DENTAL OVERJET, ARTICULATORY COMPENSATION AND ACOUSTICS OF SPEECH

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1 Introduction

Dentofacial abnormalities have been linked, with mixed evidence at times, to misarticulations before and after corrective surgery in severe cases [1, 2]. Many individuals, even in surgical populations, appear to achieve typical-sounding productions by using compensatory adaptation of the speech articulators [3]. Overjet, the horizontal overlap of upper maxillary and lower mandibular central incisors, can be both positive (upper protrusion) or negative (lower protrusion), and is one measure of malocclusion. Although a few studies have applied acoustic analysis to supplement perceptual data [2, 4], most previous research relating to malocclusion has been based on judgments of misarticulation rather than objective acoustic measures [5, 6]. As such, this study seeks to investigate the association between degree of overjet in non-surgical populations and speech production using acoustic analysis.

2 Methods

Participants were 20 native English speakers (mean age = 24.7 years, 5 males, 15 females), none of whom reported speech or hearing disorders. Stimuli consisted of 13 target words containing the English vowels /i, u, ɑ/, fricatives /s, z/ and affricates /ʃ, tʃ, dʒ/. Fricatives were placed in both word-initial and -final contexts while vowels were between two consonants. All words were presented in the sentence "Repeat the term _____ often" for a duration of three seconds using PsychoPy (version 1.81.02) software [7]. Participants were instructed to read the full sentence as quickly as they could to control for reading speech rate and to encourage more natural elicitations. The speech samples were recorded in a sound-treated booth with a Samson C03U USB multi-pattern condenser microphone on Audacity 2.1.2 at a sampling rate of 44.1kHz.

Dental overjet was measured by intraoral assessment, considered a reliable technique [8] using disposable metric rulers accurate to 1 mm. All measurements were recorded in millimetres. Other facial measures of mandible width and nose-to-lip distance were taken to prevent participants from learning the purpose of our study. They were asked to comment on their dentofacial history, such as having had braces or major dental surgery, and to fill in a questionnaire on language background information.

Incorrect elicitations were omitted; in total, 3146 tokens were included in the analysis. Target fricatives and vowels were annotated manually in Praat [9]. In the case of fricatives, the duration and four spectral moments (centre of gravity [COG], standard deviation, skewness and kurtosis) were extracted from the portion between one-quarter and three-quarters of the total duration. Measurements of the first three formants were taken from the midpoint of all vowels.

3 Results

Participants were split into four groups for analysis according to the overjet measurements, detailed in Table 1. Two-way Multivariate ANOVAs (MANOVAs) were run in R on formants values (vowels), and duration and spectral moments (fricatives), where the factors were Overjet group and Vowel (/i, u, ɑ/) or Fricative (/s, z, ʃ, tʃ, dʒ/), respectively.

Overjet	*n*	mean age	M	F
1 mm	5	24 years	1	4
2 mm	4	21 years	0	4
3 mm	5	26.4 years	2	3
4 mm	6	26.2 years	2	4

Table 1: Participant details by the four groups of overjet.

Two-way MANOVA results indicate that there was a statistically significant difference between vowels (Pillai's Trace = 0.80426, $F(6, 94) = 10.5374$, $p < 0.001$) by F1, F2 and F3. There were no statistically significant effects of overjet group on formants, nor for interactions between specific vowels and degree of overjet in the formant values.

There was a statistically significant difference between fricatives (Pillai's Trace = 1.30155, $F(20, 316) = 7.6209$, $p < 0.001$) by COG, standard deviation, and skewness and duration, but not kurtosis. There was a statistically significant difference between overjet groups across all fricatives (Pillai's Trace = 0.35501, $F(15, 234) = 2.0938$, $p = 0.01096$) in standard deviation, kurtosis and duration. Interactions between specific fricatives and overjet group were statistically non-significant in terms of spectral moment and duration values.

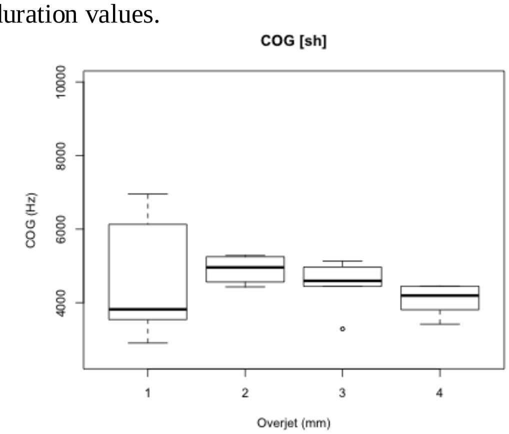

Figure 1: Mean COG values of /ʃ/ for each participant by overjet.

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Some trends do appear in the means for post-alveolar and alveolar fricatives the spectral moments, shown in Table 2 and 3. In the post-alveolar consonants, trends show the 2-4 mm groups in a linear relationship, but with the 1 mm group reversing the direction. Alveolar fricatives pattern differently where both 1 mm and 4 mm groups appear to reverse the 2-3 mm trend in opposite directions.

Overjet	COG (Hz)	SD	Skewness	Kurtosis
1 mm	4656.3	1683.9	1.4642	4.4680
2 mm	4906.8	1980.4	1.1910	1.6420
3 mm	4668.7	1938.3	1.4143	3.1932
4 mm	4164.0	1864.0	1.8540	4.4530

Table 2: Means of spectral moments across post-alveolar sibilants.

Overjet	COG (Hz)	SD	Skewness	Kurtosis
1 mm	7811.9	1430.1	0.4066	2.5897
2 mm	8250.7	1407.1	0.2918	3.0457
3 mm	7939.0	1619.0	0.4566	2.7988
4 mm	8290.6	1267.6	0.1840	6.1731

Table 3: Means of spectral moments across alveolar fricatives.

4 Discussion

Degree of overjet was compared on acoustic measures of vowels and fricatives in speakers with normal (2-3 mm) and near-normal occlusion [10]. Both the acoustics and perceptions by trained listeners conclude that phonemes were clearly contrasted. Spectral moments for /s/ have been shown to be consistently characterized by higher COG and negative skewness values, representing larger concentration of high frequencies than /ʃ/ [11]. This indicates tongue placement closer to the upper incisors. If there was no compensation present across degrees of overjet, we might expect a linear trend. The small group sample sizes limit the results generalizability, but trends in the data are not linear.

The 1 mm speakers show acoustics with more *low* frequencies than those with normal occlusion; that is, the tongue is moving *away* from an anterior place of articulation. This suggests that speakers with smaller-than-normal overjet may be compensating by pulling their tongue back to create a more typical distance from the teeth for both alveolar and post-alveolar fricatives. This converges with previous findings on articulation with malocclusion, which found tongue compensation of this type [3, 6].

Speakers with 4 mm of overjet pattern differently between places of articulation. Post-alveolar consonants show lower frequencies than speakers with normal occlusion. On the other hand, alveolar fricatives show a trend to higher frequencies, which suggests that speakers with larger-than-normal overjet only compensate by moving the tongue forward for alveolar but not post-alveolar fricatives.

These differences may be explained by the necessity of precise tongue placement for alveolar fricatives [6], which causes 1 mm speakers to move the tongue posteriorly and 4 mm speakers to move anteriorly. In contrast, the place of articulation for post-alveolar production is less dependent on the distance to the teeth, so that 4 mm speakers do not need to compensate at all. The 1 mm speakers do appear to compensate, though this may be in order to clearly differentiate between places of articulation after having adjusted for the alveolars. If this is the case, unlike alveolar fricatives, the post-alveolar compensation may be for contrastive purposes only, as opposed to compensating for articulatory constraints due to dentofacial structure.

5 Conclusion

This experiment adds quantitative acoustic data to the literature on relationships between dental anomalies and speech, as well as on the role of compensation in the case of abnormal overjet. Articulatory compensation appears to be intact in speakers with non-clinical but abnormal overjet, both perceptually and acoustically. Future work with larger sample sizes and a larger range of overjet would help determine whether these trends can be extended further.

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