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An Acoustic Analysis of Affricates in Qassimi Arabic

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ABSTRACT

The aim of the paper was to analyze affricates in Qassimi Arabic, and to examine their temporal features in comparison with other related obstruents. The target sounds were /ts/, /dz/, /t/, /s/, /d/, /z/, /k/, /g/. Various measurements were made to provide a thorough acoustic analysis of target sounds: The durations of closure, the duration of the friction phase, and the duration of affricates. In addition, the duration of the preceding vowel was also measured, as it was suggested in previous cross-linguistics studies to play a crucial role in affricate. The participants were native speakers of QA, with ages ranging from 20 to 28. The results showed that QA data conform with cross-linguistic features of affricates; the duration of affricate and friction of the voiceless affricate /ts/ were longer than the voiced counterpart /dz/. The duration of closure portion of affricate also showed a difference between the voiced and voiceless affricates, where the latter was longer than the former. Further, the duration of the preceding vowel showed a compensation with the following affricate duration. In particular, the voiceless affricate, which was longer than the voiced one, had shorter preceding vowels. The study provides preliminary and interesting results of affricates in Qassimi Arabic and contributes in filling a gap of the investigation of affricates in Arabic varieties in general.

Keywords: Affricates; Qassimi Arabic; Acoustic Features

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1. Introduction

Affricates have a complex internal structure. This is because affricates are generally defined as a result of a stop followed by a fricative. Affricates are interesting in that they require a different set of measurements to reveal their internal differences. The articulatory features of affricates have an impact on their acoustic attributes. This yields the proposal of special measurements for affricates to distinguish them from both stops and fricatives [1]. Even though there have been various studies that investigate affricates' characteristics in different languages, such as Korean [2,3], Italian [4], and Catalan [5], there is a shortage of examining acoustic features of Arabic affricates.

Affricates are present in the sound inventory of various languages, both related and unrelated [1,2,5]. They begin with a closure phase, obstruction of air, followed by the release period of the friction. Affricate sounds are sounds like /tʃ/, /dz/, /dʒ/, among other affricates. These sounds are measured by a specific set of measurements to uncover their acoustic features; the measurements include the friction duration, the closure duration, the voicing of the surrounding vowels, the ratio of silence/friction, in addition to various other measurements [1,3,4]. While the acoustic affricates in various languages have been measured, Arabic varieties are still understudied. This study attempts to fill in this gap by examining the acoustic features of affricates in Qassimi Arabic, a variety spoken in Qassim, Saudi Arabia.

The paper is organized as follows. I first begin by reviewing previous related studies, followed by background information about Qassimi Arabic phonology and affricates in particular. I then lay out the method section, and then discuss the participants, stimuli and measurements. Next, the findings are reported in the results section, followed by a discussion. I end with a conclusion.

2. Literature Review

2.1. Affrication Cross-Linguistically

Maddieson was one of the first researchers who paved the way for a typological investigation of affricates [6]. He examined English, Spanish, and Italian affricates. The study was specific for palate-alveolar affricates as they are common in the three languages. The durations of the closure, the friction phrase, and the vowel preceding affricates were measured. The results showed that the affricate duration for the three languages can be ranked as follows: Spanish << English << Italian, which shows that affricate duration is language-specific. Further, it was found that vowel duration compensates for the duration of the following affricate. There was an inverse relation between the two sounds, i.e., longer affricates had shorter preceding vowels and vice versa.

As for ratios, Maddieson found that the ratio of Silence/Friction was a crucial measurement for affricates and that it could provide accurate features of affricates across languages [6]. Friction phase also differed among the three languages. English had the longest friction, followed by Italian, while the Spanish affricates were the shortest. Even though ratios between preceding vowel duration and durations of the affricate, its closure, and friction may play a role in affricate duration, Maddieson argues that the preceding vowel duration only correlates with the closure part of affricates, and that friction does not play a role in this compensation relation. He also suggests that the ratio of Closure/Friction is a crucial measurement for affricates, and it can distinguish among affricates and between affricates from different languages.

Subsequent studies of affricates reveal further details about the temporal features of affricates. Ohale suggests a universal pattern for a voicing-dependent difference in the closure duration of obstruents [1]. Thus, voiceless affricates are generally longer and they have longer closure duration than their voiced counterparts. In addition, voiceless affricates have been found to have longer closure and friction duration than voiced affricates. This has been observed in various languages, including Italian, Hungarian, and English [5]. This amounts to saying that the duration of voiceless affricates (i.e., the sum of the closure period and friction phase) is longer than the voiced ones [5]. This difference, however, is not attributed equally to closure and friction parts of affricates. It is generally assumed that only closure duration influences the duration of affricates, as Maddieson, among others, has argued.

The duration of the preceding vowel of affricates has also been an essential feature of affricates. In particular, there is a general assumption that there is a compensation relation between vowel duration and the following affricate

duration [6]. This inverse relation between preceding vowel duration and affricate duration is found with affricate closure duration, and less likely to be with affricate friction duration (see examples for Catalan and for Italian) [4,5].

However, the above generalizations were not equally observed cross-linguistically. Recasens and Esiponsa studied two dialects of Catalan, namely, Majorcan and Valencian [5]. Contrary to previous studies, they found that vowel duration compensation is not only related to affricate and closure duration but also to friction phase as well. In addition, even though they found that Valencian conforms to the universal trend of longer affricate and closure for voiceless affricates, Majorcan affricates have longer closure for voiced affricates. Moreover, the correlation between affricate duration with closure reported in previous studies was only found in Valencian, not in Majorcan. Friction period, however, in both dialects conforms to the universal trend in having longer frication for the voiceless affricates than the voiced counterparts.

2.2. Qassimi Arabic Affricates

Qassimi Arabic (QA, henceforth) is a variety spoken in the region of Qassim, Saudi Arabia. It is a subvariety of Najdi Arabic, which covers central Saudi Arabic, including Riyadh, Qassim, and Hail. The affricates in Arabic varieties are generally assumed to be a result of an affrication rule. This has been studied phonologically in various dialects, including Najdi Arabic [7], Qatari Arabic [8], and Iraqi Arabic [9], among other varieties. In particular, there is an assumption that NA affricates /ts, dz/ are derived from /k/ and /g/, respectively [7]. Generally, it is assumed that affricates like [ts] or [tʃ] are allophones of /k/. For the contemporary varieties of Arabic, it has been assumed that diachronic affrication has occurred for the /k/ and /g/ sounds that make them realized as [ts] and [dz], respectively, when mainly adjacent to front vowels [7,10].

However, various facts argue that /ts/ and /dz/ are actually phonemes. The contrast between /ts/ and /k/ is obvious. It is morphologically realized. The following data in (1) illustrate:

(1) a. a-kallim-k
I-call-you (M)
'I am calling you'
b. a – kallim-ts I-call-you (f)
'I am calling you'

The invariant phoneme for the 2nd person feminine suffix is [ts] regardless of the preceding vowel and in all environments. This is also the case in Irqai Arabic [9], Kuwaiti Arabic and Qatari Arabic and other varieties where affrication occurs [8]. Furthermore, there are cases of minimal pairs between [ts] and [k], as shown in (2).

(2) a. ka:n *tsa:n 'was' b. tsa:n *ka:n 'if, then'

b. yamlik *yamlits 'own' c. yamlits *yamlik 'engage'

3. Research Questions & Hypotheses

The aim of the paper is to tackle the following questions:

1. What are the temporal characteristics of affricates in QA?
2. What is the relation between the preceding vowel duration and the duration of the affricate and its closure and friction parts?
3. How does the preceding vowel duration differ from /ts/ and /dz/
4. How does the preceding vowel duration differ among obstruents?

The hypotheses that derive this study are based on the universal trends discussed above. This is because the studies of affricates in related languages or other Arabic varieties are scarce. The hypotheses are as follows:

Hypothesis 1: The voiceless affricate /ts/ has a longer affricate duration than the voiced affricate /dz/. Hypothesis 2: The voiceless affricate /ts/ has a longer closure duration than the voiced affricate /dz/. Hypothesis 3: The voiceless affricate /ts/ has a longer friction duration than the voiced affricate /dz/. Hypothesis 4: Voiceless obstruents have shorter preceding vowels than voiced ones.

Hypotheses 1–3 are assumed based on the facts taken from previously discussed studies and universal trends. Hypothesis 4 deserves a special comment. It is widely assumed that voiceless have shorter preceding vowels than their voiced counterparts. This hypothesis includes our specific prediction that the voiceless affricate has a shorter preceding vowel than the voiced affricate. There was no specific hypothesis for affricates because of the currently

adopted assumption that the behavior of preceding vowel duration with other obstruents will not be different than affricates.

4. Method

4.1. Stimuli

The stimuli were designed to control the target sounds in coda position in the template CVC. The target sounds were the affricates /ts/ and /dz/and their individual components /t, d, s, z/. Also, the generally assumed underlying phonemes /k/ and /g/ for the two affricates /ts/ and /dz/ respectively were included. The stimuli consisted of 8 nonsense words. C1 was always /t/ as it would not affect the duration or the characteristics of the following vowel. The vowels in the stimuli were the front (short) high vowel /i/ and the central low vowel /a/. So, the 8 nonsense words were pronounced once with /i/ and another with /a/. The coda position (C2) was for target sounds. Each word was repeated three times by each speaker. The number of tokens was 16 (8 with CiC, and 8 with CaC). The tokens with repetitions lead to a total number of the stimuli 144 utterances (16*3*3). Stimuli of words with /i/are given in **Table 1** below; the same words were used with /a/ as well.

Table 1. Stimuli of Nonsense Words with the Vowel /i/.

tik	tits
tit	tis
tig	tidz
tid	tiz

The nonsense words were recorded in isolation. Following Faluschi and Di Benedetto [4], a carrier sentence was not used to eliminate any influence from intonation or internal stress on the parameter of interest in this study. Since this study primarily examines duration, possible influences on this parameter should be avoided.

4.2. Participants

The participants of this study were 3 male native speakers of QA. They ranged from about 26 to 35 years of age. They were all born and raised in Qassimi-spoken areas of the central region of Saudi Arabia. Both of their parents were Qassimi speakers as well. None of the participants has reported any speech or hearing problems.

4.3. Procedure

The participants were given the stimuli written in Arabic. They were given time to practice and ask questions before the recordings started. Due to the lack of Arabic corresponding letters of /ts, dz/, the corresponding sounds /k,g/ were used with a star next to it (i.e., tig* or tik*). Examples of pronunciations of affricates were given in the directions of the stimuli, and the researcher observed the participants closely to ensure full understanding. None of the participants showed any confusion, however. The recordings were made by a built-in mic of MacBook Pro and were taken by the recoding of Praat in a very quiet room. The participants were asked to speak naturally and pronounce words at a comfortable rate. They were also informed that they ask questions or clarifications whenever needed.

4.4. Measurements

4.4.1. Duration

The first measurement taken in this study was duration. As mentioned in the introduction, various duration measurements are crucial for the study of affricates. Generally, four measurements are taken for affricates, which are the duration of the preceding vowel, the duration of closure, the duration of friction phase, and the duration of affricates. All the measurements were taken for affricates and other target sounds as well. In addition, duration of utterance was also taken as this would be important for ratio measurement. The following are accurate descriptions of measurements:

(1) Duration of preceding vowel: the interval from onset of an abrupt high amplitude in the waveform to sudden drop in amplitude.

(2) Duration of closure (C): the interval from offset of the vowel and onset of consonant constriction to the release observed in both the spectrogram and the waveform.

(3) Duration of the friction phase (F): the interval from the release of the consonant closure shown as high energy in the spectrogram to a clear drop of energy shown in the spectrogram and observed in the absence of clear amplitude in the waveform as well.

(4) Duration of affricate: C + F (2+3)

(5) Duration of the utterance: from the abrupt of the release of the onset /t/ in the words to the end of release (noise for stops, and friction for fricatives and affricates).

4.4.2. Ratio

Ratios of preceding vowel duration to affricates, closure, friction, and whole utterance durations have been shown to be important for the study of affricates. Accordingly, the following ratios were taken:

(1) Vowel/Closure (V/C).
(2) Vowel/Friction (V/F).
(3) Vowel/Affrication (V/Aff).
(4) Vowel/ utterance (V/UT).
(5) Closure/Friction (C/F).

5. Results

5.1. Duration

The results of the preceding vowels' duration are reported first. It was found that the preceding vowel before the voiceless affricate /ts/ is shorter than the vowel before the voiced affricate /dz/ across the two vowel conditions (i.e., /i/ and /a/).

Further, the vowel /a/ is longer than /i/ regardless of the voicing of the following affricate. **Figure 1** below shows the results of the preceding vowel duration. To examine the difference of duration between /i/ and /a/ before both affricates, an independent-samples t-test was conducted, and it was not statistically significant ($p > 0.05$). Similarly, the difference of duration between the same vowels before voiced and voiceless affricates was not statistically significant as well, i.e., /i/ before /ts/ and before /dz/, and /a/ before /ts/ and /dz/.

The durations of closure, friction and affricate were also computed for the two affricates. The results show that affricate duration (i.e., C+F) was longer in the voiceless affricate /ts/ than the voiced one /dz/. Also, friction phase duration was also longer in the voiceless affricate /ts/ than the voiced affricate /dz/. In contrast, the closure period was longer in the voiced affricate /dz/ than the voiceless affricate /ts/. These results were true across the two vowel conditions (i.e., after /i/ and /a/). An independent-samples t-test was conducted to examine the differences in duration values between /ts/ and /dz/. The differences in vowel, closure, and friction were not statistically significant ($p > 0.05$). However, the difference in affrication duration with the preceding vowel /i/ was statistically significant (p=001). Nevertheless, this was not the case for the difference with the vowel /a/, which was not statistically significant. **Table 2** provides the mean duration values of the preceding vowel /i/, affricate, closure, and friction for both /ts/ and /dz/. **Table 3** shows the same parameters with the vowel /a/. **Figures 2** and **3** also show the results of the two tables, respectively.

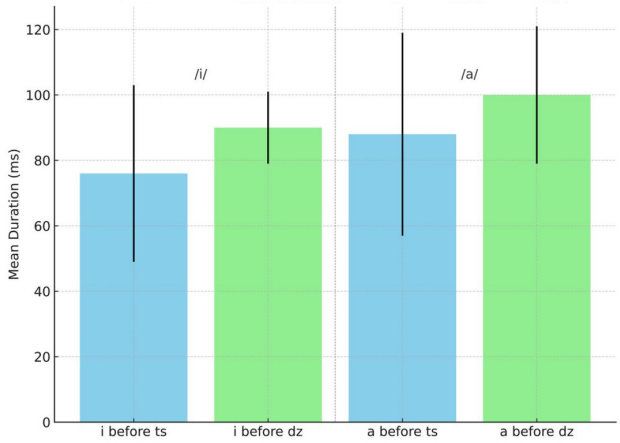

Figure 1. Preceding Vowel Duration of /i/ and /a/ Before /ts dz/.

Table 2. Mean Duration Values (in Msec) and Standard Deviations for Affricates /ts/ and /dz/ with the Preceding Vowel /i/. Means Are in Bold.

	Participant	Vowel	Affricate	Closure	Friction
	1	76	281	138	143
ts	2	52	282	124	158
	3	106	319	151	167
Mean		**78**	**294**	**138**	**156**
SD		27	22	14	12
	1	90	258	148	110
dz	2	76	242	135	107
	3	97	273	167	106
Mean		**88**	**258**	**150**	**108**
SD		11	15	16	2

Table 3. Mean Duration Values (in Msec) and Standard Deviations for Affricates /ts/ and /dz/ with the Preceding Vowel /a/. Means are in Bold.

	Participant	Vowel	Affrication	Closure	Friction
	1	83	284	154	130
ts	2	60	302	142	160

Table 3. *Cont.*

	Participant	Vowel	Affrication	Closure	Friction
	3	121	327	162	166
Means		**88**	**305**	**153**	**152**
SD		31	22	10	19
	1	103	254	183	71
dz	2	78	242	146	97
	3	119	304	198	106
Means		**100**	**267**	**176**	**91**
SD		21	33	27	18

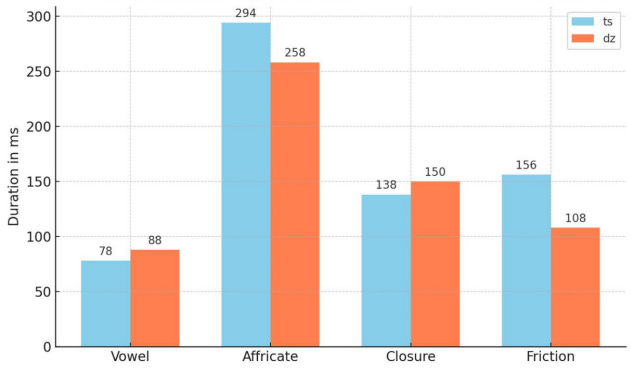

Figure 2. Mean Duration Values (in Msec) for /ts/ and /dz/ with the Preceding Vowel /i/.

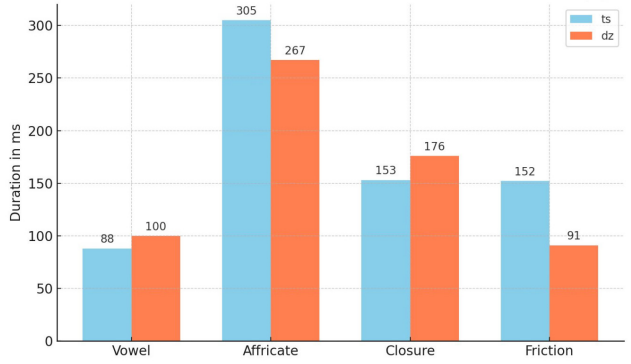

Figure 3. Mean Duration Values (in Msec) for /ts/ and /dz/ with the Preceding Vowel /a/.

5.2. Ratio

Ratio results of the vowel /i/ showed that ratios of Vowel/Closure, Vowel/Utterance, and Vowel/Affricate were almost identical for both the voiced and voiceless affricates. However, only the ratio of Vowel/Friction showed a clear difference between the voiced affricate /dz/ and the voiceless /ts/, where the former had a bigger ratio value than the latter. This is shown in **Figure 4** below. An independent-samples t-test was carried out to examine the difference of duration ratios with /i/. It was found that Vowel/Friction was statistically significant for both /ts/ (p=0.04) and /dz/ (p=0.0002). Other ratios (i.e., Vowel/Closure, V/Affrication/, and Vowel/Utterance) were not statistically significant (p>0.05) for both affricates.

Figure 4. Duration Ratio of Affricates with a Preceding Vowel /i/. V/C=Vowel/Closure, V/F= Vowel/Friction, V/UTD= Vowel/Utterance duration, and V/aff= Vowel/Affricate.

Likewise, the ratio results of the vowel /a/ showed the same ratio differences and similarities as /i/. That is, duration ratios of Vowel/Closure, Vowel/Utterance, and Vowel/Affricate were almost identical for both /dz/ and /ts/.

Contrary to the ratio results of vowel /a/ and /I/, the duration ratio of Vowel/Friction showed a clear difference; /dz/ had a double bigger ratio than /ts/. This is shown in **Figure 5** below. Here, also, an independent-samples t-test was conducted for the ratios. Similar to /i/, it showed that only the Closure/Friction ratio was statistically significant. However, unlike /i/, only the Closure/Friction ratio of /dz/ was statistically significant (p<0.05), while the same ratio was not statistically significant with /ts/ (p=0.9). Other ratios (i.e., Vowel/Closure, V/Affrication/, and Vowel/Utterance) were not statistically significant (p>0.05) for both affricates. Due to its importance, Closure/Friction ratios of both vowels are given separately in **Figure 6**.

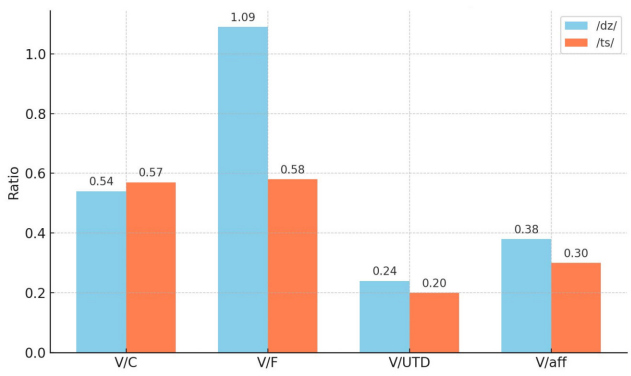

Figure 5. Duration Ratio of Affricates with a Preceding Vowel /a/.

V/C = Vowel/Closure, V/F = Vowel/Friction, V/UTD = Vowel/Utterance duration, and V/aff = Vowel/Affricate.

Contrast of voicing based on the preceding vowel duration showed that voiced obstruents had longer preceding vowels than their voiceless counterparts in both vowel conditions, i.e., /i/ and /a/, as shown in **Figure 7**. Further, the results showed that /a/ was almost always longer than /i/ across all obstruents included in this study. The only exception, however, was the voiced fricative /z/ where both /i/ and /a/ had the same mean values.

To see the compensation of duration between preceding vowels and following obstruents, the results of the duration of consonants are given in **Figure 8** below. As shown in the figure, when comparing voiced obstruents and their voiceless counterparts, voiceless obstruents were always longer than their voiced counterparts. That is, /k/ was longer than /g/, /ts/ was longer than /dz/, /t/ was longer than /d/, and /s/ was longer than /z/. In addition, obstruents were generally longer with the preceding vowel /a/ than with /i/.

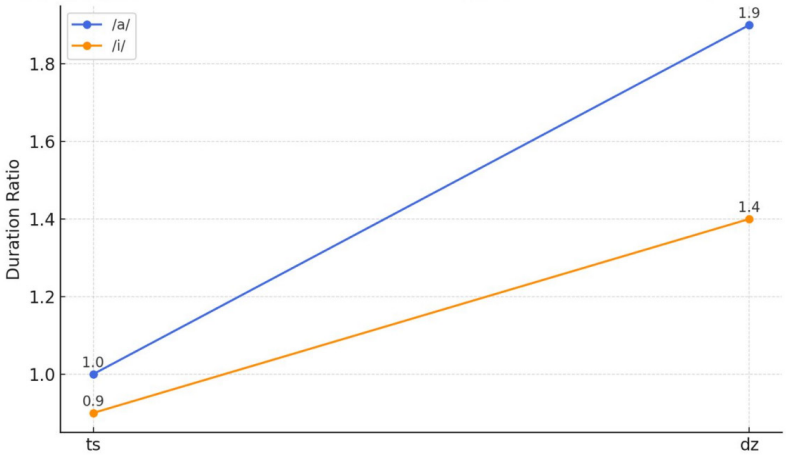

Figure 6. Duration Ratio of Closure/Friction in Preceding Vowels of /i/ and /a/.

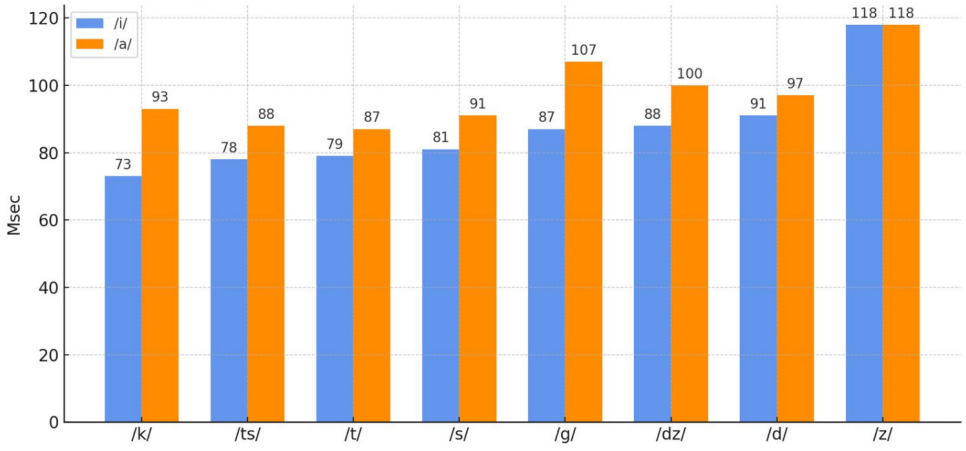

Figure 7. Mean Values of Preceding Vowels /i/ and /a/ Before Voiced vs. Voiceless Obstruents.

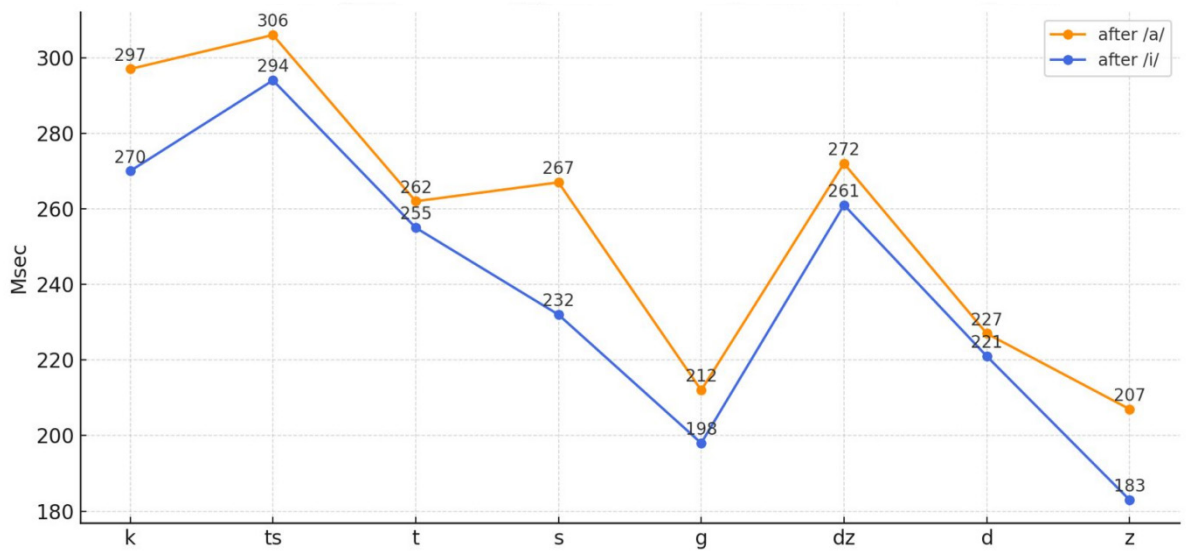

Figure 8. Consonant Duration of Obstruents.

Note: For stops, closure+post-release noise was calculated. For fricatives, the friction phase was calculated. For affricates, closure period + friction period were calculated.

6. Discussion

The preceding vowel is longer before the voiced affricate than the voiceless one. This conforms with previous studies about affricate and preceding vowel compensation relationships. Thus, hypothesis 4 was confirmed. An interesting fact, however, is that this compensation relation is not only found with affricates, but across all obstruents. That is, longer obstruents have shorter preceding vowels. As shown above, on the one hand, this amounts to saying that voiced obstruents, being always shorter in duration, have longer preceding vowels. On the other hand, voiceless obstruents are longer and have shorter preceding vowels than voiced ones. This compensation relationship of obstruents and preceding vowels conforms with a well-known fact suggested by Port and Dalby [11], among others, that the duration of the preceding vowel plays a crucial role in production and the perception of voicing contrast.

Hypothesis 1 was confirmed by the current results. The duration of voiceless affricates is longer than that of the voiced ones. QA affricates follow the universal trend found in English, Italian, Spanish and other languages. The results show that indeed the voiceless affricate /ts/ has a longer duration than the voiced affricate /dz/ in both vowel conditions (i.e., after /i/ and after /a/). In affricate duration, there is a positive correlation between friction and affricate duration, and a negative correlation with the closure period. That means longer friction indicates longer affricate. Accordingly, the preceding vowel duration is negatively correlated with the duration of friction and positively correlated with the closure period.

Observing closure phase and friction phase, the voiceless affricate /ts/ has longer friction. This confirms hypothesis 3 that voiceless affricates have longer friction than their voiced counterparts. However, the voiceless affricate /ts/ has shorter closure than the voiced affricate /dz/. Thus, hypothesis 2 was refuted. Further discussion is below.

The above finding is interesting in different respects. Although it conforms with the universal trend of the inverse relation between the duration of the preceding vowel and affricate duration, it is against what Maddieson suggested that longer closure of affricates attributes to shorter preceding vowel [6]. Obviously, we have seen from the results of this study that the friction phase contributes to the duration of the affricate. That is, /ts/ has a longer friction, and longer affricate duration than /dz/. The latter has a longer closure, but the affricate duration is shorter than /ts/. Accordingly, the relation of compensation between preceding vowel duration and affricate duration in QA is reflected with friction phase duration. That is, the inverse relation found in Maddieson and other studies between preceding

vowel duration and closure duration was confirmed here.

QA data show that the compensation is with affricate duration and friction duration but not with closure duration. This has also been found in the two Catalan dialects studied by Recasens and Espinosa [5]. They state that "Results show a trend for a vowel duration to compensate not only for affricate and closure duration (as repeated in previous studies) but for the duration of friction phase as well. P.169". It is this friction phase compensation that is found here in QA as well. Nonetheless, the results of this study contrast with Recasens and Espinosa's study in that there was no compensation found with closure period duration [5].

Ratio results also show interesting patterns. The Vowel/Friction ratio is larger with the voiced affricate /dz/ than /ts/. This is because, as seen above, voiced affricates have longer preceding vowels and shorter friction durations. Other ratios did not differ significantly between the voiced and voiceless affricates. The ratio of Closure/Friction also shows an interesting difference between the voiced and voiceless affricates. As Maddieson suggested, this ratio would provide a clearer distinction between affricates as shown here as well. The Closure/Friction ratio of the voiced affricate /dz/ was significantly larger than the voiceless affricate /ts/. This is because, as seen from the results above, the voiced affricate has longer closure and shorter friction. The opposite is also true for the voiceless affricate /ts/. The ratio of closure to friction was, thus, clearly larger for the voiced affricate.

7. Conclusions

The study examined temporal features of affricates in QA and highlighted the current results with the cross-linguistic properties of affricates. By studying the voiced affricate /dz/ and the voiceless affricate /ts/, various findings are reported. Conforming to universal trends of affricates, it was found that the voiceless affricate /ts/ is longer than the voiced affricate /dz/. Furthermore, it was found that the voiceless affricate /ts/ has a longer friction phase than the voiced affricate /dz/. In addition, the duration of the preceding vowel is shorter before the voiceless affricate than of the voiced one. These findings parallel the results found in different languages, such as Italian and Spanish, as discussed in the preceding paragraphs.

The results of the closure period duration do not conform with findings from previous studies. Contrary to the general assumption, the voiced affricate has a longer closure period than the voiceless affricate. This was also found in Majorcan [5], which shows that QA is not unique in this respect.

The results from this study shed light on the universality of some properties of affricates. It was found that voiceless affricates are longer than voiced affricates. This is not, though, special to affricates but across obstruents in general. In addition, the friction phase of affricates is longer in voiceless affricates than in voiced ones whereas closure period of affricates seems to be language-specific. Ohale's assumption of universal longer closure for voiceless affricates is challenged by the current findings [1]. This comes from the data of this study and from the Catalan dialect of Majorcan.

The results of this study, however, should be taken with caution. The limited number of participants might have affected the observed patterns. Further measurements of affricates should also reveal further details. The formants of preceding vowels, rise time of affricates and fricatives, and F0 measurements would provide more information about the characteristics of the affricates in QA, and Najdi varieties in general. The researcher leaves these for future work.

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Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

Data can be given upon a reasonable request.

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Conflicts of Interest

The author declares no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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