A PALATOGRAPHIC, PHOTOGLOTTOGRAPHIC AND AIRFLOW STUDY OF SOME CORONAL GEMINATES IN FIGUIG BERBER

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ABSTRACT

This paper reports two experiments that investigate the articulatory and acoustic properties of the following geminate stops in Figuig Berber: aspirated [tt^{h}], and unaspirated [tt^{ˤ}] and [d̪d̪]. The first experiment examines the laryngeal adjustments in these consonants by means of photoglottography and the second experiment investigates the place of articulation by means of static palatography. Results of the first experiment show that the articulation of the three geminates is quite the same: apico-laminal at the dentialveolar region, but with [d̪d̪] tending to be rather anterodorsal. Results of the second experiment indicate that even if the difference between aspirated [tt^{h}] and unaspirated [tt^{ˤ}] and [d̪d̪] is both one of timing and of large vs. narrow glottal opening, the temporal coordination between laryngeal and oral articulations is the most important factor in the control of aspiration.

Keywords: Berber, geminates, photoglottography, static palatography, aspiration, VOT

1. INTRODUCTION

Research on the phonetics of Figuig Berber is nonexistent. There are only two published studies on this Berber variety [5, 11]. The first is a descriptive grammar and the second is a morphophonolgical study. Figuig Berber is spoken in Figuig and belongs to the Zenati branch of the Berber language family. The voiced geminates /bb, dd, dd^{ˤ}, gg, gg^{w}/, which Figuig Berber shares with other Berber varieties, are realized as voiceless both at the lexical and morphophonenic level. The consequence of this devoicing rule is the presence of three voiceless coronal geminates: devoiced unaspirated [d̪d̪] from /dd/, voiceless aspirated non pharyngealized [tt^{h}] from /tt/ and voiceless pharyngealized [tt^{ˤ}] from both / tt^{ˤ}/ and /dd^{ˤ}/.

This paper reports two experiments that purport to understand the articulatory and acoustic properties of these geminates: [tt^{h}], [tt^{ˤ}] and [d̪d̪]. In particular we would like to (a) explore their precise place of articulation ([5] considered them to be dental, but did not carry any experimentation); (b) and to investigate if the difference between aspirated and unaspirated geminates is based on timing and/or large vs. narrow glottal opening. The first experiment investigates the place of articulation of the three geminates by means of static palatography. The second experiment examines the laryngeal adjustments in these consonants by means of photoglottography.

2. METHOD

2.1. Static palatography

Palatograms and linguograms were taken by the direct method using a colored substance (a mixture of charcoal and olive oil). The imprints of the articulation on the roof of the mouth and on the tongue were recorded as a video image.

2.2. Photoglottography and airflow

Oral air flow, photoglottographic (PGG) and audio signals were recorded simultaneously on three channels of an instrumentation recorder. PGG was performed noninvasively with a photo-sensor and an LED light source. The latter was placed on the lateral neck to illuminate the laryngeal cavity [3, 12] (this technique allows us to record glottal articulation in both open and close-vowel environments together with an airflow mask.) Measurements were done manually on a computer.

2.3. Word list

One adult male speaker of Figuig[1] Berber served as subject and produced 27 words containing the target consonants in a frame sentence five times: "inna …. idʒən n merret" ("He said the word one time"). Note that for static palatography, only words in rows 1, 3 and 6 were used as these have only one coronal contact.

Table 1: List of words used in the experiments.

	[tt^h]	[d̪d̪]	[tt^ʕ]
1	itt^{h}er *"he asks for charity"*	id̪d̪ər *"he lives"*	itt^{ʕ}əs *"he sleeps"*
2	tt^{h}rid *"pancake"*	d̪d̪rin *"type of plant"*	tt^{ʕ}rin *"non-sense word"*
3	itt^{h}i *"he forgets (negative form)"*	id̪d̪i *"he grinds"*	itt^{ʕ}i *"non-sense word"*
4	irətt^{h}əʕ *"he stumbles"*	irəd̪d̪əh *"he beats"*	irətt^{ʕ}əx *"he crushes"*
5	inətt^{h}ər *"he bites"*	inəd̪d̪ər *"he moans"*	imətt^{ʕ}əl *"he buries"*
6	irətt^{h}əb *"it is stable"*	ikəd̪d̪əb "he lies"	iqətt^{ʕ}əb *"he prunes"*
7	amətt^{h}ar *"beggar"*	ibed̪d̪ar *"tumefaction "*	amətt^{ʕ}ar *"fat"*
8	att^{h}aj *"non-sense word"*	ad̪d̪aj *"below"*	att^{ʕ}as *"many"*

3. RESULTS

3.1. First experiment

Results of the first experiment show that the articulation of the three geminates is quite the same: apico-laminal at the dentialveolar region (Figs 1-2). By *apico-laminal*, we mean that both the tongue tip and blade are involved in the articulation. The central closure indicated by the palatograms is along the alveolar ridge but also covers a large area up to the upper front teeth (Fig 2). The contact extends around the rim of the tongue to cover the teeth at the sides. However, the linguogram corresponding to [d̪d̪] indicates that the area of contact is much broader than for [tt^ʕ] and [tt^h]; it extends from the tip, and goes beyond the blade to reach the anterodorsal part of the tongue (Fig 1b). Unspirated [d̪d̪] might best be described as a palatalized or anterodorsal dentialveolar.

3.2. Second experiment

3.2.1. Results from PGG and airflow

Results of the second experiment indicate that during the three geminates, PGG tokens demonstrate a single glottal opening pattern (see Fig 3). Other detailed findings are summarized in Table 2 and indicate the following:

- Aspiration noise following the consonant release is present for [tt^h], but absent for [d̪d̪] and [tt^ʕ]. Average VOT values are 73 ms, 21 ms and 17 ms, respectively.
- The glottis is more open during [tt^h] than [d̪d̪] and [tt^ʕ], as [tt^h] has highest amplitude of glottal opening. Geminates [tt^ʕ] and [d̪d̪] have identical glottal opening amplitudes and VOT durations.

Figure 1: Representative linguograms for each category of geminates: a) [tt^h], b) [d̪d̪] and c) [tt^ʕ]

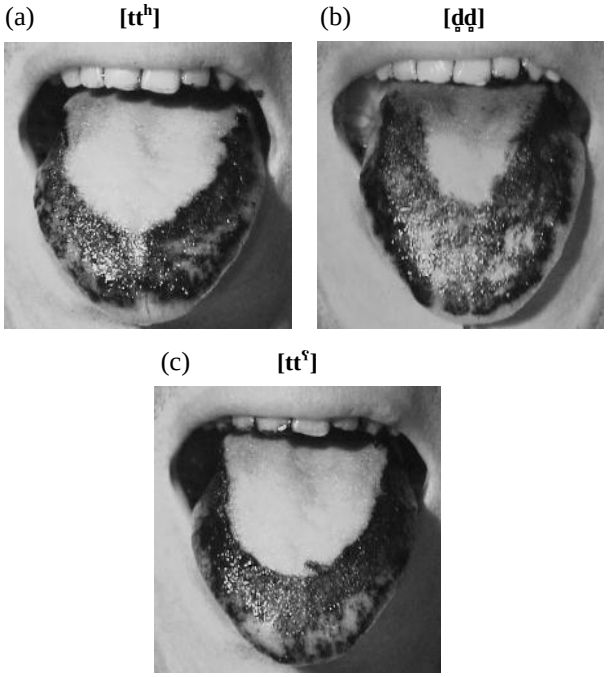
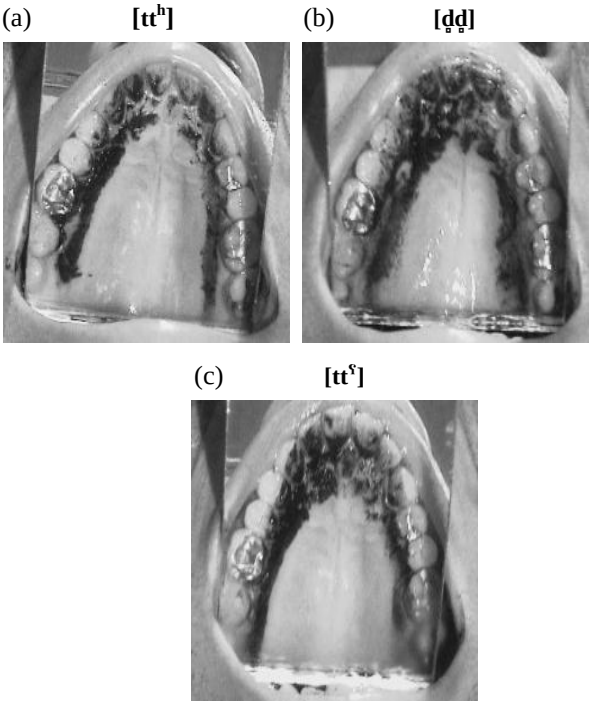


Figure 2: Representative palatograms for each category of geminates: a) [tt^h], b) [d̪d̪] and c) [tt^ʕ]



- The amplitude of glottal opening is attained around the occlusion release for [tt^h] (24 ms before the release), but is situated just after

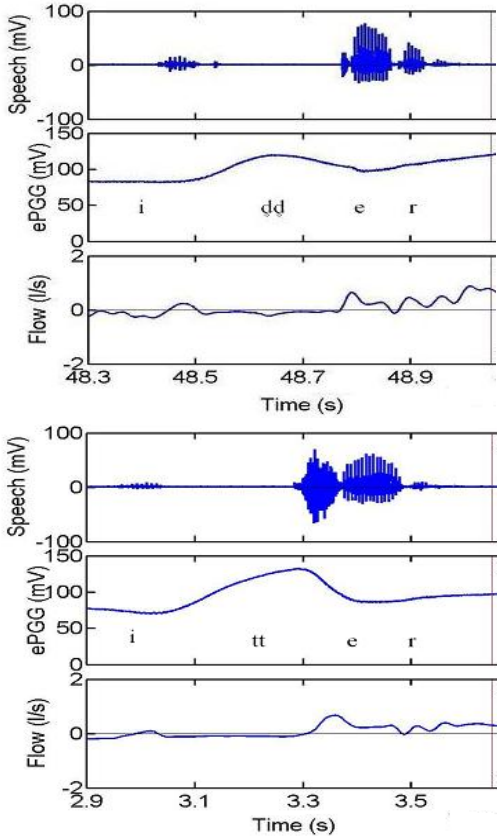
midpoint of oral occlusion for [d̪d̪] and [tt^{ʕ}] (90 and 95 ms, respectively). This finding concords with previous studies showing that aspiration in non geminates is a opening with the point of release [1, 6, 7, 8, 9]. This alignment is referred to in these studies as inter-articulator timing. For geminates, published studies on this timing show different results. In Moroccan Arabic [13] the amplitude of glottal opening is attained 34 ms before occlusion release for geminate [tt^{h}] vs 4 ms for single [t^{h}]. In Tachelhit [10], however, it is aligned 55-120 ms before occlusion release for geminate [tt^{h}] vs 0-10 ms for single [t^{h}][2].

- [tt^{h}] has the longest VOT and consonant duration but the shortest occlusion duration. This is in agreement with the inverse correlation between VOT and occlusion duration, which seems to operate across a large number of languages (for a review cf. [4]).
- The peak airflow rate of pharyngealized [tt^{ʕ}] is lower than non pharyngealized [tt^{h}] and [d̪d̪]: 0.277 l/s, 0.560 l/s, 0.544 l/s, respectively. The small value for [tt^{ʕ}] reflects a less abducted glottis. This is corroborated by fiberscopic data from Tachelhit Berber [10] and Moroccan Arabic [13] showing that the glottal aperture is relatively less wide in /t^{ʕ}/ than in /t/. It is generally known that the peak of oral air flow is correlated to the degree of glottal opening at the oral release [2]). The value of peak airflow rate during [d̪d̪] is, however, very surprising since it's as high as during [tt^{h}], even though the glottal opening at the oral release and the VOT are substantially larger during the latter compared to the former.

Table 2: Mean values of VOT, PGG, peak airflow data averaged across 5 repetitions (standard deviations in italic).

	[tt^{h}]	[d̪d̪]	[tt^{ʕ}]
Consonant Duration (in ms)	283	259	252
	25	*19*	*22*
Closure Duration (in ms)	210	238	235
	26	*18*	*19*
VOT (in ms)	73	20.6	16.7
	12	*4.6*	*8.3*
Glottal Peak location relative to	-24	-90	-95
burst onset (in ms)	*4.9*	*23*	*26*
Amplitude of Glottal opening	117	97	95
(arbitrary scale)	*36*	*25*	*24*
Peak Airflow rate in liters	0.560	0.544	0.277
per second (in l/s)	*.092*	*.100*	.077

Figure 3: PGG showing glottal opening for non-aspirated [d̪d̪] in the word [id̪d̪ər] "he lives" (top); and aspirated [tt^{h}] in [itt^{h}ər] "he asks for charity" (bottom).

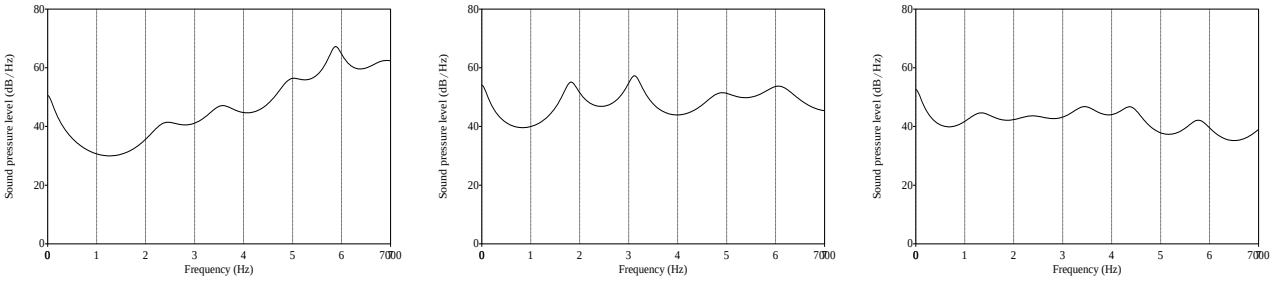


3.2.2. Spectral analysis of burst

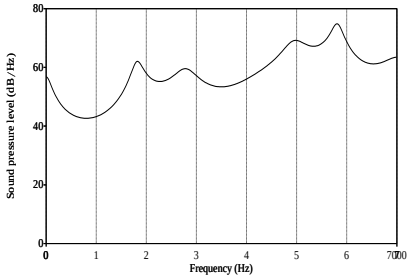
Spectra for [tt^{ʕ}] and [d̪d̪] were sampled 5 ms after the transient or release onset (using a time window of 6.4 ms) and averaged over 10 ms. For [tt^{h}] additional spectra were sampled 20 ms before the vowel. Representative spectra given in Fig 4 are very distinct: the spectrum of [d̪d̪] (Fig 4b) is dominated by the transient component and shows peaks corresponding to F2, F3 and F4, but with more prominence for F2-F3, suggesting that the noise source is near the glottis. The spectrum for [tt^{h}] after the transient shows the shape expected for denti-alveolar frication noise, with prominent peaks that correspond to F4 and higher, but little evidence of mid-frequency formant peaks (Fig 4a). The mid-frequency formant peaks, F2 and F3 begin to appear after this frication component and before the vowel, indicating aspiration noise near glottis (Fig 4d). Finally the spectrum for [tt^{ʕ}] (Fig 4c) is dominated by the transient component like [d̪d̪], but differs from [tt^{h}] and [d̪d̪] in that it appears to be rather flat: there is no dominance of neither mid- frequency nor high-frequency.

Figure 4: Representative spectra sampled after the burst transient for each category of geminates: a), d) [tt^{h}], b) [d̪d̪] and c) [tt^{ʕ}].

(a) [tt^{h}] (frication component) (b) [d̪d̪] (c) [tt^{ʕ}]



(d) [tt^{h}] (aspiration component)



4. DISCUSSION

Findings of the present study indicate that the difference between aspirated [tt^{h}] and unaspirated [d̪d̪] is articulatory indexed both by the magnitude of glottal opening and the timing of peak glottal opening with occlusion release (timing between laryngeal and oral articulations). [tt^{h}] was assumed to have a more open glottis as its amplitude of glottal opening is higher than [d̪d̪] (mean=117, s.d.=36 vs mean=97, s.d.=25, respectively). While for aspirated [tt^{h}], the peak of glottal opening occurred closely before the release (mean= -24 ms, s.d.= 5 ms), for non aspirated [d̪d̪] peak glottal opening is timed well before (mean= -90 ms, sd.= 23ms), at around midpoint of oral occlusion.

A closer look at the above means and standard deviations shows that the differences in amplitude of glottal opening are not very significant given that the standard deviation values are high. On the contrary, the differences in timing are more significant. This leads us to believe that the most important factor in the control of aspiration is timing between laryngeal and oral articulations rather than glottal opening, as suggested by many [1, 6, 7, 8, 9]. In addition, VOT is confirmed to be a robust and effective index for quantifying aspiration, and thus differentiating aspirated from unaspirated stops.

5. REFERENCES

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[1] It has been very difficult to find Figuig Berber speakers to serve as subjects. Figuig is a oasis situated in the South East edge of Morocco. The language has recently been listed in the UNESCO Atlas of the world's endangered languages.

[2] Zeroual et al. [10] use target consonants in medial position /-it^{h}i-/ vs /-itt^{h}i-/, but do not give the word list; while Ridouane et al. [11] list the six words they used for the target consonants across three positions: initial, medial and final: /t^{h}ili, tt^{h}ili, it^{h}ili, itt^{h}ili, fit^{h}, fitt^{h}/.