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Delphi Consensus on the Use of Speech Characteristics for Mandibular Positioning in Dental Sleep Medicine

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Study Objectives: To develop and describe a protocol for the use of speech characteristics to determine mandibular position for applications in dental sleep medicine using a Delphi consensus protocol.

Methods: The Delphi process was chosen as a method to reach expert consensus through structured iterative feedback in relation to defining the procedure of using speech characteristics to determine mandibular position in dental sleep medicine.

Results: Eleven experts in the fields of sleep medicine and otolaryngology, dental sleep medicine, speech language pathology and orofacial myofunctional therapy, physiotherapy, and optometry provided feedback through the Delphi process. Multiple rounds of expert feedback were necessary prior to consensus being reached in defining and describing the use of speech characteristics to determine mandibular position in dental sleep medicine.

Conclusion: A consensus-based definition for the use of speech characteristics in mandibular positioning for dental sleep medicine was achieved. Not only does this provide the foundation and allow for reproducibility in teaching clinicians and for future research; the use of the Delphi process in this manner for the development of a dental protocol may also provide a template for future dental research in dental protocol development.

Clinical Implications: The primary adjustment method for OAT involves anterior mandibular titration with resulting risks of muscle pain, temporomandibular joint dysfunction, and occlusal changes dependent on the degree of protrusion. The use of speech characteristics for mandibular position may provide alternative positioning for OAT that may decrease the risk of adverse effects and improve patient response.

Keywords: Speech characteristics, orofacial myofunctional therapy, dental sleep medicine, oral appliance therapy

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INTRODUCTION

Sleep breathing disorders are a grouping of conditions related to difficulties with breathing during sleep, usually related to upper airway collapse, that affect approximately 15% of the adult population.[1-5] These conditions range in severity from persistent snoring to obstructive sleep apnea (OSA), with associated health consequences including cardiovascular disease, diabetes, and daytime sleepiness.[6-9]

Primary medical treatments for OSA include continuous positive airway pressure (CPAP) machines and dentist-directed oral appliance therapy (OAT), whereas secondary treatments range from weight loss to orofacial myofunctional therapy.[5,10-12] Although CPAP is considered first-line treatment for all forms of sleep apnea, long-term adherence to therapy is poor.[13,14] OAT is also considered a first-line treatment for mild and moderate OSA and is much better tolerated, although its efficacy is not as good as that of CPAP.[12,15] The high acceptance and tolerance rate for OAT compared to CPAP is a driving factor in its medical benefit, including for patients with severe OSA who cannot tolerate CPAP as a primary treatment. The portability of OAT is also a great advantage compared to CPAP for patients who travel or enjoy outdoor overnight activities because OAT does not require power or water. Despite the differences in efficacy and adherence, overall effectiveness between CPAP and OAT is generally equivalent due to superior patient adherence to care with OAT.[16]

In OAT, the devices work by holding the mandible in a suitable position to maintain an open airway. Traditionally, mandibular position for OAT has been determined through the anterior protrusion technique (APT).[17,18] The APT works by measuring the most retruded and most protruded position of the mandible (known as the protrusive range) and placing the mandible between 50% to 70% of the maximum protruded position.[18-20] The device is then adjusted to titrate the mandible anteriorly until the patient cannot tolerate further mandibular protrusion, the patient's OSA is successfully managed, or further protrusion will not benefit the patient. For the APT, vertical positioning of the mandible is not individualized to the patient but is primarily determined by the required material thickness of the appliance being selected by the dentist for OAT (usually 5 mm due to appliances used in OAT traditionally being made of acrylic).[21,22]

More recently, speech sounds have been used to help in determining mandibular positioning for OAT.[21-23] In dentistry, the use of sibilant sounds to determine mandibular position is known as the sibilant phoneme technique (SPT) and was originally used for determining mandibular position and denture teeth positioning in

edentulous patients.[24-27] It has since been modified and shown to be a potential method for determining mandibular position while minimizing mandibular protrusion for OAT and therefore limiting the potential incidence of adverse effects commonly associated with OAT, including occlusal changes, temporomandibular joint dysfunction, and muscle pain.[21,22,28-30] This may occur due to the SPT providing a patient-specific vertical mandibular range within which to position the mandible while also maintaining oropharyngeal muscular stability in the phonetic neutral zone.[22-27] However, although a definitive protocol has been described for the use of the SPT for dentures, the modification of the SPT for use in OAT has not been described in detail.[24]

Although the SPT has been proposed as an alternative to the APT, a validated formal protocol for measuring mandibular position through and/or vertical position the use of speech characteristics for mandibular positioning for application in dental sleep medicine has not been developed. The APT has been described and studied extensively with protocols for its appropriate use published in peer reviewed literature as well as its limitations and common adverse effects with its use.[17-20,31,32] Comparatively, the SPT has minimal research and no formally described protocol in peer-reviewed published literature specific to dental sleep medicine.[22,23] As previously mentioned, due to the potential for significantly decreased protrusion, the SPT may have less risk of adverse effects in comparison with the APT, including occlusal changes, temporomandibular joint dysfunction, and muscle pain.[21,22,28-30] There is currently no research within the dental sleep medicine field that would limit using only sibilant sounds to determine mandibular position for OAT, and using the SPT as originally intended for denture prosthodontics provides only the closest speaking space, or smallest vertical position at which to position the mandible.[24] Because this space has minimal interincisal distance, this space in insufficient for the fabrication of a dental appliance for OAT due to material thickness requirements. Modification to the SPT to allow for increased interincisal distance has been mentioned in peer-reviewed published literature, although not described in detail.[23] Expert opinions have provided subjective descriptions for the modification of the SPT for use in dental sleep medicine, although these may be subject to personal opinions and bias. [33-42] To date there has been no validated protocol for the appropriate use of speech characteristics for mandibular positioning in dental sleep medicine.

Establishment of a protocol is proposed for the use of speech characteristics to determine mandibular position for applications in dental sleep medicine using a Delphi method. Due to variations in expert opinions and lack of detail within the literature, achieving a consensus definition on how to appropriately use speech characteristics for mandibular positioning in dental sleep medicine is a necessary first step for future assessment of its efficacy and, if demonstrated, to develop a standardized clinical protocol for use in clinical practice.[33-42] The Delphi method is a well-established structured technique for reaching expert consensus for research questions that cannot be answered empirically.[43] Through an iterative process with structured feedback, statements are modified and returned to experts for review and this process is repeated until consensus is reached.[43] The Delphi method may be used to appropriately define and describe a protocol for the use of speech characteristics to determine mandibular positioning in dental sleep medicine, including for OAT, to provide a standard methodology for its use and reproducibility in teaching clinicians and for future research.

METHODOLOGY

Ethics approval

This study was approved by the Alberta Research Information Services: Human Research Ethics Board (Pro00128767). The Delphi process was chosen as a method to reach expert consensus through structured iterative feedback in relation to defining the procedure of using speech characteristics to determine mandibular position in dental sleep medicine. This included a search and review to discover literature related to the procedure and existing knowledge gaps. A steering committee was formed to amalgamate this information, prepare structured feedback forms, predetermine agreement cutoffs for expert consensus, and identify experts to invite to participate within the Delphi process. Experts who responded in agreement to participate were then provided with information-structured feedback forms that were evaluated by the steering committee. Based on the feedback, modifications were made to the protocol under question and sent back to panelists for review. This process was repeated until expert consensus was achieved.

Literature search/review

A recently conducted literature review covered this topic.[21] The literature review search terms were used again to update the articles, which resulted in a single additional article according to the review's strict inclusion criteria.[22] In addition, the same search terms were used in Google where the first three pages of results were reviewed to avoid limiting results to peer-reviewed articles only. An additional six articles were found to be of relevance, two of which appeared to be duplicates.[33-37,42] In addition, four videos were noted demonstrating a methodology on using speech characteristics to determine mandibular position.[38-41] These articles and videos provided expert opinion and description on the use of speech characteristics to determine mandibular positioning in dental sleep

appliances. Authors and mentions of experts by name were also searched in the PubMed database for peer-reviewed articles of relevance. No additional articles specific to the use of speech characteristics for mandibular positioning were found.

Steering committee

A steering committee was formed consisting of one board certified orthodontist (ML), one dentist board certified in dental sleep medicine (EN), and one professor of research methodology and qualitative research (APG). The steering committee created a list of experts to invite to participate within the Delphi process as well as the predetermined levels of agreement for acceptable consensus and the format for expert feedback. All members of the steering committee were precluded from being considered an expert in providing feedback within the Delphi process.

Based on information gathered from the literature review, the steering committee determined that the fields of speech language pathology, otolaryngology, physiotherapy, optometry, and dental sleep medicine would be of relevance in relation to the use of speech characteristics for mandibular positioning in dental sleep medicine.

An agreement level of 66% between Delphi panelists was preselected by the steering committee as an acceptable level of consensus.

Based on information gathered from the literature review, the use of speech characteristics for mandibular positioning in dental sleep medicine was subdivided into phases and steps for easier evaluation. A formalized template was created by the steering committee for structured feedback from potential panelists (Appendix A).

Formulation of procedure for evaluation

Based on information gathered from the literature search/review, the steering committee aggregated the data and formulated it into phases that described the process of using speech characteristics to determine mandibular position. A total of five phases were identified by the steering committee. These phases were then further deconstructed into steps, with a total of 19 steps identified by the steering committee.

The five phases identified by the steering committee were (1) recording anatomic landmarks, (2) pre- procedural testing, (3) patient positioning, (4) identifying speech measurement limits, and (5) capturing occlusal relationships for mandibular position. The 19 steps were then assigned to the appropriate phase by the steering committee.

A structured template was created by the steering committee for expert panelists to provide their feedback. The template was designed with specific instructions relevant to the evaluation of titles/names, inclusion or exclusion, additional lines, sequencing, and other suggestions. An example of this structured template can be found in Appendix A. The phases and steps were also organized into a list for expert panelist informational reference. The informational document can be found in Appendix B.

Expert panelists

Eighteen experts in the fields of sleep medicine and otolaryngology, dental sleep medicine, speech language pathology and orofacial myofunctional therapy, physiotherapy, and optometry were invited by formal email to participate. All otolaryngologists were involved in sleep medicine and had a history of collaboration with dentists involved in sleep medicine. All speech language pathologists were also certified orofacial myologists. All physiotherapists had advanced training in temporomandibular joint dysfunction. All optometrists were also registered nurses and involved in the field of orofacial myofunctional therapy. All dentists were board certified in dental sleep medicine with the American Board of Dental Sleep Medicine and had been listed as an author in peer-reviewed publications related to the use of speech characteristics in mandibular positioning from articles revealed in the literature review. Of the 18 experts invited, 6 were dentists, 5 were otolaryngologists, 3 were physiotherapists, 3 were speech language pathologists also certified as orofacial myologists, and 1 was an optometrist.

Eleven of the 18 experts invited to participate responded with agreement to participate as experts on the Delphi panel. Four were dentists, two were otolaryngologists, two were physiotherapists, two were speech language pathologists also certified as orofacial myologists, and one was an optometrist. Both otolaryngologists who elected to participate requested their feedback be limited purely to aspects specific to nasal function.

Expert feedback

The Delphi method is a well-established structured technique for reaching expert consensus for research questions that cannot be answered empirically. Through an iterative process with structured feedback from panelists, statements are modified and returned to experts for review; this process is repeated until consensus is reached. Panelists are generally selected for their expertise in relation to some or all of the questions being researched.

Panelists were asked to provide their expert opinion on the phases related to the use of speech in mandibular positioning and to return their feedback within 2 weeks. The formalized template was provided with instructions specific to the evaluation of the names of the phases, their importance in inclusion or exclusion, whether additional

phases should be included, and the sequencing of the phases. Panelists were provided with a summary of all proposed phases and steps for reference. Panelist feedback was reviewed and incorporated into the phases, which were then sent back to the panelists for review. A summary of changes was included within the feedback template. This process was then repeated for evaluation of the steps within each phase.

RESULTS

Phases

Nine experts provided feedback in evaluation of the phases related to use of speech characteristics for mandibular positioning. Both participating otolaryngologists declined to provide feedback, stating a preference to limit their feedback specific to nasal function. Two rounds of expert feedback were necessary to reach consensus threshold. The name of one phase was expanded (preprocedural testing was expanded to preprocedural screening and testing). The order sequencing of the phases did not change from what was originally proposed. No phases were removed and no additional phases were added. Although the evaluation of phases was not specific to the steps within each phase, based on panelist feedback steps were added into or updated within phases. These changes are summarized in Appendix C.

Steps

Recording anatomic landmarks

Nine experts provided feedback in evaluation of the steps within the phase of recording anatomic landmarks. Both participating otolaryngologists declined to provide feedback stating a preference to limit their feedback specific to nasal function. Two rounds of expert feedback were necessary to reach consensus threshold. Two steps were added: *record dental and occlusal relationships (such as overjet, overbite, dental crowding, etc.)* and *recording mandibular ranges of motion (such as maximum opening, protrusion, deflection of opening, etc.)*. The two additional steps were placed in order positions one and two; the order sequencing of the rest of the steps did not change from what was originally proposed. No steps were removed. Consensus threshold was reached by the second round. These changes are summarized in Appendix D.

Preprocedural screening and testing

Eleven experts provided feedback in evaluation of the steps within the phase of preprocedural screening and testing. Two rounds were necessary to reach consensus threshold. The descriptions of multiple steps were expanded. One step was added: *visually screen for nasal obstructions (such as gross nasal deviations and enlarged inferior turbinates)*. The order sequencing of the first three steps was modified from what was originally proposed and the additional step placed after the first step.

Consensus threshold was reached by the second round. These changes are summarized in Appendix E.

Patient positioning

Nine experts provided feedback in evaluation of the steps within the phase of patient positioning. Both participating otolaryngologists declined to provide feedback stating a preference to limit their feedback specific to nasal function. Two rounds were necessary to reach consensus threshold. The descriptions of multiple steps were expanded;: *measure baseline (habitual) posture and head position* was expanded to *measure baseline (habitual) posture and head position in both standing and sitting position, provide interventions to relax the patient's orofacial musculature* was expanded to *provide interventions to relax the patient's orofacial musculature (for example, by massage or cold laser), instruct patient to position arms hanging neutrally without support on either side of their body* was expanded to *instruct patient to position arms hanging neutrally without support on either side of their body (or hands on lap neutrally, if preferred for comfort by patient)*, and *instruct patient to look straight ahead with eyes not focused on any particular object or landmark* was expanded to *instruct patient to look straight ahead with eyes directed towards a blank wall or blank paper and not focused on any particular object or landmark*. No steps were added. The last four steps were amalgamated into a single step. The order sequencing of the steps did not change from what was originally proposed. Consensus threshold was reached by the second round. These changes are summarized in Appendix F.

Identifying speech measurement limits

Nine experts provided feedback in evaluation of the steps within the phase of identifying speech measurement limits. Both participating otolaryngologists declined to provide feedback stating a preference to limit their feedback specific to nasal function. Consensus threshold was met within the first round. The descriptions of two steps were clarified: *instruct patient to count the numbers out loud from 60 to 80 in English at a normal speed* was expanded to *instruct patient to count the numbers out loud from 60 to 80 in English at a normal conversational speed and volume* and the word *lisps* was removed from *note any lateral mandibular movements and any lateral tongue movements/lisps*. No steps were added or removed. The order sequencing of the steps did not change from what was originally proposed. These changes are summarized in Appendix G.

Capturing occlusal relationships for mandibular position

Nine experts provided feedback in evaluation of the steps within the phase of capturing occlusal relationships for mandibular position. Both participating otolaryngologists declined to provide feedback, stating a preference to limit their feedback specific to nasal function. Consensus threshold was met within the first round. No descriptions were changed. No steps were added or removed. The order sequencing of the steps did not change from what was originally proposed. These changes are summarized in Appendix H.

Final Review

After consensus thresholds were reached for all phases and steps, the entire protocol on the use of speech characteristics for mandibular positioning was sent for final review to all panelists for open feedback. During the first round, significant feedback was received, resulting in changes to phase 2 and phase 3, with the first step of phase 3 added to phase 2 to ensure an evaluation of head position prior to any of the interventional steps in phase 2. The two steps in phase 1 for individually evaluating ankylolabia and ankyloglossia were combined into a single step. Descriptions for certain steps were expanded and examples included in order to provide guidance for clinical application. Spelling and grammar were corrected. In the second round of feedback there were no additional changes suggested.

The finalized protocol is attached in Appendix I.

DISCUSSION

OAT is a primary treatment option for OSA, with significantly greater adherence when compared to CPAP therapy.[16] Traditionally, mandibular positioning and titration in OAT uses the APT with a set vertical thickness usually determined by material thickness. Clinically significant adverse effects are frequently associated with increased anterior titration of the mandible. Recent research has shown that alternative mandibular positioning techniques, such as through the use of speech characteristics to determine mandibular position, may be viable in OAT. However, although preliminary research has shown promise, an appropriate definition and protocol for the use of speech characteristics in determining mandibular positioning has not previously been published. As the description of such a procedure is not empirically measurable, the Delphi method was applied to obtain an appropriate definition and description of the procedure of using speech characteristics for mandibular positioning in dental sleep medicine.

Although a number of clinical experts in the field of dental sleep medicine have provided their personal opinions and instructional videos on how to use speech characteristics to determine mandibular position, an appropriately rigorous process has not been undertaken to properly define and describe the procedure. By use of the Delphi process, a consensus-based definition including interdisciplinary expert feedback for the use of speech characteristics in mandibular positioning for dental sleep medicine was achieved. Multiple rounds of feedback were necessary, with input from different specialties providing insight into different aspects that may have significant effect on mandibular movement in speech. These included aspects not previously described such as nasal patency, eyesight and eye focus, lateral tongue movements, and body posture necessitating expertise from the fields of otolaryngology, optometry, speech language pathology, and physiotherapy. All expert feedback was weighted equally and panelists were blinded to the named opinions of their colleagues to prevent any peer pressure in feedback. Predefined consensus thresholds determined by the steering committee were strictly adhered to. The final full description of the procedure reached consensus threshold among all panelists. Although this definition does not predict clinical outcomes, it does provide a standardized methodology for the procedure to allow for its appropriate standardized use in clinical training and for future research.

Aside from the previously mentioned applications for the clinical use of speech characteristics in mandibular positioning, the application of the Delphi method for such a complex multilayered process involving multiple phases and multiple steps within each phase may provide a template for future application in other descriptive research within dentistry and medicine. Traditionally, all steps are evaluated in unison for each round in the Delphi methodology. In procedures that require steps nested under phases for order sequencing, or with a significant number of steps that require order sequencing, it may not be practical or possible to assess all steps at once. Evaluation of phases without steps, and then steps within each phase while also providing panelists with information on all steps and phases, may provide a template for evaluation of complex multiphase multistep protocols.

The Delphi process was used because of its strengths in structured feedback, anonymity for unbiased feedback, and flexibility in accepting asynchronous feedback by email reply. However, there are inherent limitations with the use of the Delphi process. These limitations include a lack of open discussion, the time requirement for multiple rounds of feedback, and that the outcomes from feedback are highly expertise dependent. The time commitment was likely a factor in the number of invited experts who did not elect to participate. Despite this, the expert panelists who did participate included representation across all healthcare fields invited. The inclusion of specific areas for open feedback and the diversity of expert panelists were attempts to address these limitations, although there were

no methods by which to evaluate their effectiveness.

CONCLUSION

This project encapsulated the application of the Delphi method to define and describe the use of speech characteristics for mandibular positioning in dental sleep medicine. Throughout the process, significant feedback from experts in multiple healthcare fields including otolaryngology, physiotherapy, optometry, speech language pathology, and dentistry highlighted the importance and diversity of thought that provided significant insight into the development of this protocol. From this process a consensus-based definition for the use of speech characteristics in mandibular positioning for dental sleep medicine was achieved. Not only does this provide the foundation and allow for reproducibility in teaching clinicians and for future research, the use of the Delphi process in this manner for the development for a dental protocol may also provide a template for future dental research in dental protocol development.

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DISCLOSURE STATEMENT

The authors declare no conflict of interest.

APPENDICES

Appendix A

Information Table

The following information about potential steps related to the proposed phases of using speech characteristics to determine mandibular positioning for dental appliances is provided for information purposes only. Please do not evaluate the potential steps at this time.

Proposed Phase 1: Recording anatomical landmarks

Proposed Steps

- Record the presence, grading, and grading method for maxillary ankylolabia (upper lip tie).
- Restriction has potential to affect lip seal
- Record the presence, grading, and grading method for mandibular ankylolabia (lower lip tie).
- Restriction has potential to affect lip seal
- Record the presence, grading, and grading method for ankyloglossia (tongue tie). Restriction has potential to affect speech and mandibular movement

Proposed Phase 2: Pre-Procedural testing

Proposed Steps

- Review cone beam computed tomography of the upper airway for potential pathology or obstructions
- Perform modified Cottle maneuver on each patient's nostril to screen for nasal valve compromise
- Instruct patient to use saline nasal rinse for debris removal to screen for improvements to nasal patency from debris removal
- Assess for potential effects of nasal valve patency on the patient's speech and mandibular movement

Proposed Phase 3: Patient positioning

Proposed Steps

- Seat patient in an upright manner on a stool or chair without back support
- Ensure patient's feet are firmly planted flatly and evenly on the floor
- Instruct patient to position arms hanging neutrally without support on either side of their body
- Instruct patient to look straight ahead with eyes not focused on any particular object or landmark

Proposed Phase 4: Identifying speech measurement limits

Proposed Steps

- Instruct patient to count the numbers out loud from 60 to 80 in English at a normal speed.
- Repeat if needed
- Note the maxillary and mandibular incisal edge positions in an anterior-posterior direction during the production of /s/ as the anterior limit of the mandible
- Note the maxillary and mandibular incisal edge positions in a superior-inferior direction during the production of /s/ as the superior limit of the mandible
- Note the maxillary and mandibular incisal edge positions in a superior-inferior direction during the production of /i/ as the inferior limit of the mandible
- Note the positions of the maxillary and mandibular midlines to one another as the lateral limits of positioning of the mandible

Proposed Phase 5: Capturing occlusal relationships for mandibular position

Proposed Steps:

- If the exact desired vertical dimension is known, capture the relative positions of the mandibular occlusion to the maxillary occlusion using a round object of thickness that matches the desired specific vertical dimension and that only allows for point contact in order to maintain proper orientation of the occlusal planes relative to each other in three dimensions and verify position again with the speech measurement limits previously noted
- If a specific vertical range is desired, capture the relative positions of the mandibular occlusion to the maxillary occlusion using a round object of thickness that matches the minimum desired specific vertical dimension and that only allows for point contact in order to maintain proper orientation of the occlusal planes relative to each other in three dimensions. Verify position again with the speech measurement limits previously noted. Note the maximum vertical range desired. Do not exceed the absolute maximum vertical range as denoted in the speech measurement limits
- If an unspecified vertical range is desired, capture the relative positions of the mandibular occlusion to the maxillary occlusion using a round object of minimal thickness that matches the inter-incisal distance during the production of /s/ sounds and that only allows for point contact in order to maintain proper orientation of the occlusal planes relative to each other in three dimensions. Verify position again with the speech measurement limits previously noted. Note the maximum vertical range as the inter-incisal distance during the production of /i/ sounds and capture the relative positions of the mandibular occlusion to the maxillary occlusion using a round object that matches the inter-incisal distance during the production of /i/ sounds and that only allows for point contact in order to maintain proper orientation of the occlusal planes relative to each other in three dimensions. Verify position again with the speech measurement limits previously noted

Appendix B

Expert consensus on the procedure of using speech characteristics for mandibular positioning in dental appliances
The purpose of this research is to define the procedure of using speech characteristics to determine mandibular positioning in dental appliances through expert consensus. You have been identified as an expert in this procedure (or part of it) considering your clinical and/or research experience. As you know, procedures are made up of phases and steps within those phases. In this second round of expert feedback, we would like to know your view about the STEPS of the phase "identifying speech measurement limits". Your answers and comments will not be shared with other experts. In upcoming rounds, you will be asked about steps within other phases. Thank you in advance for your time and support.
Please read the information provided in Table 1 before judging whether the following steps are sufficient and properly sequenced.

Section 2: Identifying speech measurement limits

Please indicate whether the following steps, which were derived from the literature and other sources (eg, videos), should be part of the steps of the phase of identifying speech measurement limits for the procedure of using speech characteristics for mandibular positioning in dental appliances. Feel free to improve the name of the suggested steps if necessary and elaborate on your answer of including/excluding each phase using the comment box.

Table 1.

Steps	Include this Step	Exclude this step	Rename this step (if necessary)	Comment
Instruct patient to count the numbers out loud from 60 to 80 in English at a normal speed. Repeat if needed				
Note any lateral mandibular movements and any lateral tongue movements/lisps				
Note the maxillary and mandibular incisal edge positions in an anterior- posterior direction during the production of /s/ as the anterior limit of the mandible				
Note the maxillary and mandibular incisal edge positions in a superior-inferior direction during the production of /s/ as the superior limit of the mandible				
Note the maxillary and mandibular incisal edge positions in a superior-inferior direction during the production of /i/ as the inferior limit of the mandible				
Note the positions of the maxillary and mandibular midlines to one another as the lateral limits of positioning of the mandible				

Section 2: Additional steps

Please suggest additional steps if necessary and elaborate on your suggestion(s) using the comment box. Leave this section blank if no additional step(s) is/are needed.

Suggested additional step	**Reasoning for additional step**

Section 3: Steps order

Please order the steps in the sequence they should be performed, including those you may have suggested. If the order does not matter for certain or all steps, please indicate so.

1. _____

2. _____

3. _____

4. _____

5. _____

6. _____

7. _____

8. _____

Appendix C

Changes to phases and steps from the first round of expert feedback are shown below in redlined format

Proposed Phase 1: Recording anatomic landmarks

Proposed Steps

- Record dental and occlusal relationships (such as overjet, overbite, dental crowding, etc.)
- Record mandibular ranges of motion (such as maximum opening, protrusion, deflection on opening, etc.)
- Record the presence, grading, and grading method for maxillary ankylolabia (upper lip tie).
- Restriction has potential to affect lip seal
- Record the presence, grading, and grading method for mandibular ankylolabia (lower lip tie).
- Restriction has potential to affect lip seal
- Record the presence, grading, and grading method for ankyloglossia (tongue tie). Restriction has potential to affect speech and mandibular movement

Proposed Phase 2: Preprocedural screening and testing

Proposed Steps

- Assess orofacial musculature (for example, by palpation)
- Screen for temporomandibular joint dysfunction sign and symptoms
- Review ~~CBCT~~ of imaging (for example, cone beam computed tomography or magnetic resonance imaging) of the upper airway for potential pathology or obstructions as well as temporomandibular joint position and condition
- Perform modified Cottle maneuver on each patient's nostril to screen for nasal valve compromise
- Instruct patient to use saline nasal rinse for debris removal to screen for improvements to nasal patency from debris removal
- Assess for potential effects of nasal valve patency on the patient's speech and mandibular movement

Proposed Phase 3: Patient positioning

Proposed Steps

- Measure baseline (habitual) posture and head position
- Provide interventions to relax the patient's orofacial musculature
- Seat patient in an upright position on a stool or chair without back support, with palms facing medially
- Ensure patient's feet are firmly planted flatly and evenly on the floor
- Instruct patient to position arms hanging neutrally without support on either side of their body
- Instruct patient to look straight ahead with eyes not focused on any particular object or landmark

Proposed Phase 4: Identifying speech measurement limits

Proposed Steps

- Instruct patient to count the numbers out loud from 60 to 80 in English at a normal speed.
- Repeat if needed
- Note the maxillary and mandibular incisal edge positions in an anterior-posterior direction during the production of /s/ as the anterior limit of the mandible
- Note the maxillary and mandibular incisal edge positions in a superior-inferior direction during the production of /s/ as the superior limit of the mandible
- Note the maxillary and mandibular incisal edge positions in a superior-inferior direction during the production of /i/ as the inferior limit of the mandible
- Note the positions of the maxillary and mandibular midlines to one another as the lateral limits of positioning of the mandible

Proposed Phase 5: Capturing occlusal relationships for mandibular position

Proposed Steps:

- If the exact desired vertical dimension is known, capture the relative positions of the mandibular occlusion to the maxillary occlusion using a round object of thickness that matches the desired specific vertical dimension and that only allows for point contact in order to maintain proper orientation of the occlusal planes relative to each other in three dimensions, and verify position again that the speech measurement limits previously noted
- If a specific vertical range is desired, capture the relative positions of the mandibular occlusion to the maxillary occlusion using a round object of thickness that matches the minimum desired specific vertical dimension and that only allows for point contact in order to maintain proper orientation of the occlusal planes relative to each other in three dimensions. Verify position again with the speech measurement limits previously noted. Note the maximum vertical range desired. Do not exceed the absolute maximum vertical range as denoted in the speech measurement limits
- If an unspecified vertical range is desired, capture the relative positions of the mandibular occlusion to the maxillary occlusion using a round object of minimal thickness that matches the inter-incisal distance during the production of /s/ sounds and that only allows for point contact in order to maintain proper orientation of the occlusal planes relative to each other in three dimensions. Verify position again with the speech measurement limits previously noted. Note the maximum vertical range as the interincisal distance during the production of /i/ sounds and capture the relative positions of the mandibular occlusion to the maxillary occlusion using a round object that matches the interincisal distance during the production of /i/ sounds and that only allows for point contact in order to maintain proper orientation of the occlusal planes relative to each other in three dimensions. Verify position again with the speech measurement limits previously noted
- Perform post-bite registration confirmation and evaluation with additional testing if indicated

Appendix D – Changes to recording anatomic landmarks

Changes to the steps within the phase of "recording anatomic landmarks" from expert feedback are shown below in redlined format

Proposed Phase 1: Recording anatomic landmarks

Proposed Steps

- Record dental and occlusal relationships (such as overjet, overbite, dental crowding, etc)
- Record mandibular ranges of motion (such as maximum opening, protrusion, deflection on opening, etc)
- Record the presence, grading, and grading method for maxillary ankylolabia (upper lip tie).
- Restriction has potential to affect lip seal
- Record the presence, grading, and grading method for mandibular ankylolabia (lower lip tie).
- Restriction has potential to affect lip seal
- Record the presence, grading, and grading method for ankyloglossia (tongue tie). Restriction has potential to affect speech and mandibular movement

Appendix E – Changes to preprocedural screening and testing

Changes to the steps within the phase of "preprocedural screening and testing" from expert feedback are shown below in redlined format

Proposed Phase 2: Preprocedural screening and testing

Proposed Steps

- Review of imaging (for example, cone beam computed tomography or magnetic resonance imaging) of the upper airway for potential pathology or obstructions as well as temporomandibular joint position and condition
- Visually screen for nasal obstructions (such as gross nasal deviations and enlarged inferior turbinates)
- Screen for temporomandibular joint dysfunction signs and symptoms (such as clicking, popping, deviation of mandibular movement, and pain)
- Assess orofacial musculature (for example, by palpation held for 5 seconds to include assessment of potential radiation of symptoms)
- Perform modified Cottle maneuver on each patient's nostril to screen for nasal valve compromise
- Instruct patient to use saline nasal rinse to screen for improvements to nasal patency from debris removal (such as subjective improvement to airflow and/or breathing and visual decrease of inferior turbinate and septal swell body size). Repeat with nasal decongestant if possible
- Assess for the effects of changes to nasal patency on the patient's speech and mandibular movement

Appendix F – Changes to patient positioning

Changes to the steps within the phase of "patient positioning" from expert feedback are shown below in redlined format

Proposed Phase 3: Patient positioning

Proposed Steps

- Measure baseline (habitual) posture and head position in both standing and sitting positions
- Provide interventions to relax the patient's orofacial musculature (for example, by massage or cold laser)
- Seat patient in an upright position on a stool or chair without back support with palms facing medially. Ensure patient's feet are firmly planted flatly and evenly on the floor. Instruct patient to position arms hanging neutrally without support on either side of their body (or hands on lap neutrally, if preferred for comfort by patient). Instruct patient to look straight ahead with eyes directed towards a blank wall or blank paper and not focused on any particular object or landmark

Appendix G – Changes to identifying speech measurement limits

Changes to the steps within the phase of "identifying speech measurement limits" from expert feedback are shown below in redlined format

Proposed Steps

- Instruct patient to count the numbers out loud from 60 to 80 in English at a normal conversational speed and volume. Repeat if needed
- Note any lateral mandibular movements and any lateral tongue movements~~/lisps~~
- Note the maxillary and mandibular incisal edge positions in an anterior-posterior direction during the production of /s/ as the anterior limit of the mandible
- Note the maxillary and mandibular incisal edge positions in a superior-inferior direction during the production of /s/ as the superior limit of the mandible
- Note the maxillary and mandibular incisal edge positions in a superior-inferior direction during the production of /i/ as the inferior limit of the mandible
- Note the positions of the maxillary and mandibular midlines to one another as the lateral limits of positioning of the mandible

Appendix H – Changes to capturing occlusal relationships for mandibular position

Changes to the steps within the phase of "capturing occlusal relationships for mandibular position" from expert feedback are shown below in redlined format

Proposed Steps

- If the exact desired vertical dimension is known, capture the relative positions of the mandibular occlusion to the maxillary occlusion using a round object of thickness that matches the desired specific vertical dimension and that only allows for point contact in order to maintain proper orientation of the occlusal planes relative to each other in three dimensions and verify position again with the speech measurement limits previously noted
- If a specific vertical range is desired, capture the relative positions of the mandibular occlusion to the maxillary occlusion using a round object of thickness that matches the minimum desired specific vertical dimension and that only allows for point contact in order to maintain proper orientation of the occlusal planes relative to each other in three dimensions. Verify position again with the speech measurement limits previously noted. Note the maximum vertical range desired. Do not exceed the absolute maximum vertical range as denoted in the speech measurement limits
- If an unspecified vertical range is desired, capture the relative positions of the mandibular occlusion to the maxillary occlusion using a round object of minimal thickness that matches the inter-incisal distance during the production of /s/ sounds and that only allows for point contact in order to maintain proper orientation of the occlusal planes relative to each other in three dimensions. Verify position again with the speech measurement limits previously noted. Note the maximum vertical range as the inter-incisal distance during the production of /i/ sounds and capture the relative positions of the mandibular occlusion to the maxillary occlusion using a round object that matches the inter-incisal distance during the production of /i/ sounds and that only allows for point contact in order to maintain proper orientation of the occlusal planes relative to each other in three dimensions. Verify position again with the speech measurement limits previously noted.
- Perform post-bite registration confirmation and evaluation with additional testing if indicated

Appendix I – Protocol on the use of speech characteristics for mandibular positioning in dental sleep medicine

Phase 1: Recording anatomic landmarks

Proposed Steps:

1. Evaluate and record dental and occlusal relationships (such as overjet, overbite, teeth and gingival ratios, dental crowding, tooth ratios, skeletal and dental midlines, etc.)
2. Evaluate and record mandibular ranges of motion (such as maximum opening, protrusion, deflection of opening, etc)
3. Evaluate and record the presence, grading, and grading method for maxillary and mandibular ankylolabia (upper and lower lip tie). Restriction has potential to affect lip seal

   Evaluate and record the presence, grading, and grading method for ankyloglossia (tongue tie). Restriction has potential to affect speech and mandibular movement

Phase 2: Preprocedural screening and testing

Proposed Steps:

1. Measure baseline (habitual) posture and head position in both standing and sitting position
2. Review imaging (for example, cone beam computed tomography or magnetic resonance imaging) of the upper airway for potential pathology or obstructions as well as temporomandibular joint position and condition
3. Visually screen for nasal obstructions (such as gross nasal deviations and enlarged inferior turbinates)
4. Screen for temporomandibular joint dysfunction signs and symptoms (such as clicking, popping, deviation of mandibular movement, and pain)
5. Assess orofacial musculature (for example, by palpation held for 5 seconds to include assessment of potential radiation of symptoms)
6. Perform modified Cottle maneuver on each nostril to screen for nasal valve compromise. If positive, consider use of a nasal dilator (or similar) and referral to otolaryngology for evaluation
7. Instruct patient to use saline nasal rinse to screen for improvements to nasal patency from debris removal (such as subjective improvement to airflow and/or breathing and visual decrease of inferior turbinate and/or septal swell body size). Repeat with nasal decongestant if possible
8. Assess for the effects of changes to nasal patency on the patient's speech and mandibular movement (for example, visually or by validated questionnaires such as the NOSE or SNOT-22 at baseline and after nasal patency evaluative interventions)

Phase 3: Patient positioning

Proposed Steps:

1. Reevaluate posture and head position in both standing and sitting position
2. Provide interventions to relax the patient's orofacial musculature (for example, by massage or cold laser)

   Seat patient in an upright manner on a stool or chair without back support with arm and palms in a neutral position. Ensure patient's feet are firmly planted flatly and evenly on the floor.
3. Instruct patient to position arms hanging neutrally without support on either side of their body (or hands on lap neutrally, if preferred for comfort by patient). Instruct patient to look straight ahead with eyes directed toward a blank wall or blank paper and not focused on any particular object or landmark

Phase 4: Identifying speech measurement limits

Proposed Steps:

1. Instruct patient to count the numbers out loud from 60 to 80 in English at a normal conversational speed and volume. Repeat if needed

   Note any lateral mandibular movements and any lateral tongue movements

   Note the maxillary and mandibular incisal edge positions in an anterior-posterior direction during the production of /s/ as the anterior limit of the mandible
2. Note the maxillary and mandibular incisal edge positions in a superior-inferior direction during the production of /s/ as the superior limit of the mandible

   Note the maxillary and mandibular incisal edge positions in a superior-inferior direction during the production of /i/ as the inferior limit of the mandible

   Note the positions of the maxillary and mandibular midlines to one another as the lateral limits of positioning of the mandible

Phase 5: Capturing occlusal relationships for mandibular position

Proposed Steps:

If the exact desired vertical dimension is known, capture the relative positions of the mandibular occlusion to the maxillary occlusion using a round object of thickness that matches the desired specific vertical dimension and that only allows for point contact of incisal edges in order to maintain proper orientation of the occlusal planes relative to each other in three dimensions and verify both sufficient occlusal clearance and position for the speech measurement limits previously noted (for example, with injection of polyvinyl siloxane bite registration material between the teeth, digital intraoral scanning, or through digital recording of jaw and occlusion tracking)

1. If a specific vertical range is desired, capture the relative positions of the mandibular occlusion to the maxillary occlusion using a round object of thickness that matches the minimum desired specific vertical dimension and that only allows for point contact of incisal edges in order to maintain proper orientation of the occlusal planes relative to each other in three dimensions and verify both sufficient occlusal clearance and position for the speech measurement limits previously noted (for example, with injection of polyvinyl siloxane bite registration material between the teeth, digital intraoral scanning, or through digital recording of jaw and occlusion tracking). Note the maximum vertical range desired with an absolute maximum as denoted in the speech measurement limits

   If an unspecified vertical range is desired, capture the relative positions of the mandibular occlusion to the maxillary occlusion using a round object of minimal thickness that matches the interincisal distance during the production of /s/ sounds and that only allows for point contact of incisal edges in order to maintain proper orientation of the occlusal planes relative to each other in three dimensions and verify both sufficient occlusal clearance and position for the speech measurement limits previously noted (for example, with injection of polyvinyl siloxane bite registration material between the teeth, digital intraoral scanning, or through digital recording of jaw and occlusion tracking). Note the maximum vertical range as the interincisal distance during the production of /i/ sounds and capture the relative positions of the mandibular occlusion to the maxillary occlusion using a round object that matches the inter- incisal distance during the production of /i/ sounds and that only allows for point contact of incisal edges in order to maintain proper orientation of the occlusal planes relative to each other in three dimensions and verify both sufficient occlusal clearance and position for the speech measurement limits previously noted

2. Perform post-bite registration confirmation and evaluation with additional testing if indicated