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Acoustic Differences between Dental and Alveolar Stops of Urdu

Abstract: *The differences between dental and alveolar stops of Urdu not only lie in their bursts but also in their formant transitions. This paper lists these acoustic differences and also presents the reasons for these differences.*

Keywords: *Stop, Dental, Alveolar, Burst, Formants*

1. INTRODUCTION

Urdu is a language of many a thousands of people around the globe. It is a blend of different languages e.g. Persian, Arabic etc, that is why it has a rich phonemic and phonetic inventory. Unfortunately, there is no serious research done on this language due to which the behavior and speech pattern of lots of its speech sounds are almost unknown or undocumented. One example of such cases is the dental stop.

Since the dental sounds are not present in most of the widely researched languages of the world e.g. English, so their exact acoustic pattern is not known. However, the place of the articulation of dental and alveolar stops is near to each other so at times dental and alveolar formant transitions seem to be identical. But certainly, there are differences between both of them.

This paper will specifically pin point the differences of Urdu dental and alveolar stops in different vowel contexts.

2. LITERATURE REVIEW

The speech pattern of any sound is highly dependent on the place of its articulation. In fact, the place of articulation causes change in the shape of vocal tract, so as expected many of the acoustic contrasts between the places of articulation can be seen in the difference of the formant patterns. Strictly speaking, F1 transition can be a cue to determine manner of production and the F2 and F3 transitions may provide cues for determining the place of articulation (Kent and Read, 1992).

Unfortunately, the literature for the problem at hand is unavailable because it is perhaps not documented to date. However information about English alveolar stops is available in the phonetics literature. So this section will mainly focus on the information about English alveolar stops.

The research about perception has demonstrated that the release burst of stops and early transition of the vowel contains the crucial hints for determining the place of articulation of these stops. Therefore, here we will discuss both the burst and formant transitions of English alveolar stops.

2.1 Stops

The stops are produced by complete closure of the vocal tract. During the closure of the vocal tract, there is complete silence or only a weak or low frequency sound. When the closure of the stop consonant is released to form a following vowel, a burst like sound occurs during the release. In other words, stop consonants have a silent interval (or approximately silent), followed up by a release burst of sound (Clark and Yallop, 1992).

A constant feature of stop articulation is that the transition from consonant to vowel or vice versa is about 50 ms in duration. All the formant frequencies shift from their values for stop to the values of vowel within these 50 ms (Kent and Read, 1992).

2.2 Dental and Alveolar Stops

Dental stops are produced by making a constriction against the dental area (teeth) of the oral tract, whereas alveolar stops are produced by making a constriction against the alveolar ridge in the oral cavity (Pickett, 1999). Both places of articulation are quite near to each other so sounds produced by them are not easily distinguishable.

2.3 Alveolar Burst

Alveolar stops have a strong burst. The energy level of the burst gets stronger and stronger from and above approximately 2000 Hz. In other words, the burst peaks are diffused and stronger in the higher frequencies of the alveolar stops.

The release of stops from different places of consonant constrictions causes spectral differences. The production factors leading to these spectral differences have been described. One of these factors is the size and the shape of the oral cavity in front of the turbulence noise of the mouth pressure. In the case of alveolar stops [t] and [d], the front cavity is small which behaves as a high pass filter i.e. transmitting more turbulence energy in high frequencies. That is why, the burst peaks of alveolar stops are of high amplitude in high frequencies (Pickett, 1999).

2.4 Formant Transitions

When the vowels follow alveolar stops, the formant transitions of the vowels are as follows (Stevens, 1998).

For back vowels

- The opening F2 transition is downward.
- F3 more or less parallel with F2.
- The bursts are stronger in energy at F2.

For Front Vowels

- The opening F2 transition is upward.

? The bursts are stronger in energy at F2.

2.5 Known Results for English

In 1985, Jongman and Blumstein conducted a comparative study of dental and alveolar stops of English language. According to them, burst amplitude is an important characteristic of burst for stop identification. They also proposed that the dental stop burst is diffused and flat or falling contrary to the alveolar stop burst which is rising (Kent and Read, 1992).

3. PROBLEM STATEMENT

What are the exact acoustic differences between dental and alveolar stops of Urdu that make native speakers of Urdu perceive two sounds as distinct speech sounds in different vowel contexts?

4. METHODOLOGY

An empirical study was conducted to determine the difference between dental and alveolar stops formant transitions. The opted methodology is as follows.

4.1 Selection of Words

For the experiment, two contexts were selected in which stops could have appeared

? CV (*C*onsonant *V*owel) Context
? VC (*V*owel *C*onsonant) Context

Then the consonants and vowels were chosen to fill these contexts. In order to make the analysis simple and more effective, unvoiced un-aspirated dental and alveolar stops (i.e.ʔʔ ʔ) were selected. The selected vowels were /ʔ/, /ʔ/, /ʔ/, /ʔ/. Keeping all these things in mind, the words were selected from the Urdu dictionary for recordings (refer appendix).

4.2 Recordings and Speaker Selection Process

Six native Urdu speakers were selected for the recording of the selected 16 words. Each of the 16 words was recorded 5 times from each speaker in a noise free environment. It was ensured that the speakers speak these words in a natural manner without any deliberate manipulation. So in this way, 480 words were analyzed. Three of the speakers were male and the other three were female. The age of all the speakers ranged from 20-22 years. The recorded sounds were analyzed using the softwares 'WinSnoori 1.3" and "Praat 3.9.35".

4.3 Collection of Data

For each word; following values were recorded

? Frequencies of the first three peaks in the spectrum of the burst of the stop.
? For CV context, the F1, F2, F3 of the vowels in the start and middle of the vowel were recorded.
? For VC context, the F1, F2, F3 of the vowels in the middle and end of the vowel were recorded.

The collected data was used for determining the difference between the two places of articulation. Standard statistical methods such as average, standard deviation were then applied to the collected data for further analysis of the problem.

5. RESULTS

The study yielded the following differences between the two sounds i.e. dental stop and alveolar stop. Common features of both the sounds are not presented in this section.

5.1 Differences in CV context

5.1.1 High Front Vowel /ʔ/

Burst:

? For both male and female speakers, the first peak of the burst in the case of dental stop is nearly at 900 Hz as compared to the first peak of alveolar stop, which is approximately at 500 Hz.
? The third peak of the burst in dental stop, for male speakers, is approximately at 3000 Hz (3100 Hz for female speakers) as compared to alveolar stop, where third peak of the burst is approximately at 2800 Hz (2900 Hz for female speakers).

Formant Transitions:

According to the results obtained from the analysis of data, difference cannot be generalized according to the gender of the speaker. For male speakers, no significant difference is found in the formant transition of /i/ when it followed the dental or alveolar stop. Table 1 lists the values of formants for male speakers. However, for female speakers, the value of F3 of alveolar stop is quite high in the start and middle of the vowel than that of the dental stop. Table 2 gives the exact values of the formants in this case.

Table 1 Formant values for Male Speakers

	Formant	ʔʔ	ʔ
Start	F1	300	300
	F2	2275	2350
	F3	2850	2850
Middle	F1	300	300
	F2	2525	2525
	F3	3075	3100

Table 2 Formant values for Female Speakers

	Formant	ʔʔ	ʔ
Start	F1	300	300
	F2	2500	2550
	F3	3000	3125
Middle	F1	300	300
	F2	2750	2825
	F3	3350	3550

5.1.2 Low Front Vowel /ʔ/

Burst:

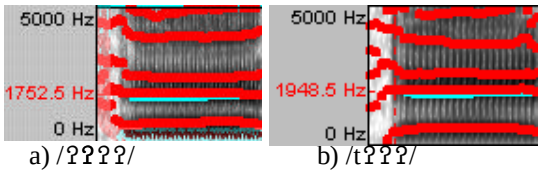
? The first peak of the burst in the case of dental stop, for male speakers, is approximately at 800 Hz (700 Hz for female speakers) as compared to the first peak of the alveolar stop, which is at 550 Hz approximately (600 Hz for female speakers).

Formant Transitions:

? The difference of F2 of the vowel /ʔ/ in the context of dental and alveolar stop is nearly 200 Hz (both at the start of the vowel and in the middle). Figure 1 shows the difference. Refer to the Table 1 for exact values of formants.

Table 3 Values of F2 (Hz) for Vowel /ʔ/.

	ʔʔ	ʔ
Male	1800	2000
Female	2100	2300



a) /ʔʔʔʔ/ b) /tʔʔʔ/

Figure 1 Partial diagram of spectrogram for /ʔʔʔʔ/ and /tʔʔʔ/

4.1.3 High Back Vowel /ʔ/

Burst:

? The first peak of the burst in the case of dental stop, for male speakers, is approximately at 850 Hz (700 Hz for female speakers) as compared to the first peak of alveolar stop, which is at 550 Hz approximately (600 Hz for female speakers).

? The second peak of the burst in dental stop, for male speakers, is approximately at 1750 Hz (1650 Hz for female speakers) as compared to alveolar stop, who has its second peak at 1550 Hz approximately (1400 Hz for female speakers).

Formant Transitions:

According to the results obtained from the analysis of data, difference cannot be generalized according to the gender of the speaker. For male speakers, the value of F3 in the start of the vowel is higher for the dental stops than for the alveolar stops. Table 4 lists the values of formants for male speakers. However, for female speakers, the value of F2 of alveolar stops is higher in the start and middle of the vowel as compared to that of dental stop. Table 5 gives the exact values of the formants in this case.

Table 4 Formant values for Male Speakers

	Formant	ʔʔ	ʔ
Start	F1	300	300
	F2	1275	1300
	F3	2625	2450
Middle	F1	300	300
	F2	825	825
	F3	2525	2475

Table 5 Formant values for Female Speakers

	Formant	ʔʔ	ʔ
Start	F1	350	350
	F2	1325	1450
	F3	2775	2700
Middle	F1	350	350
	F2	775	750
	F3	2850	2800

5.1.4 Low Back Vowel /ʔ/

Burst:

? The first peak of the burst in case of dental stop, for male speakers, is approximately at 750 Hz (800 Hz for female speakers) as compared to the first peak of alveolar stop, which is approximately at 550 Hz (700 Hz for female speakers).

? The second peak of the burst in dental stop, for male speakers, is approximately at 1650 Hz (1800 Hz for female speakers) as compared to the second peak of alveolar stop, which is at approximately at 1800 Hz (1950 Hz for female speakers).

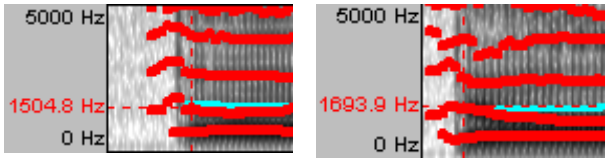
Formant Transitions:

? The difference of starting F2 of the vowel /ʔ/ in context to dental and alveolar stop is nearly 200 Hz. Table 2 lists the approximate values of F2 in this case.

Table 6 Starting F2 (Hz) Values for two consonants

	ʔʔ	t
Male	1500	1700
Female	1600	1800

? F2 falls smoothly from the start to the middle of the vowel in the case of dental stops whereas this fall is quite sharp and more prominent in alveolar stops. The spectrogram of Figure 2. roughly shows this fall.



a) /ʔʔ/ b) /tʔ/

Figure 2 Partial Spectrograms for /ʔʔ/ and /tʔ/

5.2 Differences in VC Context

5.2.1 High Front Vowel /ʔ/

Burst:

In VC context, for the vowel /ʔ/, no significant difference was found between the burst spectrum of dental and alveolar stops for male speakers. Table 7 lists the values of the peaks for male speakers. However for female speakers, the third peak of the burst of the alveolar stop is high as compared to the dental stop. Table 8 lists the values of burst peaks for female speakers.

Table 7 Formant values for Male Speakers

	ʔʔ	ʔ
First Peak	775	700
Second Peak	1900	1900
Third Peak	2975	2925

Table 8 Formant values for Female Speakers

	ʔʔ	ʔ
First Peak	800	775
Second Peak	2100	2125
Third Peak	3125	3400

Formant Transitions:

? From the middle of the vowel to the end, F2 falls more in the case of the dental stop (approximately

250 Hz) as compared to the F2 fall of alveolar stop (approximately 100 Hz).

5.2.2 Low Front Vowel /ʔ/

Burst:

In this case, no significant difference is found in the bursts of both stops for the female speakers. However for male speakers, the second peak of the burst of alveolar stop is higher than that of the dental stop. Table 9 lists the values for male speakers.

Table 9 Formant values for Male Speakers

	ʔʔ	ʔ
First Peak	725	725
Second Peak	1650	1875
Third Peak	2750	2800

Table 10 Formant values for Female Speakers

	ʔʔ	ʔ
First Peak	800	775
Second Peak	2050	2050
Third Peak	3125	3150

Formant Transitions:

- F2 of the vowel /ʔ/ falls or remains straight in case of dental stops whereas in case of alveolar stop, F2 falls from the middle towards the end of the vowel /ʔ/ (approximately 150Hz-200Hz).

5.2.3 High Back Vowel /ʔ/

Burst:

For this vowel context, the differences between dental and alveolar stops vary according to the gender of the speaker. Hence collected data cannot generalize the differences for both genders. For male speakers, the third peak of the burst for dental stops is at a higher frequency than of the alveolar stop. Table 11 lists all the values for male speakers. For female speakers, the second peak of the alveolar stop is at a higher frequency values than that of the dental stops. Table 12 shows the exact values for this case.

Table 11 Formant values for Male Speakers

	ʔʔ	ʔ
First Peak	775	700
Second Peak	1725	1725
Third Peak	2950	2436

Table 12 Formant values for Female Speakers

	ʔʔ	ʔ
First Peak	725	700
Second Peak	1800	1925
Third Peak	2875	2925

Formant Transitions:

- When the vowel /ʔ/ is followed by a dental stop, F2 in the middle of the vowel is relatively high (1100 Hz for male, 1200 for female) as compared to the F2 in the middle of the vowel /ʔ/ when it is followed by an alveolar stop (850 Hz for male, 750 Hz for female).
- In the case of both dental and alveolar stops, F2 rises from the middle of the vowel to the end of the vowel. However, this rise is less in dental stop (100 Hz) as compared to the alveolar stop where it rises approximately 200 Hz.
- F3 of the vowel /ʔ/ rises from the middle to the end of the vowel in dental stop but it decreases in case of alveolar stop.

5.2.4 Low Back Vowel /ʔ/

Burst:

- The first peak of the burst in case of dental stop, for male speakers, is approximately 800 Hz (850 Hz for female speakers) as compared to the first peak of alveolar stop, which is at 550 Hz approximately (700 Hz for female speakers).
- The second peak of the burst in dental stop, for male speakers, is approximately at 1900 Hz (2100 Hz for female speakers) as compared to the burst of alveolar stop, which is at 1750 Hz approximately (1900 Hz for female speakers).

Formant Transitions:

- There is a slight rise in F2 from the middle of the vowel /ʔ/ to its end (approx. 200 Hz for male, 300 Hz for female) but in the alveolar stop, this rise is more prominent (approx. 450 Hz for both male and female speakers).
- F3 does not change from the middle to the end of the vowel /ʔ/ for the dental stop i.e. more or less remains straight. But in the case of alveolar stop, F3 falls drastically from middle to the end of vowel /ʔ/. This fall is about 450 Hz for male speakers and 500 Hz for female speakers.

6. DISCUSSION

The results have shown the acoustic differences between dental and alveolar stops. These differences vary from vowel to vowel context. So according to the collected statistics, one cannot categorize these differences according to any vowel category such as Front, Back, High, and Low etc.

One common difference in CV context was that the first peak of the burst of the dental stop was at high frequency as compared to that of the alveolar stop. The one possible reason is that in alveolar stops, the constriction with the alveolar ridge is more as compared to the dental constriction of dental stops. And the amount of constriction is inversely proportional to F1 (in this case, first peak of the burst) (Pickett, 1999). So that may be the reason of low frequency of first peak in the burst of alveolar stops.

As described in literature review section that in English the dental stops have diffused spectrum having flat/falling trend and alveolar stops have diffused spectrum with rising trend, our results agree with this point for Urdu as well. But a final conclusion cannot be drawn because amplitude of the peaks was not recorded during the data collection phase for this study. However, by looking at the general trends of the spectrum of the burst, we are compelled to say that the amplitude can be one of the keys for determining the difference between the dental and alveolar stops of Urdu.

In some cases, the formant transitions are the key factors to determine the particular stop. For example, in VC context, when the stop consonant is at syllable boundary, the burst of the stop is not present in the spectrogram, however, the listener can still differentiate between the two stops. It means that in certain cases formant transitions alone can be a cue for stop identification. If there is no difference in the formant transitions of the vowels then the difference can be found in the bursts of the stops.

The results of this paper relates to the four corner vowels of Urdu i.e. /ʔ/, /ʔ/, /ʔ/, /ʔ/. However, these results can be extended to determine the differences between alveolar and dental stops in some other vowel contexts. In short vowels /ʔ/, /ʔ/, /ʔ/, we think that similar differences will prevail. As shortening of the vowel does not affect the release of burst, so the burst spectrum of both the stops will remain same. However, we cannot establish any solid opinion about the formant transitions (upwards or downwards) in case of short vowels.

For long middle vowels, these collected statistics are not sufficient to predict any differences. For vowel /ʔ/ context, the differences between dental and alveolar stops will be a mixture of differences in vowel /ʔ/ and /ʔ/ context because the vowel /ʔ/ is in middle of /ʔ/ and /ʔ/. For other rounded vowels /ʔ/, /ʔ/, they may exhibit mixed differences of vowel /ʔ/, /ʔ/.

For this paper, the selected consonant were /ʔʔʔ/ which are unvoiced. The differences for their voiced counterparts /ʔʔʔ/ will be similar.

7. CONCLUSION

The study has shown some of the differences between two classes of stops i.e. dental and alveolar. These differences lie in the burst of both the stops and also in the formant transitions of the preceding or following vowels. The study also validates the prior assumption that states that amplitude can also be a key factor for identification of dental and alveolar stops.

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APPENDIX

Table 1 Words Selected for recording

	CV context		VC context	
Vowel	Dental	Alveolar	Dental	Alveolar
ʔ	ʔʔʔ	ʔʔʔ	ʔʔʔʔ	ʔʔʔ
ʔ	ʔʔʔa	ʔʔʔʔ	ʔʔʔʔ	ʔʔʔ
ʔʔʔ	ʔʔʔ	ʔʔʔ	ʔʔʔʔ	ʔʔʔ
ʔ	ʔʔʔʔ	ʔʔʔ	ʔʔʔ	ʔʔʔ