming to verify changes of voice
production after swallowing. The study was approved by the
Ethics Research Committee under protocol 293.856.

Men and women 18 years or older capable of continuous
voice production for at least 4 seconds and swallowing at
least one of the consistencies in the evaluation (pasty, liquid
and solid) were included. The study sample was divided into
two groups: individuals with (G1) and individuals without
(G2) oropharyngeal dysphagia. Subjects who were diagnosed
with swallowing disorder by videofluoroscopy composed G1
and were stratified according to the score in the dysphagia
severity scale from 1 to 5, signifying severe to discrete
dysphagia. Individuals in G2 showed no swallowing disorders
and scored 7 on the scale used, compatible with normality.12

Pairing by sex and age was performed, with a difference of up
to 5 years between pairs. Individuals with tracheostomy,
organic-functional and organic vocal fold lesions, or injury
of laryngeal nerves causing vocal fold paralysis were exclu-
ded. Subjects who had surgical removal of tumor and tissues
involved in the swallowing process and all those individuals
cognitively unable to respond to the protocol were also
excluded.

Fifty-two individuals, 27 (14 men and 13 women) in G1
and 25 (12 men and 13 women) in G2, were evaluated, with
mean ages of 71.07 for men and 76.69 for women in the first
group and 68.05 and 78.53, respectively, in the second group.
The evaluations performed yielded 201 vocal recordings,
including 101 in G1 and 100 in G2. The difference in the
number of recordings between groups was due the greater
number of subjects in G1: the number of recordings was also
less than expected due to the impossibility of evaluating some
consistencies due to limitations of bolus preparation and
oropharyngeal dysphagia.

Procedures
All study participants underwent evaluation of vocal produc-
tion before and after a sequence of swallows during video-
fluoroscopy, using three consistencies of foods evaluated in
the following order: pasty, liquid and solid. For the recording
of vocal productions, the digital recorder DVR-Powerpack
576.BK (Powerpack, China) with external microphone was
used. Before the exam, subjects were asked to perform a deep
inspiration followed by emission of vowel /a/ in the usual tone
of voice; if the emission lasted at least 4 seconds, it was
considered valid. The same instructions were made for eval-
uations performed after swallowing each food consistency
tested in the exam.

Videofluoroscopy
Videofluoroscopy examinations were performed with the
Siemens Axion Iconos R100 fluoroscopy (Siemens, USA)
model coupled to an image recording system in a computer,
which allows further detailed analysis of the exam. During
the examination, subjects remained seated and images were
captured in the lateral and anteroposterior positions, with
upper and lower limits ranging from the oral cavity to the
stomach.

The examinations were performed by evaluating pasty,
liquid and solid consistencies prepared, respectively, as
follows: yogurt-type petit suisse with liquid barium
(Bariogel®, Brazil) at a ratio of 1:1 (20 mL of yogurt to
20 mL of barium); distilled water with liquid barium
(Bariogel®) at a ratio of 1:1 (40 mL of water to 40 mL of
barium); and bread soaked in liquid barium (Bariogel®).

Based on the dysphagia severity scale,12 the degree of
dysphagia was determined on each subject and used to
allocate subjects into their study groups. Individuals with
functional swallowing (a score 6 on the scale) were excluded
because they were considered to have neither normal swal-
lowing nor dysphagia, which could compromise data analysis.
The examination data were only used to include subjects in
each study group and will not be described in detail here. Nevertheless, it should be noted that 18 (66.6%) subjects had grade 5 dysphagia, 5 (18.5%) had grade 4, 1 (3.70%) had grade 3, 3 (11%) had grade 2 and 0 (0%) had grade 1, demonstrating that the majority of the sample had mild to moderate oropharyngeal dysphagia.

Perceptual Analysis of Vocal Quality
At the end of data collection, voice recordings were given to three judges with clinical experience in voice analysis and evaluation of swallowing. The perceptual analysis was classified using the GRBAS scale (grade, roughness, breathiness, asthenia and strain).

The three judges received an instructional guide with the objectives and procedures of analysis to be performed. Values were assigned on a scale from 0 to 3 (no change, mild alteration, moderate alteration and severe alteration, respectively) to the parameters described in the protocol. In addition, the wet voice feature was included in perceptual assessment because it is commonly attributed to the vocal production of individuals with dysphagia after swallowing. The judges were blinded to the information and evaluation results of patients. Moreover, they were not informed about which recordings occurred before or after swallowing or to the subject’s study group to maintain the reliability of the data and to not influence these aspects in the analysis. The recordings were sent in stages, with each stage not containing more than one recording of each subject, so evaluators could not compare samples.

Statistics
The data collected were analyzed using descriptive statistics and statistical tests, arranged in tables. The Kolmogorov-Smirnov test was used to test the normality of the data. To measure the reliability of the protocol used, we applied Cronbach’s alpha to measure the correlation between judges. Moreover, the means of the results obtained from the judges for each variable evaluated were calculated. The comparison of the voice emission before and after swallowing of each consistency was performed using the t test for paired samples for variables with normal distribution and the Wilcoxon U test for variables with non-normal distribution. Maximum level of significance of 5% was adopted and the statistical software used for data analysis was SPSS version 20.0.

Results
- Table 1 shows the reliability of the protocol used, GRBAS scale and wet voice in various stages of evaluation by the three judges. Cronbach’s alpha coefficient demonstrated a good correlation between the answers provided by evaluators for all times.
- Table 2 shows a significant decrease only in the voice grade after swallowing pasty food and - Table 3 demonstrates a significant decrease in the aspect of asthenia and increased strain after swallowing pasty food in individuals with oropharyngeal dysphagia.
- Table 4 presents the data before and after swallowing on the G2 of variables with significant vocal change in the G1. Through the Wilcoxon U test, a statistical difference in voice modification after swallowing was not observed in G2.

<table>
<thead>
<tr>
<th>Table 1 Compatibility between judges in the application of GRBAS scale and wet voice at each moment of evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Moment of evaluation</strong></td>
</tr>
<tr>
<td>-------------------------</td>
</tr>
<tr>
<td>Before swallowing</td>
</tr>
<tr>
<td>After swallowing pasty food</td>
</tr>
<tr>
<td>After swallowing liquid food</td>
</tr>
<tr>
<td>After swallowing solid food</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2 Emission before and after swallowing of each consistency in individuals with oropharyngeal dysphagia (Student t test)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>G</strong></td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
</tr>
<tr>
<td>Before swallowing</td>
</tr>
<tr>
<td>After swallowing pasty food (n = 27)</td>
</tr>
<tr>
<td>ρ</td>
</tr>
<tr>
<td>Before swallowing</td>
</tr>
<tr>
<td>After swallowing liquid food (n = 26)</td>
</tr>
<tr>
<td>ρ</td>
</tr>
<tr>
<td>Before swallowing</td>
</tr>
<tr>
<td>After swallowing solid food (n = 21)</td>
</tr>
<tr>
<td>ρ</td>
</tr>
</tbody>
</table>

Abbreviations: B, breathiness; G, grade; R, roughness; SD, standard deviation.

*p < 0.05.
Discussion

The same anatomical structures are involved in phonation and swallowing, especially in the laryngeal region, which is responsible for the main execution of these functions [14]. Some studies have been conducted to identify vocal parameters that can contribute to detection of oropharyngeal dysphagia.11,14–16

Vocal production is initiated by the exhalation of air, which passes through the vocal folds in adduction position, producing a sound that is modified by the vocal tract that features the voice of each individual. The length and diameter of the vocal tract, ranging from the vocal folds to the nasal cavity, the placement of structures, such as the tongue and lips, as well as the permeability of the paranasal sinuses modify the sound produced by the vocal folds, making the voice of each person unique due to anatomical peculiarities.17,18 Thus, anatomical or functional modifications in these structures, as well as the presence of food in the pharyngolaryngeal cavity in cases of oropharyngeal dysphagia, can lead to perceptual changes in the usual voice.11,18

The results of this study helped confirm that perceptual parameters commonly evaluated for vocal characterization may vary after swallowing in individuals with oropharyngeal dysphagia. This is not observed in subjects without this change, which is of fundamental importance in clinical applicability.19 Furthermore, judges were compatible on the assignment of the observed features, as shown in Table 1. Perceptual analysis needs to have high compatibility in intra- and interevaluators so that the data are reliable compared with the real vocal production.20 The scale used for perceptual analysis in this study is often by professionals that work in the voice area and has shown fairly consistent applicability by independent evaluators, allowing greater reliability between results obtained in this study.13,21 A provisor should be made for the wet voice parameter added to the protocol in this study, which will be discussed later.

Voice grade depends on the perception of the evaluator and consequently, previous experiences in voice analysis is necessary to assign a gravity score based on a set of vocal characteristics perceived as variations of normality.13,21 The

Table 3 Emission before and after swallowing of each consistency in individuals with oropharyngeal dysphagia (Wilcoxon U test)

<table>
<thead>
<tr>
<th></th>
<th>A Median</th>
<th>IR</th>
<th>S Median</th>
<th>IR</th>
<th>Wet voice Median</th>
<th>IR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before swallowing</td>
<td>0.66</td>
<td>0–2.3</td>
<td>0.66</td>
<td>0–2</td>
<td>0.3</td>
<td>0–2</td>
</tr>
<tr>
<td>After swallowing pasty food (n = 27)</td>
<td>0</td>
<td>0–2</td>
<td>0.66</td>
<td>0–2.3</td>
<td>0.33</td>
<td>0–1.3</td>
</tr>
<tr>
<td>$p$</td>
<td>0.011a</td>
<td></td>
<td>0.028a</td>
<td></td>
<td>0.142</td>
<td></td>
</tr>
<tr>
<td>Before swallowing</td>
<td>0.66</td>
<td>0–2.3</td>
<td>0.5</td>
<td>0–2</td>
<td>0.16</td>
<td>0–1.3</td>
</tr>
<tr>
<td>After swallowing liquid food (n = 26)</td>
<td>0</td>
<td>0–2</td>
<td>0.33</td>
<td>0–2.3</td>
<td>0.33</td>
<td>0–1.3</td>
</tr>
<tr>
<td>$p$</td>
<td>0.71</td>
<td></td>
<td>0.077</td>
<td></td>
<td>0.345</td>
<td></td>
</tr>
<tr>
<td>Before swallowing</td>
<td>0</td>
<td>0–1</td>
<td>0.3</td>
<td>0–2</td>
<td>0.3</td>
<td>0–1.3</td>
</tr>
<tr>
<td>After swallowing solid food (n = 21)</td>
<td>0.33</td>
<td>0–2</td>
<td>0.33</td>
<td>0–2.6</td>
<td>0.33</td>
<td>0–1.3</td>
</tr>
<tr>
<td>$p$</td>
<td>0.428</td>
<td></td>
<td>0.586</td>
<td></td>
<td>0.444</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: A, asthenia; IR, interquartile range; S, strain.

$p < 0.05.$

Table 4 Emission before and after swallowing of each consistency in group 2 (Wilcoxon U test)

<table>
<thead>
<tr>
<th></th>
<th>G Median</th>
<th>IR</th>
<th>A Median</th>
<th>IR</th>
<th>S Median</th>
<th>IR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before swallowing</td>
<td>0.66</td>
<td>0.3–2.3</td>
<td>0</td>
<td>0–1</td>
<td>0.33</td>
<td>0 to 2.3</td>
</tr>
<tr>
<td>After swallowing pasty food (n = 25)</td>
<td>1</td>
<td>0–2</td>
<td>0</td>
<td>0 to 0.6</td>
<td>0.33</td>
<td>0–2</td>
</tr>
<tr>
<td>$p$</td>
<td>0.357</td>
<td></td>
<td>0.803</td>
<td></td>
<td>0.101</td>
<td></td>
</tr>
<tr>
<td>Before swallowing</td>
<td>0.6</td>
<td>0.3–2.3</td>
<td>0</td>
<td>0–1</td>
<td>0.3</td>
<td>0–2.3</td>
</tr>
<tr>
<td>After swallowing liquid food (n = 25)</td>
<td>1</td>
<td>0.3–2.3</td>
<td>0</td>
<td>0–1</td>
<td>0.3</td>
<td>0–2.3</td>
</tr>
<tr>
<td>$p$</td>
<td>0.406</td>
<td></td>
<td>0.167</td>
<td></td>
<td>0.439</td>
<td></td>
</tr>
<tr>
<td>Before swallowing</td>
<td>0.6</td>
<td>0.3–2.3</td>
<td>0</td>
<td>0–1</td>
<td>0.3</td>
<td>0–2.3</td>
</tr>
<tr>
<td>After swallowing solid food (n = 25)</td>
<td>0.6</td>
<td>0.3–2</td>
<td>0</td>
<td>0–1</td>
<td>0.3</td>
<td>0–1.6</td>
</tr>
<tr>
<td>$p$</td>
<td>0.646</td>
<td></td>
<td>0.428</td>
<td></td>
<td>0.586</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: A, asthenia; G, grade; IR, interquartile range; S, strain.
use of this parameter in the evaluation of dysphagia allowed the identification of changes in the oropharyngeal transit of pasty food, with a decrease in severity of grade, even in a blinded analysis. It was noted that this modification only occurs for this consistency and was not modified for other consistencies evaluated. The viscosity of the pasty food permits it to adhere to the pharyngolaryngeal structures when there are changes in motility, as observed in imaging studies. The presence of food in the pharyngolaryngeal cavity acts as a voice modifier and changes voice characteristics during the sound passage produced by the vocal folds over the vocal tract. The obstruction at any point in the vocal tract, as commonly accomplished by the lips and tongue during speech, changes the formants that compose the voice, giving more bass or treble according to the position of these structures. Thus, the stasis of pasty food modified speech and decreased the aspects considered not normal and reduced the evaluator’s perception of the grade of alteration, which can be associated with changes in the sound wave caused by the presence of food. Nevertheless, the changes related to swallowing liquids and solids are not able to change this perception. The consumption of liquid is a beneficial resource for vocal production as it reduces the salivary viscosity and decreases dryness of the tract after long-term use, with little immediate benefits perceived aurally. In case of change in motility for this consistency, no impact occurs on the voice after swallowing when there is no adherence of the material in the tract modifying the passage of sound. So as observed in a previous study, the use of liquid food for voice variability evaluation after swallowing shows little sensitivity because there is no immediately perceptible voice modification even in cases of tracheal aspiration. In solid swallowing, it is believed that this change will not occur once the food causes a mechanical obstruction, leading to discomfort due to prolonged transit time of food, which affects effective breathing; phonation is performed only when there is clearance of the tract after conducting multiple swallows, as observed in the tests performed.

Beyond the modification of voice grade, the parameters of vocal effort also changed after swallowing. During the perceptual analysis, the judges characterized the voice by assigning a marker of vocal effort, either asthenia or strain. Individuals with vocal asthenia showed a decrease in this aspect after swallowing, consequently verifying higher strain; those who already had vocal strain had an increase of this parameter. The vocal strain is caused by the increased resistance of the vocal tract during passage of expiratory air, performed in an attempt to compensate for structural changes or a lack of balance between air and vocal muscle use during phonation, with excessive muscular effort during emission. This effort also occurs during coughing, when the muscles contract abruptly to expel a foreign body. When there is food residue in the tract, phonation occurs with more effort to keep the usual voice pattern, because the food causes obstruction, demonstrating that the increased vocal strain is associated with the attempt to maintain a normal pattern of speech and withdrawing food deposited in the tract.

Although there is scarce literature about the use of voice modifications to evaluate dysphagia, it is based primarily on clinical identification of the presence of wet voice after swallowing. Although commonly described as being a characteristic of voice in which there is a change in the usual pattern after swallowing, no features describe this variability in the literature, as opposed to the concepts of other vocal classifications observed. This aspect complicates the standardization of analyses made by professionals in the area, because it involves subjective characterization with little scientific background. No significant change in this parameter before and after swallowing was observed in this study. As discussed in previous studies, this vocal characterization is sensitive and it is not always possible to identify individuals with alterations; the subjectivity and lack of standardization cause poor reproducibility between evaluators, reflecting a poor diagnostic prediction for dysphagia.

Despite the important findings presented in this study, it is necessary to point out some limitations, among them, the sample size. Other authors who studied this method of evaluation also had this same difficulty concerning the limitations of the patients, because participation and integrity of oropharyngeal structures are necessary. In addition, the use of gold standard methods for evaluation are restricted to individuals who have conditions to accomplish such evaluation. Even with this limitation, the results corroborate previous studies and demonstrate that this method of evaluation shows specificity to differentiate individuals without swallowing disorder. Further studies should be conducted to confirm our data to better standardize the use of voice assessment as a method of identification for oropharyngeal dysphagia. Other data obtained from this same sample demonstrating the use of parameters of vocal self-perception, acoustic voice analysis and comparison between voice modifications and video-fluoroscopic examination will be presented in other publications to probe studies in this area.

Conclusion

Based on the data presented in this study, after swallowing pasty food, individuals with dysphagia decreased the grade of vocal alteration and increased strain, with no change in these vocal parameters for individuals without swallowing disorder, demonstrating its specificity for clinical use in the detection of oropharyngeal dysphagia. Nevertheless, the use of the wet voice parameter was not found to contribute to indicating this disorder, requiring further studies and standardization like other vocal parameters used in this study to allow a reliable evaluation for clinical applicability.

References