Title

Delphi consensus on the use of speech for mandibular positioning in dental sleep medicine

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Abstract

Study Objectives

To develop and describe a protocol for the use of speech 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 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 to determine mandibular position in dental sleep medicine.

Conclusions

A consensus based definition for the use of speech 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; our 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 dysfunction, and occlusal changes dependent upon the degree of protrusion. The use of speech for mandibular position may provide alternative positioning for OAT that may decrease side effect risk and improve patient response.

Keywords

Speech, 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 fabricated oral appliance therapy (OAT) while secondary treatments range from weight loss to orofacial myofunctional therapy.[5,10-12] While 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 though its efficacy is not as great as 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 as 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 50-70% 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 treated, 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 5mm due to appliances used in OAT being traditionally 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 side 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, while 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]

While the SPT has been proposed as an alternative to the APT, a validated formal protocol for measuring mandibular position and/or vertical positioning in the use of speech 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 side 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 undesired side effects compared to 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 in speech 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] As this space has minimal inter-incisal distance, this space in insufficient for the fabrication of a dental appliance for OAT due to material thickness. Modification to the SPT to allow for increased inter-incisal distance has been mentioned in peer reviewed published literature, though not described in detail.[23] Expert opinions have provided subjective descriptions for the modification of the SPT for use in dental sleep medicine though 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 for mandibular positioning in dental sleep medicine.

We propose to establish a protocol for the use of speech 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 for mandibular positioning in dental sleep medicine is a necessary first step to 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 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 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 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 cut-offs 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 which 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 is repeated until expert consensus is 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 reviews strict inclusion criteria.[22] In addition, the same search terms were used in google where the first three pages of results were reviewed to not limit 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 to determine mandibular position.[38-41] These articles and videos provided expert opinion and description on the use of speech 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 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 determining levels of agreement for acceptable consensus and 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 for mandibular positioning in dental sleep medicine.

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

Based on information gathered from the literature review, the use of speech 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 which described the process of using speech 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 nineteen steps identified by the steering committee.

The five phases identified by the steering committee were: 1. recording anatomical landmarks, 2. pre-procedural testing, 3. patient positioning, 4. identifying speech measurement limits, and 5. capturing occlusal relationships for mandibular position. The nineteen 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 dysfunction. All optometrists were also registered nurses and involved in the field or 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 in mandibular positioning from articles revealed in the literature review. Of the eighteen experts invited six were dentists, five were otolaryngologists, three were physiotherapists, three were speech language pathologists also certified orofacial myologists, and one was an optometrist.

Eleven of the eighteen 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 orofacial myologists and one was an optometrist. Both otolaryngologists who elected to participate requested their feedback be limited purely to portions 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 and 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 two 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 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; *pre-procedural testing* was expanded to *pre-procedural 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. While 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 anatomical landmarks

Nine experts provided feedback in evaluation of the steps within the phase of recording anatomical 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.

Pre-Procedural screening and testing

Eleven experts provided feedback in evaluation of the steps within the phase of pre-procedural 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 sixty to eighty in English at a normal speed* was expanded to *instruct patient to count the numbers out loud from sixty to eighty 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 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. 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

Once consensus thresholds were reached for all phases and steps, the entire protocol on the use of speech 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 into 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 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 side 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 to determine

mandibular position, may be viable in OAT. However, while preliminary research has shown promise, an appropriate definition and protocol for the use of speech in 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 for mandibular positioning in dental sleep medicine.

While 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 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 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 impact 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 opinions of their colleagues to prevent any peer pressure in feedback. Pre-defined consensus thresholds determined by the steering committee were strictly adhered to. The final full description of the procedure reached consensus threshold amongst all panelists. While 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 in mandibular positioning, the application of the Delphi method for such a complex multi-layered 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 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 in all steps and phases, may provide a template for evaluation of complex multi-phase multi-step protocols.

The Delphi process was used due to 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, though there were no methods by which to evaluate the effectiveness of such.

Conclusion

This project encapsulated the application of the Delphi method to define and describe the use of speech 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 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;

our 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.

Disclosure Statement

Conflict of interest: none. Financial Disclosure: none. Non-financial disclosure: none.

Data Availability

No new data were generated or analysed in support of this research.

Author Contributions

E.N.: conceptualization, methodology, investigation, data curation, formal analysis, writing – original draft, writing – review and editing.

M.L.: conceptualization, methodology, investigation, formal analysis, writing – original draft, writing – review and editing

A.P.G.: conceptualization, methodology, investigation, formal analysis, writing – original draft, writing – review and editing

Abbreviations

APT: anterior protrusive technique

CPAP: continuous positive airway pressure

OAT: oral appliance therapy

OSA: obstructive sleep apnea

SPT: sibilant phoneme technique

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Appendix A

Information Table

The following information about potential steps related to the proposed phases of using speech 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 CBCT imaging of the upper airway for potential pathology or obstructions
- Perform modified Cottle's 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 sixty to eighty 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 for mandibular positioning in dental appliances

The purpose of this research is to define the procedure of using speech 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 (e.g., videos), should be part of the steps of the phase of identifying speech measurement limits for the procedure of using speech 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 sixty to eighty 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 anatomical 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: Pre-Procedural screening and testing

Proposed Steps

- Assess orofacial musculature (for example, by palpation)
- Screen for temporomandibular dysfunction sign and symptoms
- Review of imaging (for example, CBCT or MRI) of the upper airway for potential pathology or obstructions as well as TMJ position and condition

- Perform modified Cottle's 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 manner 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 sixty to eighty 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 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 D – Changes to recording anatomical landmarks

Changes to the steps within the phase of “recording anatomical landmarks” from expert feedback are shown below in redlined format

Proposed Phase 1: Recording anatomical 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 pre-procedural screening and testing

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

Proposed Phase 2: Pre-procedural screening and testing

Proposed Steps

- Review of imaging (for example, CBCT or MRI) of the upper airway for potential pathology or obstructions as well as TMJ position and condition
- Visually screen for nasal obstructions (such as gross nasal deviations and enlarged inferior turbinates)
- Screen for temporomandibular 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's 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 manner 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 sixty to eighty 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
- 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 for mandibular positioning in dental sleep medicine

Phase 1: Recording anatomical 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: Pre-Procedural screening and testing

Proposed Steps:

1.	Measure baseline (habitual) posture and head position in both standing and sitting position
2.	Review imaging (for example, CBCT or MRI) of the upper airway for potential pathology or obstructions as well as TMJ position and condition
3.	Visually screen for nasal obstructions (such as gross nasal deviations and enlarged inferior turbinates)
4.	Screen for temporomandibular 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's 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.	Re-evaluate 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)

3. 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. 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 look straight ahead with eyes directed towards 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 sixty to eighty in English at a normal conversational speed and volume. Repeat if needed

2. 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
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:

1. 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)
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

inter-incisal 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 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 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