In *Proceedings of the 27th World Congress of the International Association of Logopedics and Phoniatrics (IALP 2007)*, Copenhagen, Denmark

Clinical Analysis in Speech and Language Therapy: Occlusal Class and Speech Production

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1. Introduction

Occlusal class refers to the manner that the upper (maxilla) and lower (mandible) dental arches relate. This relation was first described by Angle [1], who proposed a malocclusion classification based on the relative position of the maxillary first molar. Malocclusion refers to the misalignment of teeth and/or incorrect relation between the teeth of the two dental arches. Class I malocclusion, presents a normal molar relationship, but the other teeth have problems like spacing, crowding, over or under eruption. In Class II malocclusion, or distocclusion, the upper molars are placed not in the mesiobuccal groove but anteriorly to it. The anterior dental relation can vary, originating two subclasses: division 1, when the maxillary incisors are positioned forward to the lower incisors resulting in marked overjet; division 2, when there is linguoversion (retroversion) of the maxillary central incisors. Class III malocclusion, or mesiocclusion, refers to an advancement of the lower dental arch [1].

Occlusal class has been shown [2] to be directly related to articulatory perturbation of speech sounds such as fricatives. Understanding the influence of occlusal class in stomatognathic functions requires a thorough assessment of the craniofacial configuration. The size, form and relative position of the craniofacial bones may be in the origin of malocclusions and functional disorders.

X-Ray Microbeam Speech Production Database (XRMB-SPD) is a speech production database, created at Wisconsin University, USA, that uses X-Ray Microbeam technology to collect a vast amount of coordinate data describing articulatory movements, and also includes acoustic and electroglotographic data collected simultaneously [3].

XRMB-SPD articulatory data are presented in a two dimensional xy mid-saggital plane that includes: palate line, posterior pharynx wall line, lips, tongue and mandible. The coordinates of each mobile structure refer to an 8 pellet system distributed through the oral cavity: lower lip, upper lip, mandibular incisor, mandibular first molar and tongue (4 pellets) [3].

The speech samples result from different tasks, including word and sentence reading, isolated productions, and non-verbal oral movements. The speaker sample includes 57 male and female speakers of American English, with an average age of 21. The database includes individual parameters characterizing each subject (e.g., dental information), which allowed us to study the relations between speech production and occlusal class [3].

The present study was concerned with the variations of different malocclusion class subjects, namely: (a) the description of articulatory structures involved in speech production; (b) the comparison of acoustic features and articulatory processes in vowel and consonant productions; (c) the characterization of the functional adaptations found.

2. Method

Four subjects, out of the 57 American English speakers in XRMB-SPD, were selected, representing four distinct groups regarding gender and malocclusion (I and II). Since the XRMB-SPD didn't incorporate a cephalometric analysis, a method to adequately describe the subject's oral cavity dimensions, the "Modified A-Space" method [4, 5], was used to extract several measures of the Articulatory Oral Space (AOS). The “Modified A-Space” measures, shown in Figure 1, included: M1 – antero-posterior distance, calculated from the upper incisors to the posterior pharynx wall; M2 – mid-sagittal plane area, from the mandible to the palate midline; M3 – occlusal plane area, from the distal-buccal cusp tip of the second molar to the lips; M4 – posterior pharynx wall tilt, i.e, the angle between the pharynx and the occlusal planes; M5 – mandible arch angle, calculated with several mandible points; M6 – anterior oral cavity volume.

Articulatory and acoustic features of the vowels [i], [{], [A] and [u], and of the consonants [p], [t], [k], [f], [s] and [S] were studied using different tasks and methods. Tasks TP014 (isolated vowel production) and TP016 (citation VCVs), were used to extract simultaneous acoustic and articulatory data for each studied speech sound. The acoustic parameters were F1, F2 and F3 frequencies for the vowels, and multitaper spectra peak frequencies for the consonants. Overlapping articulatory configurations and trajectories of each subject’s production were also analysed and the distances between different articulatory structures’ reference points were measured. The corpus was annotated and analysed acoustically using several tools from TF32 and Matlab.

3. Results and Discussion

Only 45 out of the 57 subjects in XRMB-SPD were used during the selection process, because some of the speakers had missing values, necessary to calculate de “Modified A-Space”. There were 18 class I males, 22 class I females, 2 class II males and 3 class II females. The selected subjects were: JW15 – class I male; JW61 – class II male; JW54 – class I female; JW13 – class II female.

The major differences between these groups were related, not with occlusal class, but with gender. There was a considerably larger average oral cavity volume and greater antero-posterior distance of the AOS in male subjects than in females. Class II subjects present significant AOS reduction and a tipped posterior pharynx wall. The palate line configurations were similar in all subjects except for speaker JW13, with a 0.5 cm reduction in height at its posterior end (x = -3 cm), as shown in Figure 2. Functional behaviour suggested that speakers JW61 and JW13 may have other occlusal differences apart from the occlusal class, since speaker JW61 placed his tongue apex further back than speaker JW13, and speaker JW13 frequently advanced his jaw, suggesting a deep bite.

Vowels produced by male subjects had lower formant frequencies than females as expected, since male subjects had a wider AOS. There weren’t any significant acoustical differences related to malocclusion. However, there were several differences between class II subjects’ articulation. JW13 had predominant anterior and low tongue postures, when compared with JW61. Results showed great adaptation ability of the human vocal tract to adjust functional skills, involved in speech production, to structural variations. These adaptations could be related to the muscular groups involved in the production of some vowels, which could be quite different from those usually described for “normal” speech. As an example, in [i] production, shown in Figure 3, speaker JW13 seems to use the superior longitudinal tongue muscle to elevate the tongue tip, which isn’t usually activated in “normal” productions [6]. The study of these variations would be of particular relevance as a support to the clinical practice of speech and language therapists dealing with articulatory perturbations.

Acoustic and articulatory results for [f] and [p] did not show any significant differences between speakers. Fricative [s] presented different articulatory adaptations in class II subjects, as shown in Figure 4, and the tongue tip placement and the frequency of the broad peak in multitaper spectra were related. In [S] production, class II speakers had more posterior articulatory places than class I speakers, and the broad peak frequency of multitaper spectra was related with occlusal class: higher in class I and lower in class II (see Figure 5). Stop [t] had more anterior places of articulation in women than in men. In [k] production the articulatory configuration was similar in all subjects and the second peak frequency was related with lip opening.

There was great variability in terms of the articulatory processes used by the four subjects, but mostly in class II malocclusion subjects. Class II subjects used different articulatory postures to functionally adapt speech to their structural configuration (occlusal class and palate). The type of adaptations found should be described using cephalometric data contributing to a better understanding of normal and pathological speech production. In this study we used the “Modified A-Space” [4, 5] to provide additional information to XRMB-SPD’s original data, that can be used to characterize and describe selected subjects. In Speech and Language Therapists’ clinical practice it would be important to better understand and use cephalometric analysis information, to adjust therapeutic intervention's temporal planning, mainly in speech disorders that require orthodontic or maxillofacial surgical procedures.

4. Conclusions

Vowel production did not show acoustic differences related to occlusal class, but females presented higher second formant frequency values than males. There were several individual adaptations in articulatory patterns, related to the structural differences.

In consonant productions, we observed that: [s] – there were different adaptations by class II speakers; [S] – place of articulation was more posterior in class II than in class I speakers; [t] – the articulatory configuration was related to gender; [k] – there were differences related to gender, concerning the curvature of the back of the tongue. We've shown that [s], [S] and [k]'s acoustic and articulatory measures were related.

This study was important to show the great variability of the adaptation processes used in speech articulation. It's important to the clinical activity of speech and language therapists to understand and use cephalometric analysis to improve the assessment and planning of the intervention in articulatory and other stomatognathic function disorders related to cranio-facial anomalies (e.g., orofacial clefts).

5. Acknowledgements

Supported (in part) by research grant number R01 DC 00820 from the National Institute of Deafness and Other Communicative Disorders, U. S. National Institutes of Health.

6. References

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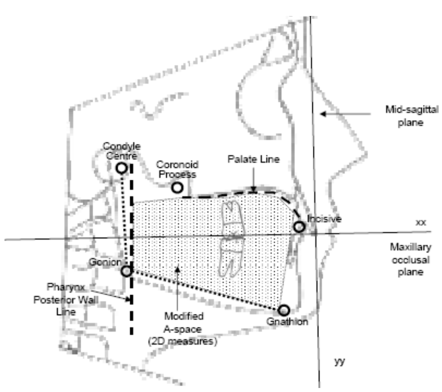

Figure 1 Representation of several points included in XRMB-SPD and the "Modified A-Space" in the mid-sagittal plane.

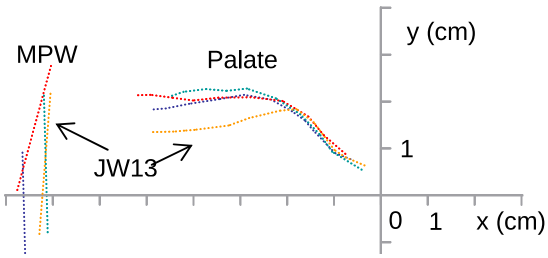

Figure 2 Palate and Middle Pharynx Wall (MPW) of speakers JW15 (blue), JW61 (red), JW54 (green) and JW13 (yellow).

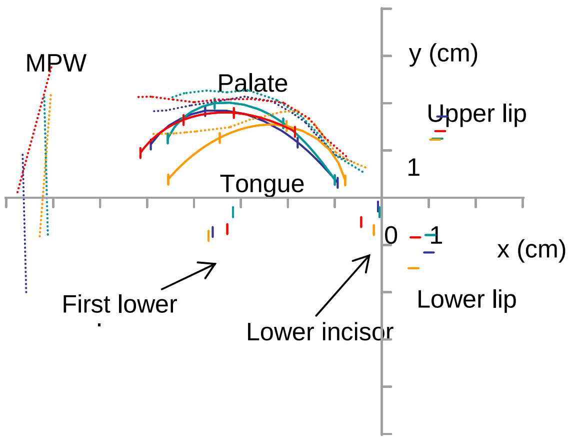

Figure 3 Overlapping articulatory configurations of [i] production by speakers JW15 (blue), JW61 (red), JW54 (green) and JW13 (yellow).

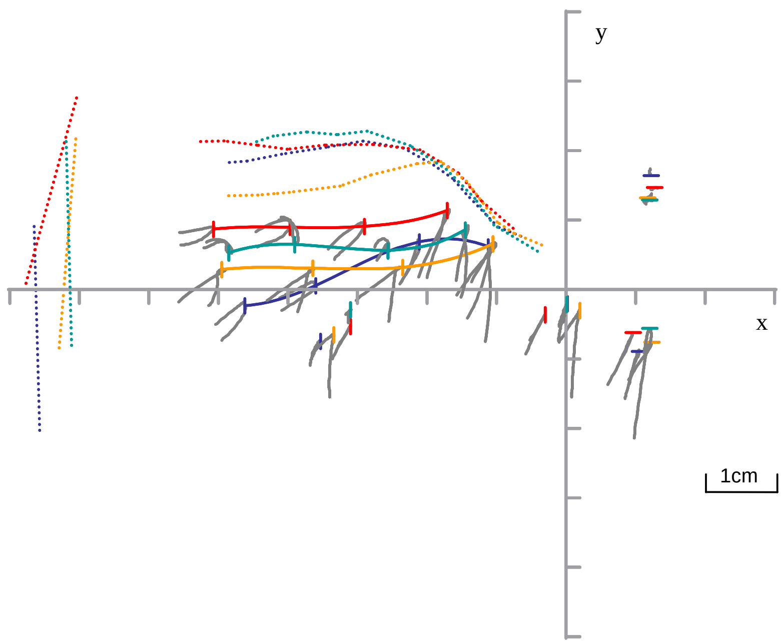

Figure 4 Overlapping articulatory configurations and trajectories (grey) of [s] production by speakers jw15 (blue), jw61 (red), jw54 (green) and jw13 (orange).

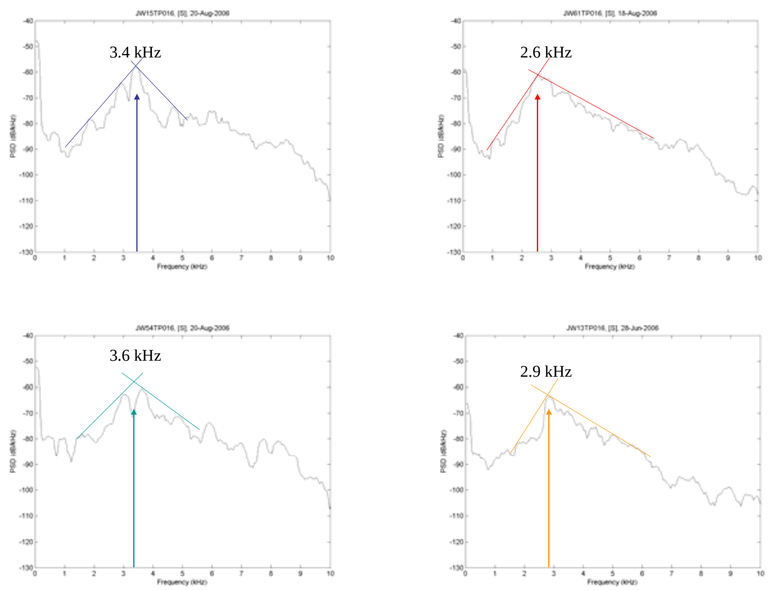

Figure 5 Multitaper spectra of [S] produced in task TP016 by speakers jw15 (uppper left), jw61 (upper right), jw54 (lower left) and jw13 (lower right).

[Word Count: 1663]