

## Article

# Fundamental Frequency and Phonation Differences in the Production of Stop Laryngeal Contrasts of Endangered Shina

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**Abstract:** Shina is an endangered Indo-Aryan (Dardic) language spoken in Gilgit, Northern Pakistan. The present study investigates the acoustic correlates of Shina's three-way stop laryngeal contrast across five places of articulation. A wide range of acoustic correlates were measured including fundamental frequency (F0), spectral tilt (H1\*-H2\*, H1\*-A1\*, H1\*-A2\*, and H1\*-A3\*), and cepstral peak prominence (CPP). Voiceless aspirated stops were characterized by higher fundamental frequency, spectral tilt, and cepstral peak prominence, compared to voiceless unaspirated and voiced unaspirated stops. These results suggest that Shina is among those languages which have a raising effect of aspiration on the pitch and spectral tilt onsets of the following vowels. Positive correlations among fundamental frequency, spectral tilt, and cepstral peak prominence were observed. The findings of this study will contribute to the phonetic documentation of endangered Dardic languages.



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**Keywords:** F0; spectral tilt; Shina; acoustics; phonation; Dardic; typology

## 1. Introduction

Shina is an endangered Indo-Aryan (Dardic) language spoken in Gilgit, Northern Pakistan. There is a three-way laryngeal contrast in Shina stops (e.g., voiceless unaspirated /p/, voiceless aspirated /p<sup>h</sup>/, and voiced unaspirated /b/) at five places of articulation (bilabial, dental, retroflex, palatal, and velar; Hussain 2018; Radloff 1999). From a typological perspective, voiceless aspirated stops have been described to have either a raising effect on fundamental frequency (F0) and spectral tilt or a lowering effect (see below). A wide range of studies have been conducted on the grammatical, phonological, and sociolinguistic aspects of Dardic languages (Backstrom and Radloff 1992; Cacopardo and Cacopardo 2001; Liljegen 2017). However, Shina still lacks a detailed phonetic description. The current study investigates F0, spectral tilt (H1\*-H2\*, H1\*-A1\*, H1\*-A2\*, and H1\*-A3\*), and cepstral peak prominence (CPP) of the rich laryngeal and place contrasts of Shina. In particular, I investigate whether aspirated stops have a raising effect on F0 and spectral tilt onsets. Moreover, relationships among all the acoustic measures are explored using correlations.

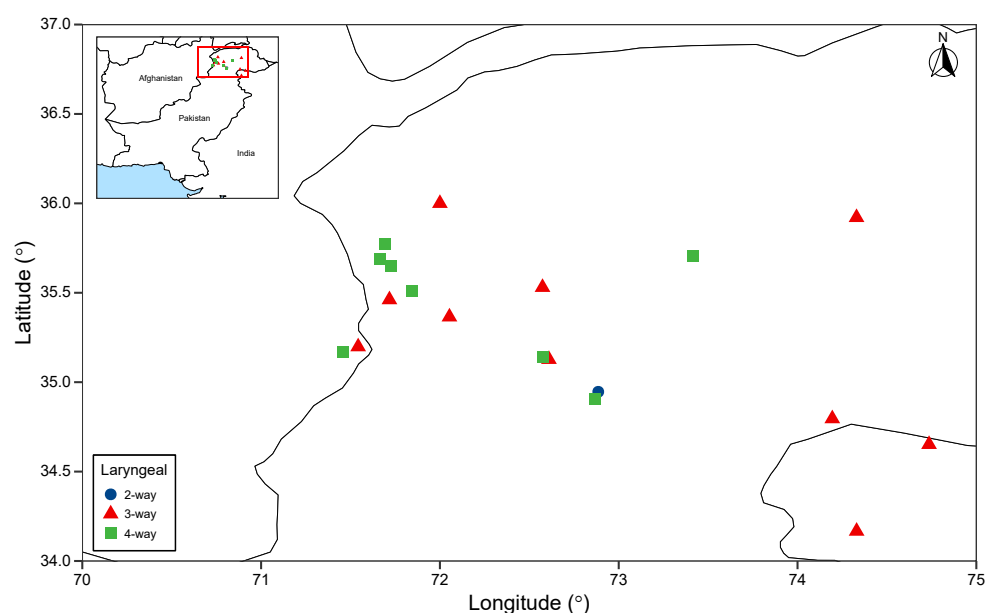
The paper is organized as follows. Section 1.1 presents a brief typological survey of the laryngeal contrasts found in Dardic languages. Section 1.2 discusses the acoustic correlates of laryngeal and place contrasts. Section 2 outlines the methods and procedures used in the current study. The main findings are presented in Section 3. In the end, Section 4 summarizes the results and highlights the implications for the general literature on laryngeal typology, tonogenesis, and phonationgenesis.

### 1.1. Typology of Laryngeal Contrasts in Dardic Languages

The term *Dardic* is generally used to refer to a group of Indo-Aryan languages spoken in the Northwestern regions of South Asia (spanning the border areas of Afghanistan, Pakistan, and India, including both the Pakistani- and Indian-administered areas of the

Kashmir region; Figure 1). There is an ongoing debate whether Dardic should be considered as a sub-family of Indo-Aryan or Nuristani languages (Morgenstierne 1932; Strand 1973). However, recent studies associate Dardic with Indo-Aryan languages (Bashir 2003; Liljegren and Akhunzada 2017; Strand 2001b). Dardic languages are characterized by two-way, three-way, or four-way laryngeal contrasts. Figure 1 presents geographical distribution of Dardic languages and the number of laryngeal contrasts in each language. Bateri is the only Dardic language which contrasts two laryngeal categories (e.g., voiceless unaspirated /p/ and voiced unaspirated /b/; Strand 2001a).<sup>1</sup> Three laryngeal categories (voiceless unaspirated /p/, voiceless aspirated /p<sup>h</sup>/, and voiced unaspirated /b/) can be found in Dameli (Morgenstierne 1942; Perder 2013), Gawarwati (Bashir 2003), Kalam Kohistani (also called Garwi, Gawri, or Bashkarik; Baart 1999; Morgenstierne 1940), Kashmiri (Wali and Koul 1997),<sup>2</sup> Kalkoti (Liljegren 2013), Khowar (Liljegren and Khan 2017), Kundal Shahi (Rehman and Baart 2005), Shina (Radloff 1999), and Ushojo (Decker 1992). Dardic languages which have a four-way laryngeal contrast (voiceless unaspirated /p/, voiceless aspirated /p<sup>h</sup>/, voiced unaspirated /b/, and voiced aspirated /b<sup>h</sup>/) include Indus Kohistani (Bashir 2003), Kalasha (Bumburate, Birir, and Rumbur dialects; Hussain and Mielke 2020; Kochetov et al. 2020), Palula (Liljegren and Haider 2009; author's own fieldwork), Sawi, and Torwali (Bashir 2003).

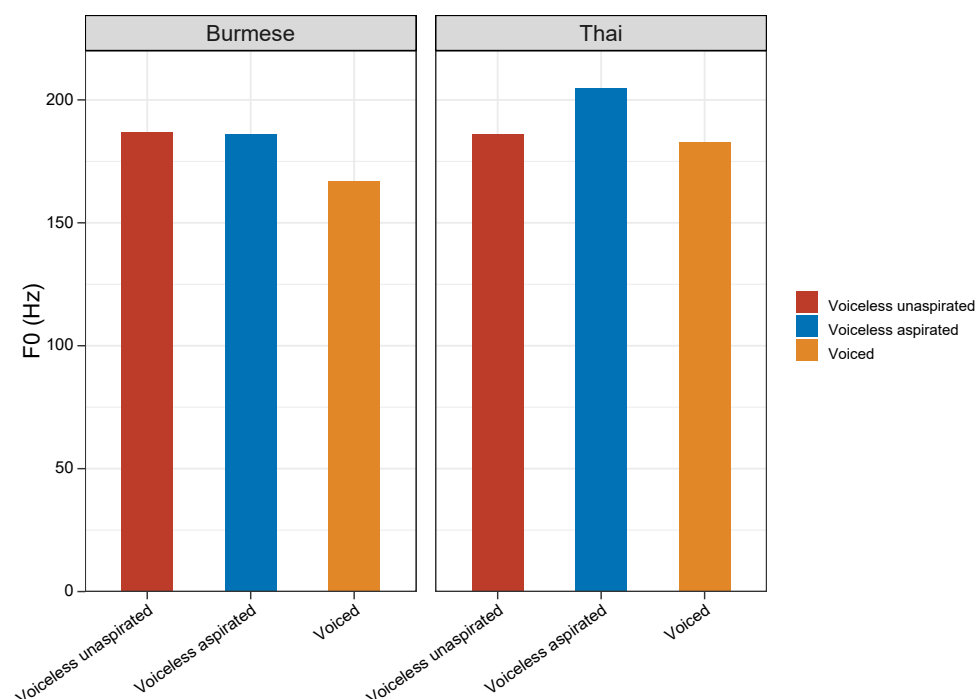
The status of voiced aspirates is still controversial in many of the above-mentioned Dardic languages (Bashir 2003). Morgenstierne (1932) noted that aspiration is preserved in voiced stops of Palula but only in word-initial position (confirmed by the current author's own fieldwork as well). However, in word-medial and word-final positions, voiced aspirates are characterized by little or no clear aspiration interval. Language contact might be one of the factors contributing to this sound change. Indus Kohistani, Kalasha, Palula, Sawi, and Torwali are surrounded by languages which have two-way (Eastern Khataviri and Pashto) or three-way (Gujari, Khowar, and Pashai) laryngeal contrasts. A high level of bilingualism is also prevalent in the Northwestern regions where speakers are fluent in at least two languages of the area. Thus, it appears that at some point, Dardic languages may completely lose the aspiration contrast in voiced stops, either due to language contact or internal sound change. Detailed acoustic-phonetic studies are needed to confirm the number of laryngeal contrasts found in Dardic languages.



**Figure 1.** Map of Northwestern region of South Asia where Dardic languages are spoken. Number of laryngeal contrasts (2-, 3-, or 4-way) found in Dardic languages are shown.

### 1.2. Acoustic Correlates of Laryngeal Contrasts

In the current phonetic literature, a number of acoustic measures have been used to investigate the laryngeal contrasts. Fundamental frequency (F0) of the following vowel onsets has been extensively used to examine the laryngeal contrasts (Chen 2011; Hombert et al. 1979; House and Fairbanks 1953; Kirby and Ladd 2016; Ladd and Schmid 2018; Lee et al. 2019). Voiced stops generally exhibit lower F0 onsets than voiceless stops (Hombert et al. 1979; Schertz and Khan 2020). Shimizu (1989) conducted a cross-linguistic study and noted that voiced stops of Japanese, Burmese, Thai, and Hindi are characterized by lower F0 onsets than voiceless stops. These patterns can be observed in Figure 2 which presents the F0 onsets of the three laryngeal categories of Burmese and Thai.<sup>3</sup> Some studies have also observed the effect of aspiration on F0 onsets but there appears to be inconsistency in the reported results. Voiceless unaspirated stops of Burushaski (Hussain 2021), Cantonese, Mandarin (Luo et al. 2016), Kalasha (Hussain and Mielke 2020), Marathi (Dmitrieva and Dutta 2020), and Shanghai Chinese (Chen 2011) showed higher F0 onsets than voiceless aspirated stops. In contrast, voiceless unaspirated stops of Chru (Brunelle et al. 2020), Madurese (Misnadin 2016), and Thai (Shimizu 1989) entailed lower F0 onsets than voiceless aspirated stops. Dzongkha's voiceless unaspirated and aspirated categories showed high F0 onsets, indicating no clear differences (Lee and Kawahara 2018). Ohde (1984) also showed that voiceless unaspirated and voiceless aspirated stops of English are not distinguished by F0 onsets.



**Figure 2.** F0 onsets across three laryngeal categories of Burmese and Thai (average values based on Shimizu 1989, p. 5).

If we look at the typology of obstruent voicing and its effects on F0 onsets, three general patterns emerge: (a) languages which have a raising effect on the F0 onsets of voiceless aspirated stops (Chru, Madurese, and Thai); (b) languages which have a lowering effect on the F0 onsets of voiceless aspirated stops (Burushaski, Cantonese, Hindi, Kalasha, Mandarin, Marathi, and Shanghai Chinese); and (c) languages which show no clear or large differences in the F0 onsets of voiceless unaspirated and aspirated stops (Burmese, Dzongkha, and English; see also Kirby and Hyslop 2019 which showed raising effects on the F0 onsets of voiceless aspirated stops in male speakers of Dzongkha whereas female

speakers showed the opposite pattern). It should also be noted that F0 onsets are generally used to investigate the laryngeal contrasts. [Lai et al. \(2009\)](#) showed minor but significant effects of place on F0 onsets in Taiwanese. It is not clear which articulatory forces may be involved and resulted in these place effects. It is also worth noting that the apparent differences in F0 may arise due to the number of laryngeal and place categories found in a language, and whether a language has undergone the processes of tonogenesis and registrogenesis, and the type of pitch and/or focus contrasts ([Brunelle et al. 2019](#); [Tan et al. 2019](#); [Wayland and Jongman 2002](#)).

Spectral tilt/balance has also been used to investigate voicing and aspiration contrasts across diverse languages ([Esposito and Khan 2020](#); [Garellek 2019](#); [Iseli et al. 2007](#)). There are four spectral tilt measures: (a) H1\*-H2\* (the amplitude difference between the first [H1] and second [H2] harmonic); (b) H1\*-A1\* (the amplitude difference between the first harmonic [H1] to the amplitude of F1); (c) H1\*-A2\* (the amplitude difference between the first harmonic [H1] to the amplitude of F2); and (d) H1\*-A3\* (the amplitude difference between the first harmonic [H1] to the amplitude of F3) ([Garellek 2019](#)). Aspirated stops have higher spectral tilt at the onset of following vowels than non-aspirated stops ([Brunelle et al. 2019](#); [Esposito and Khan 2012](#); [Gao et al. 2020](#); [Seyfarth and Garellek 2018](#)). For example, in Dzongkha ([Kirby and Hyslop 2019](#)), Hindi/Urdu ([Schertz and Khan 2020](#)), Gujarati ([Esposito et al. 2020](#)), and Marathi ([Berkson 2019](#); [Dmitrieva and Dutta 2020](#)), aspirated stops have been reported to show higher H1\*-H2\* and H1\*-A1\* at the onset of following vowels than voiceless unaspirated stops. In terms of voicing, there were no clear differences in H1\*-H2\* onsets of voiceless unaspirated and voiced unaspirated stops in Hindi/Urdu ([Schertz and Khan 2020](#)). Voiced unaspirated and voiceless aspirated stops of Yerevan Armenian were characterized by identical H1\*-H2\* ([Seyfarth and Garellek 2018](#)). In addition to spectral tilt, cepstral peak prominence (CPP), which captures any form of noise in an acoustic signal (breathiness and/or aspiration), has been reported to distinguish modal and breathy vowels ([Garellek and Keating 2011](#)). Since breathiness results in less distinct harmonics, the CPP values are expected to be much lower in vowels following aspirated stops ([Garellek 2019](#); [Misnadin 2016](#)).

A number of studies have reported correlations among F0 and spectral tilt. [Iseli et al. \(2007\)](#) observed positive correlations between H1\*-H2\* and F0 for one group of talkers (older males). [Koreman \(1996\)](#) noted that an increase in the tension of the cricothyroid muscle in the larynx results in an increase of F0 and H1\*-H2\* (see also [Kreiman et al. 2012](#) and [Keating and Esposito 2007](#) for further discussion). The results of these studies suggest that there may be correlations among F0 and spectral tilt across laryngeal categories which differ on the dimensions of aspiration and/or voicing.

The aim of the current study is to investigate F0, spectral tilt (H1\*-H2\*, H1\*-A1\*, H1\*-A2\*, and H1\*-A3\*), and CPP of the rich laryngeal contrasts (voiceless unaspirated, voiceless aspirated, and voiced unaspirated) and places of articulation (bilabial, dental, retroflex, palatal, and velar) of Shina, an endangered Dardic language spoken in Gilgit, Northern Pakistan. Relationships among F0, spectral tilt, and CPP are further explored using correlations.

## 2. Methods

### 2.1. Speakers

Five Shina speakers (range: 18–32 years; mean age: 24.6 years) were recruited from Gilgit, Northern Pakistan. All the speakers were healthy adults and had no speech and/or hearing disabilities. The sample was homogeneous. The speakers learned Shina as their first language and could also speak Urdu, a national language and lingua franca of Pakistan. All the speakers were screened before including in the study. Only those speakers who regularly spoke Shina with their family and friends were selected. Speakers who were predominantly Urdu speakers (i.e., most of the time they used Urdu) were not included in the study.

## 2.2. Speech Materials and Recording Procedure

A wordlist of Shina was created, where word-initial C represented a stop consonant (/p p<sup>h</sup> b t t<sup>h</sup> d t t<sup>h</sup> d tʃ tʃ<sup>h</sup> dʒ k k<sup>h</sup> g/), followed by vowel /a/ (each word had a CV syllable structure; see Table A1 in Appendix A). As the quality of vowels can affect fundamental frequency and other acoustic measures, nonsense words were created to better control for the phonological environment and vowel contexts. The nonsense wordlist was created in consultation with the native Shina speakers. The speakers were asked whether the selected words occur in their language or have they used any of these words in their everyday conversations. All the target words were balanced across consonant types and places of articulation. The target stops were investigated in word-initial position as this is the only position where full set of laryngeal and place contrasts are found. Before the start of the recording, speakers were familiarized with the wordlist and were asked to produce the words as they are speaking Shina using their natural speech tempo. A portable Zoom digital voice recorder with a built-in microphone was placed near the speakers to make audio recordings (44.1 kHz, encoded in 16-bit; recorder was placed around 1.5 feet from the speakers' mouth). It was made sure that there was no background noise during the recordings. All the words were produced in citation form. Each word was repeated five times (5 speakers × 15 words × 5 repetitions of each word = 375 tokens).

## 2.3. Acoustic and Statistical Analyses

A total of 375 tokens were segmented in Praat (Boersma and Weenink 2007; 11 tokens were excluded due to mispronunciations and missing repetitions; 364 tokens were used for the final analysis). Fundamental frequency, spectral tilt (H1\*-H2\*, H1\*-A1\*, H1\*-A2\*, and H1\*-A3\*; asterisks indicate that the measurements were corrected for the boosting effects of formants; Iseli et al. 2007), and CPP were measured from the onset of following vowels, using PraatSauce (Kirby 2018b). The most important information about a laryngeal category and place of articulation is found right after the release of a consonant (i.e., near the onset or beginning of the following vowel). Therefore, all the measurements are based on the onset which refers to a single time point at the beginning of the vowel /a/.

The statistical analyses of the data were conducted in R (R Core Team 2013). Separate Linear Mixed Effects Regression (LMER) models were performed for all the acoustic measures, using the *lme4* package (Bates et al. 2015). The *lmerTest* package was used to obtain *p* values for all the LMER models with Satterthwaite approximations for degrees of freedom (Kuznetsova et al. 2017). In all the LMER models, Laryngeal (voiceless unaspirated, voiceless aspirated, and voiced unaspirated) and Place (bilabial, dental, retroflex, palatal, and velar) were included as fixed factors, and Speaker as a random factor (alpha value: *p* = 0.05). By-speaker random slopes for Laryngeal and Place were included in all the models. Pairwise comparisons were performed using the *emmeans* package (Lenth 2016). The correlation networks were plotted using the Gaussian Graphical Model (Bhushan et al. 2019; Epskamp et al. 2018).

## 3. Results

Figure 3 presents violin plots of F0. The ranking of the F0 onsets at each place of articulation is shown in Table 1 whereas LMER models are presented in Table 2. F0 onsets reliably differentiated the voiced unaspirated vs. voiceless aspirated stops (*p* < 0.001) and voiced unaspirated vs. voiceless unaspirated stops (*p* < 0.001). The average F0 values of each laryngeal category showed the following pattern: voiceless aspirated > voiceless unaspirated = voiced unaspirated. In terms of place, bilabial stops were significantly different from retroflex (*p* < 0.001) and velar (*p* = 0.001) stops (see also interactions among place and laryngeal categories in Table 2). There were minor differences in voiceless aspirated and voiceless unaspirated stops. F0 of voiceless aspirated vs. voiceless unaspirated stops is non-significant at all places of articulation, except palatal (see pairwise comparisons in Table A2 in Appendix A). F0 ranking of the three laryngeal categories at each place of



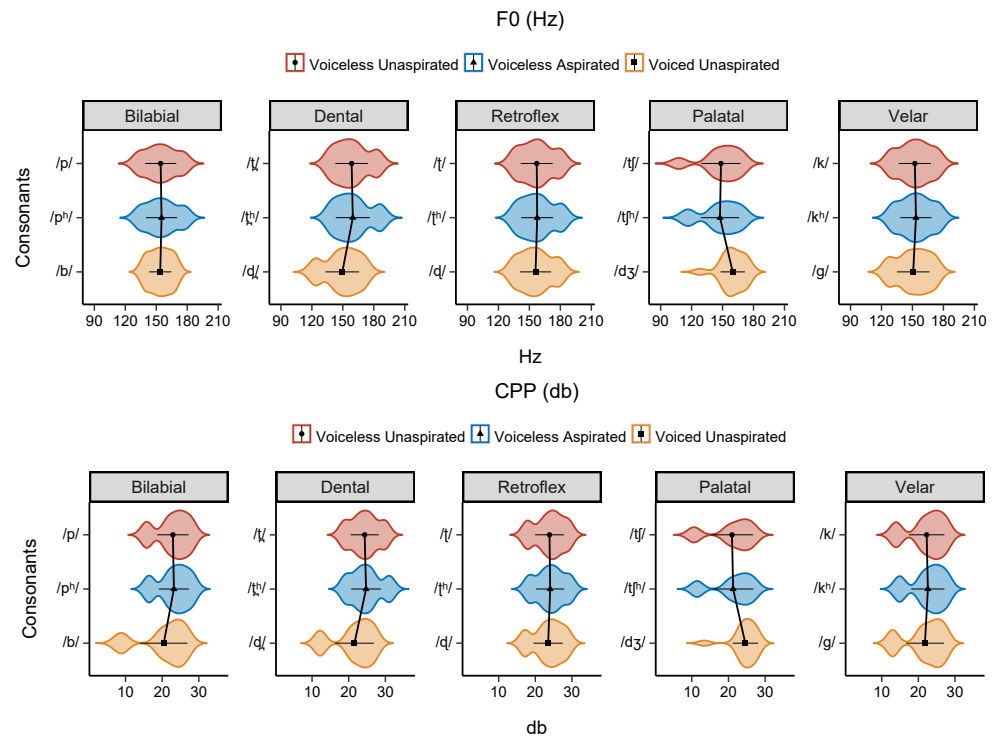
articulation (Table 1) suggests that voiceless aspirated stops of China are characterized by higher F0 onsets at all the places of articulation, except palatal.

**Table 1.** F0 ranking of the three laryngeal categories at each place of articulation.

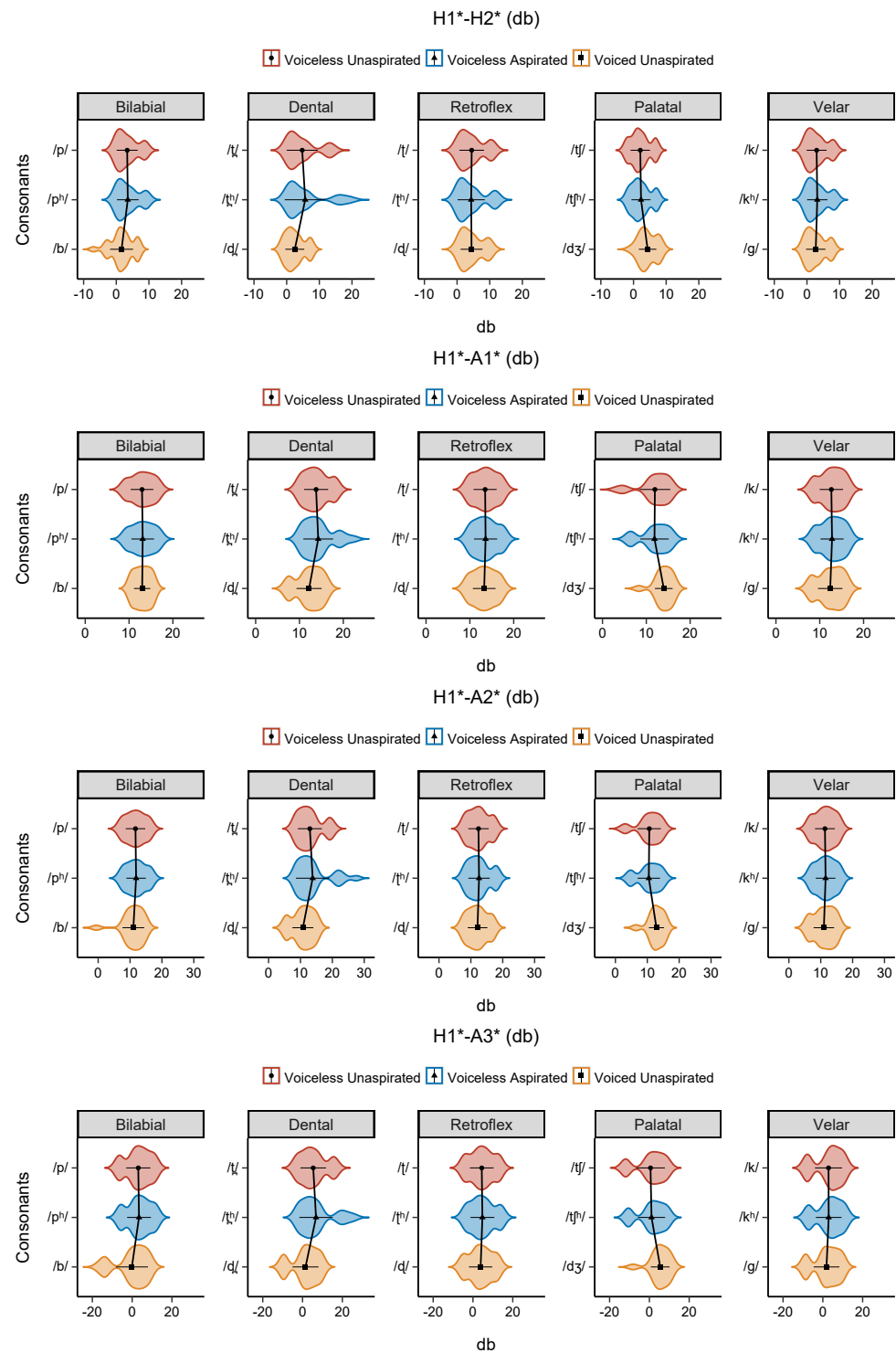
Place	F0 Ranking
Bilabial	voiceless aspirated > voiceless unaspirated > voiced unaspirated
Dental	voiceless aspirated > voiceless unaspirated > voiced unaspirated
Retroflex	voiceless aspirated > voiceless unaspirated > voiced unaspirated
Palatal	voiced unaspirated > voiceless aspirated > voiceless unaspirated
Velar	voiceless aspirated > voiceless unaspirated > voiced unaspirated

Spectral tilt/balance measures are generally higher (steeper) for breathier phonations and lower (shallower or negative) for creakier phonations (see discussion above). Figure 4 presents violin plots of H1\*-H2\*, H1\*-A1\*, H1\*-A2\*, and H1\*-A3\*. Table 2 shows results of the LMER models. H1\*-H2\* differentiated the voiced unaspirated vs. voiceless unaspirated stops ( $p < 0.001$ ) and bilabials vs. palatals ( $p = 0.001$ ), bilabials vs. retroflexes ( $p = 0.002$ ), and bilabials vs. velars ( $p = 0.002$ ). H1\*-H2\* onset was higher in the voiceless aspirated than voiceless unaspirated and voiced unaspirated stops (voiceless aspirated > voiceless unaspirated > voiced unaspirated).

H1\*-A1\* onsets distinguished the voiced unaspirated vs. voiceless aspirated stops ( $p = 0.001$ ) and voiced unaspirated vs. voiceless unaspirated stops ( $p < 0.001$ ). In terms of place contrasts, bilabials vs. retroflexes ( $p = 0.002$ ) and bilabials vs. velars ( $p = 0.006$ ) showed significant differences in H1\*-A1\*. Voiceless aspirated stops were characterized by slightly higher H1\*-A1\* onsets than voiceless unaspirated and voiced unaspirated stops (voiceless aspirated > voiceless unaspirated > voiced unaspirated).



**Figure 3.** Violin plots of F0 and CPP. Black lines connect the means of the three laryngeal categories (voiceless unaspirated, voiceless aspirated, and voiced unaspirated) at each place of articulation (bilabial, dental, retroflex, palatal, and velar).



**Figure 4.** Violin plots of H1\*-H2\*, H1\*-A1\*, H1\*-A2\*, and H1\*-A3\*. Black lines connect the means of the three laryngeal categories (voiceless unaspirated, voiceless aspirated, and voiced unaspirated) at each place of articulation (bilabial, dental, retroflex, palatal, and velar).

H1\*-A2\* onsets differentiated the voiced unaspirated vs. voiceless aspirated stops ( $p = 0.001$ ) and voiced unaspirated vs. voiceless unaspirated stops ( $p < 0.001$ ). Bilabials vs. palatals ( $p = 0.045$ ), bilabials vs. retroflexes ( $p < 0.001$ ), and bilabials vs. velars ( $p < 0.001$ ) showed significant differences in H1\*-A2\*. The voiceless aspirated stops exhibited the highest H1\*-A2\* onsets, followed by voiceless unaspirated and voiced unaspirated stops (voiceless aspirated > voiceless unaspirated > voiced unaspirated).

**Table 2.** Results of LMER models of F0, H1\*-H2\*, H1\*-A1\*, H1\*-A2\*, H1\*-A3\*, and CPP. Statistically significant results are shown in bold, with an alpha value of  $p = 0.05$ .

Factors	F0					H1*-H2*				
	Est.	SE	df	t	p	Est.	SE	df	t	p
(Intercept)	148.30	7.75	3.26	19.13	<0.001	1.62	1.44	3.92	1.12	=0.325
Laryngeal [Voiceless Aspirated]	6.83	0.81	6.16	8.45	<0.001	1.90	0.52	5.03	3.64	=0.015
Laryngeal [Voiceless Unaspirated]	5.96	0.59	10.28	10.03	<0.001	1.72	0.34	7.10	5.02	=0.001
Place [Dental]	1.25	0.77	5.70	1.62	=0.158	0.87	0.76	4.36	1.13	=0.315
Place [Palatal]	1.76	3.01	3.33	0.58	=0.597	1.44	0.30	11.24	4.73	=0.001
Place [Retroflex]	7.66	0.69	7.03	11.13	<0.001	2.03	0.40	5.97	5.09	=0.002
Place [Velar]	2.47	0.52	9.56	4.78	=0.001	1.05	0.25	11.30	4.15	=0.002
Laryngeal [Voiceless Aspirated]*Place [Dental]	3.31	0.53	328.17	6.22	<0.001	1.28	0.27	330.71	4.75	<0.001
Laryngeal [Voiceless Unaspirated]*Place [Dental]	3.04	0.53	328.17	5.71	<0.001	0.55	0.27	330.71	2.03	=0.043
Laryngeal [Voiceless Aspirated]*Place [Palatal]	-9.38	0.58	330.91	-16.16	<0.001	-2.66	0.30	326.52	-8.98	<0.001
Laryngeal [Voiceless Unaspirated]*Place [Palatal]	-10.42	0.58	330.67	-17.87	<0.001	-2.70	0.30	326.52	-9.13	<0.001
Laryngeal [Voiceless Aspirated]*Place [Retroflex]	-5.23	0.53	328.17	-9.83	<0.001	-1.24	0.28	330.67	-4.47	<0.001
Laryngeal [Voiceless Unaspirated]*Place [Retroflex]	-5.21	0.54	328.05	-9.73	<0.001	-1.39	0.28	330.83	-4.95	<0.001
Laryngeal [Voiceless Aspirated]*Place [Velar]	-4.22	0.54	328.26	-7.89	<0.001	-1.42	0.27	330.72	-5.22	<0.001
Laryngeal [Voiceless Unaspirated]*Place [Velar]	-4.41	0.54	328.26	-8.23	<0.001	-1.43	0.27	330.72	-5.26	<0.001

Factors	H1*-A1*					H1*-A2*				
	Est.	SE	df	t	p	Est.	SE	df	t	p
(Intercept)	12.00	1.25	4.08	9.63	=0.001	10.03	1.65	3.61	6.06	=0.005
Laryngeal [Voiceless Aspirated]	1.11	0.20	6.80	5.62	=0.001	1.87	0.41	6.15	4.53	=0.004
Laryngeal [Voiceless Unaspirated]	0.96	0.13	21.94	7.57	<0.001	1.67	0.28	10.74	6.03	<0.001
Place [Dental]	0.20	0.27	4.78	0.74	=0.497	0.73	0.59	4.88	1.25	=0.267
Place [Palatal]	0.26	0.52	4.86	0.50	=0.636	0.95	0.38	6.32	2.49	=0.045
Place [Retroflex]	1.27	0.14	11.39	8.89	<0.001	2.06	0.32	6.76	6.35	<0.001
Place [Velar]	0.40	0.13	17.72	3.15	=0.006	0.98	0.22	23.05	4.47	<0.001
Laryngeal [Voiceless Aspirated]*Place [Dental]	0.97	0.14	328.71	6.72	<0.001	1.20	0.27	330.81	4.51	<0.001
Laryngeal [Voiceless Unaspirated]*Place [Dental]	0.64	0.14	328.71	4.43	<0.001	0.51	0.27	330.81	1.91	=0.057
Laryngeal [Voiceless Aspirated]*Place [Palatal]	-1.50	0.16	329.99	-9.51	<0.001	-2.36	0.29	330.02	-8.14	<0.001
Laryngeal [Voiceless Unaspirated]*Place [Palatal]	-1.78	0.16	329.90	-11.23	<0.001	-2.54	0.29	330.92	-8.68	<0.001
Laryngeal [Voiceless Aspirated]*Place [Retroflex]	-0.79	0.14	328.71	-5.45	<0.001	-1.38	0.27	330.81	-5.18	<0.001
Laryngeal [Voiceless Unaspirated]*Place [Retroflex]	-0.81	0.15	328.73	-5.57	<0.001	-1.46	0.27	330.85	-5.46	<0.001
Laryngeal [Voiceless Aspirated]*Place [Velar]	-0.71	0.15	328.67	-4.86	<0.001	-1.35	0.27	330.83	-5.04	<0.001
Laryngeal [Voiceless Unaspirated]*Place [Velar]	-0.71	0.15	328.67	-4.91	<0.001	-1.36	0.27	330.83	-5.07	<0.001

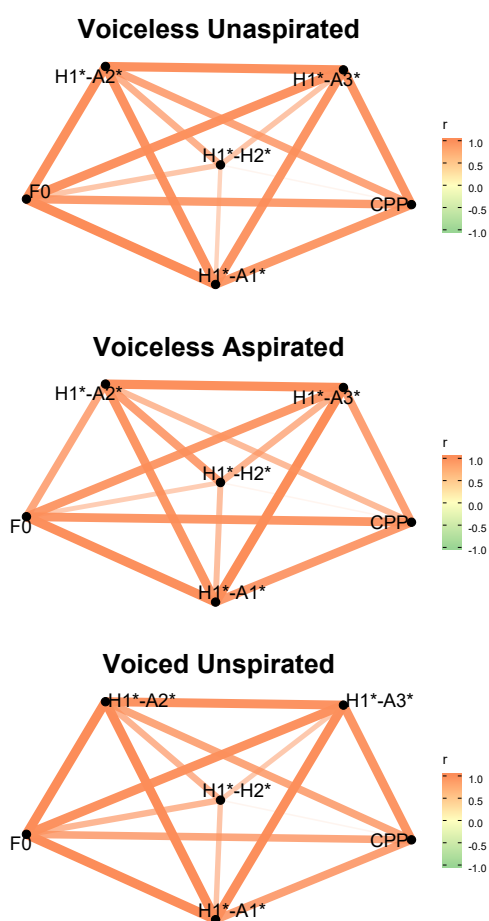
  

Factors	H1*-A3*					CPP				
	Est.	SE	df	t	p	Est.	SE	df	t	p
(Intercept)	-0.14	3.43	3.97	-0.04	=0.969	20.43	2.69	4.17	7.59	=0.001
Laryngeal [Voiceless Aspirated]	3.58	0.73	4.82	4.94	=0.005	2.77	0.62	4.41	4.46	=0.009
Laryngeal [Voiceless Unaspirated]	3.21	0.54	5.82	5.93	=0.001	2.50	0.53	4.59	4.72	=0.007
Place [Dental]	1.62	0.91	4.30	1.78	=0.144	1.14	0.49	4.48	2.30	=0.076
Place [Palatal]	1.95	0.48	7.98	4.12	=0.003	1.00	0.51	4.86	1.97	=0.108
Place [Retroflex]	4.00	0.72	4.81	5.51	=0.003	3.08	0.66	4.33	4.66	=0.008
Place [Velar]	2.04	0.32	13.50	6.31	<0.001	1.43	0.16	42.18	8.95	<0.001
Laryngeal [Voiceless Aspirated]*Place [Dental]	1.70	0.36	330.75	4.75	<0.001	0.39	0.21	336.78	1.87	=0.063
Laryngeal [Voiceless Unaspirated]*Place [Dental]	0.67	0.36	330.75	1.87	=0.062	0.28	0.21	336.78	1.33	=0.185
Laryngeal [Voiceless Aspirated]*Place [Palatal]	-4.32	0.39	329.54	-11.00	<0.001	-2.93	0.23	338.26	-12.75	<0.001
Laryngeal [Voiceless Unaspirated]*Place [Palatal]	-4.46	0.39	329.54	-11.33	<0.001	-2.97	0.23	338.26	-12.93	<0.001
Laryngeal [Voiceless Aspirated]*Place [Retroflex]	-2.69	0.36	330.75	-7.52	<0.001	-2.22	0.21	336.78	-10.60	<0.001
Laryngeal [Voiceless Unaspirated]*Place [Retroflex]	-2.79	0.36	330.84	-7.77	<0.001	-2.21	0.21	336.88	-10.51	<0.001
Laryngeal [Voiceless Aspirated]*Place [Velar]	-2.80	0.36	330.84	-7.69	<0.001	-2.05	0.21	336.82	-9.72	<0.001
Laryngeal [Voiceless Unaspirated]*Place [Velar]	-2.74	0.37	330.96	-7.41	<0.001	-2.10	0.21	336.82	-9.98	<0.001



H1\*-A3\* onsets distinguished the voiced unaspirated vs. voiceless aspirated stops ( $p = 0.005$ ) and voiced unaspirated vs. voiceless unaspirated stops ( $p = 0.001$ ). Bilabials vs. palatals ( $p = 0.003$ ), bilabials vs. retroflexes ( $p = 0.003$ ), and bilabials vs. velars ( $p < 0.001$ ) showed significant differences in H1\*-A3\*. The general pattern of H1\*-A3\* across three laryngeal categories was voiceless aspirated > voiceless unaspirated > voiced unaspirated.

Figure 3 presents violin plots of CPP. The LMER model of CPP (Table 2) indicated a significant difference in voiced unaspirated vs. voiceless aspirated stops ( $p = 0.009$ ) and voiced unaspirated vs. voiceless unaspirated stops ( $p = 0.007$ ). Bilabials vs. retroflexes ( $p = 0.008$ ) and bilabials vs. velars ( $p < 0.001$ ) had significant differences in CPP. There were no clear patterns of CPP across three laryngeal categories of Shina (Figure 3). However, voiceless aspirated stops showed higher CPP onsets than the other two laryngeal categories (voiceless aspirated > voiceless unaspirated > voiced unaspirated).



**Figure 5.** Correlation networks of F0, H1\*-H2\*, H1\*-A1\*, H1\*-A2\*, H1\*-A3\*, and CPP (collapsed across places of articulation). The thickness and colour shading of lines represent the strength of the relationships among all the acoustic variables. The absence of a line indicates very weak and/or no correlations among the variables.

### Correlations

Correlations among F0, H1\*-H2\*, H1\*-A1\*, H1\*-A2\*, H1\*-A3\*, and CPP were examined using the Gaussian Graphical Model (GGM) (Bhushan et al. 2019; Epskamp et al. 2018). The advantage of GGM correlation networks is their ease of interpretation and visualization. In Figure 5, the thickness and colour shading of the lines indicate the strength of the relationships among acoustic variables. It can be observed that the four spectral tilt measures were highly correlated with F0. Table 3 shows results of the correlation models.

Within the category of voiceless unaspirated stops, the highest correlation was found in  $F0 \times H1^*-A1^*$  ( $r = 1.00$ ) and the lowest correlation in  $H1^*-H2^* \times CPP$  ( $r = 0.88$ ). This pattern can also be visualized in the colour and thickness of the lines in Figure 5 (top correlation network: voiceless unaspirated). In the voiceless aspirated stops, the highest correlation was found in  $H1^*-A1^* \times H1^*-A3^*$  ( $r = 1.00$ ) and the lowest correlation in  $H1^*-H2^* \times CPP$  ( $r = 0.86$ ). Within the category of voiced unaspirated stops, the highest correlations were observed in  $F0 \times H1^*-A1^*$  ( $r = 1.00$ ),  $F0 \times H1^*-A2^*$  ( $r = 1.00$ ),  $F0 \times H1^*-A3^*$  ( $r = 1.00$ ),  $H1^*-A1^* \times H1^*-A2^*$  ( $r = 1.00$ ), and  $H1^*-A1^* \times H1^*-A3^*$  ( $r = 1.00$ ) but lowest correlation was found in  $H1^*-H2^* \times CPP$  ( $r = 0.96$ ). All the correlations suggest a strong relationship among the acoustic variables.

**Table 3.** Correlations among  $F0$ ,  $H1^*-H2^*$ ,  $H1^*-A1^*$ ,  $H1^*-A2^*$ ,  $H1^*-A3^*$ , and  $CPP$ .

Parameter 1	Parameter 2	Voiceless Unaspirated		Voiceless Aspirated		Voiced Unaspirated	
		<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>
F0	$H1^*-A1^*$	1.00	<0.001	0.99	<0.001	1.00	<0.001
F0	$H1^*-A2^*$	0.99	<0.001	0.96	<0.001	1.00	<0.001
F0	$H1^*-A3^*$	0.99	<0.001	0.98	<0.001	1.00	<0.001
F0	$H1^*-H2^*$	0.94	<0.001	0.92	<0.001	0.96	<0.001
F0	CPP	0.98	<0.001	0.98	<0.001	0.98	<0.001
$H1^*-A1^*$	$H1^*-A2^*$	0.99	<0.001	0.99	<0.001	1.00	<0.001
$H1^*-A1^*$	$H1^*-A3^*$	0.99	<0.001	1.00	<0.001	1.00	<0.001
$H1^*-A1^*$	$H1^*-H2^*$	0.92	<0.001	0.94	<0.001	0.95	<0.001
$H1^*-A1^*$	CPP	0.99	<0.001	0.98	<0.001	0.98	<0.001
$H1^*-A2^*$	$H1^*-A3^*$	0.99	<0.001	0.99	<0.001	0.99	<0.001
$H1^*-A2^*$	$H1^*-H2^*$	0.96	<0.001	0.97	<0.001	0.96	<0.001
$H1^*-A2^*$	CPP	0.97	<0.001	0.94	<0.001	0.98	<0.001
$H1^*-A3^*$	$H1^*-H2^*$	0.94	<0.001	0.95	<0.001	0.94	<0.001
$H1^*-A3^*$	CPP	0.99	<0.001	0.97	<0.001	0.99	<0.001
$H1^*-H2^*$	CPP	0.88	<0.001	0.86	<0.001	0.90	<0.001

#### 4. Discussion

The current study investigated the  $F0$ , spectral tilt, and  $CPP$  of the three-way laryngeal contrast across five places of articulation in Shina, an endangered Indo-Aryan (Dardic) language spoken in Gilgit, Northern Pakistan. The findings indicated that Shina speakers may rely on a number of acoustic correlates to tease apart the laryngeal and place contrasts.  $F0$  onsets were higher in the voiceless aspirated stops than voiceless unaspirated and voiced unaspirated stops. This suggests that Shina is among those languages where aspiration has a raising effect on the  $F0$  onsets of the following vowels (Chru: Brunelle et al. 2020; Khmer, Central Thai, and Northern Vietnamese: Kirby 2018a; Madurese: Misnadin 2016; Thai: Shimizu 1989) but it differs from other languages where voiceless unaspirated stops raise the  $F0$  onsets (Burushaski: Hussain 2021; Burmese: Shimizu 1989; Cantonese: Luo et al. 2016; Hindi: Shimizu 1989; Kalasha: Hussain and Mielke 2020; Mandarin: Luo et al. 2016; Marathi: Dmitrieva and Dutta 2020; Shanghai Chinese: Luo et al. 2016). Voiceless aspirated stops are produced with a wider opening of the vocal cords so that the air can pass through without any obstruction (Kim et al. 2010). Thus, a wider opening during the aspiration/frication intervals of voiceless aspirated stops leads to the raising of  $F0$  onsets on the following vowels. We also noted significant effects of place on  $F0$  onsets in Shina. It needs to be further investigated how different vocal tract configurations affect  $F0$  onsets (see discussion below).

Voiceless aspirated stops were characterized by the highest  $H1^*-H2^*$ ,  $H1^*-A1^*$ ,  $H1^*-A2^*$ , and  $H1^*-A3^*$  onsets compared to other two laryngeal categories. These results are in line with other languages of the world where aspirated stops have been shown as having a higher spectral tilt at the onset of the following vowels than unaspirated stops (Shanghai

Chinese: [Gao et al. 2020](#); Yerevan Armenian: [Seyfarth and Garellek 2018](#); Dzongkha: [Kirby and Hyslop 2019](#); Hindi/Urdu: [Schertz and Khan 2020](#); Gujarati: [Esposito et al. 2020](#); Marathi: [Berkson 2019](#); [Dmitrieva and Dutta 2020](#)). Raising of the spectral tilt due to aspiration appears to be a universal correlate. There are no known languages where we observe that aspiration lowers the spectral tilt. Voiced stops of Shina were consistently characterized by the lowest spectral tilt which also appears to be consistent across languages. The results of CPP were surprising. Breathiness/aspiration causes less distinct harmonics in the acoustic signal which lowers the CPP values ([Garellek 2019](#)). However, in Shina's voiceless aspirated stops, CPP values were higher than voiceless unaspirated and voiced unaspirated stops. These results differ from Madurese ([Misnadin 2016](#)) and Yerevan Armenian ([Seyfarth and Garellek 2018](#)) which showed low CPP in aspirated stops.

F<sub>0</sub>, spectral tilt, and CPP measures have been primarily used for investigating the laryngeal contrasts ([Kirby 2018a](#); [Kirby and Hyslop 2019](#); [Lee and Kawahara 2018](#); [Seyfarth and Garellek 2018](#)). However, their usage for the characterization of rich place contrasts is not widely explored ([Hussain 2021](#); [Misnadin and Kirby 2020](#)). [Lai et al. \(2009\)](#) observed minor but significant effects of place on F<sub>0</sub> onsets in Taiwanese. The laryngeal distinctions are mainly achieved by vibrating (opening/closing) of the vocal cords. Thus, all the spectral tilt measures are sensitive to these subtle movements. In contrast, different places of articulation are achieved by making constrictions in the vocal tract (there are some places of articulation that involve constrictions in the pharyngeal cavity, e.g., pharyngeal consonants, glottal stops). It still needs to be explored how different vocal tract configurations (which make the front and back cavities either long or short, e.g., larger sublingual cavity in retroflexes) affect the vocal cord vibrations. In the current study, there appeared to be minor place differences in F<sub>0</sub> and spectral tilt. However, at most of the places of articulation, voiceless aspirated stops were characterized by the highest F<sub>0</sub> and spectral tilt. This suggests that the F<sub>0</sub> and spectral tilt rankings are consistent across laryngeal categories and places of articulation.

Significant correlations were observed among F<sub>0</sub> and all the other acoustic measures. These findings corroborate other studies which reported correlations among F<sub>0</sub> and spectral tilt ([Iseli et al. 2007](#)). [Koreman \(1996\)](#) found that higher F<sub>0</sub> and H1\*-H2\* may occur due to the increasing tension in the cricothyroid muscle in the larynx (see also [Kreiman et al. 2012](#)). These correlations may also help inform the emergence of tones (tonogenesis) and phonation (phonationogenesis) contrasts in the world's languages. A wide range of Sino-Tibetan and Austronesian languages contrast tones on the dimension of phonation (checked, creaky, high, and low tones in Burmese; [Gruber 2011](#)). The development of phonation and tonal contrasts in different varieties of Kammu has been explored using comparative lexical data. For example, one Western Kammu variety has low tone (/pù:c/ 'rice wine') where another has breathiness (/pù:c/), and both stem from the voicing still seen in Eastern Kammu (/bu:c/) ([Kingston 2011](#)). This indicates that the development of tonal contrasts may occur together with the development of phonation contrasts (see discussion in [Garellek and Esposito 2021](#); [Gruber 2011](#); [Ratliff 2015](#)).

In a typological review, [Esposito and Khan \(2020\)](#) grouped languages into four categories: (a) languages which do not use phonation as a cue for tone (Japanese, Navajo, Punjabi, Manange, most West African languages, Swedish, and Central Thai); (b) languages which use phonation as a cue for tone (Cantonese Yue, Khmu' Rawk, Mandarin, Pakphanang Thai, Ph. Penh Khmer, and Yueyang Xiang); (c) languages where phonation and tone are orthogonal (Dinka, Mazatec languages, Mpi, Yalálag Zapotec, and Yi languages); and (d) languages which fuse the phonation and tone (Black Miao, Burmese, Green Mong, most Zapotec languages, Tamang, Vietnamese, White Hmong, and Wu). Thus, in some languages, there may be a strong relationship among F<sub>0</sub> and the phonation measures. Shina uses both F<sub>0</sub> and phonation to distinguish the three-way laryngeal contrast which, at some point, may also contribute to the development of phonemic tones.

The emergence of tones in a language can be linked to the type of laryngeal categories. The onset-based tonogenesis more often arises from the voiced unaspirated category going its own path, apart from all voiceless categories, or the voiced aspirated category going its own path. The effect of voiced (un)aspirated stops has been widely acknowledged in the tonogenesis literature (Hombert et al. 1979; Ratliff 2015) but frication can also play a key role. For example, glottal fricative /h/ in Punjabi led to the emergence of high tone (Urdu /kehna/ vs. Punjabi /kéna/ 'say'; Hussain 2020; Hussain et al. 2019). Voiceless aspirated stops involve two acoustic/articulatory events: stop closure + aspiration/frication of /h/. Fricatives, in general, have a raising effect on F0 (Michaud and Sands 2020; Pearce 2007). Moreover, fricative /h/ and the aspiration interval of voiceless aspirated stops share the articulatory feature associated with the vocal cords (e.g., both have a wider opening of the vocal cords). Thus, we can assume that at some point, voiceless aspirated stops will have the same effect on F0 as found in glottal fricative /h/ (i.e., raise the F0 and then lead to the development of high tone). In other words, if frication of /h/ can result in high tone in Punjabi, then the aspiration/frication in voiceless aspirated stops can also clear path for the development of tones. It appears that breathiness caused by the aspiration of the word-initial consonants (as noted in Shina) may be the first step in the development of contrastive tones and/or phonation. Languages may transfer the aspiration feature to the following vowels and may either develop phonemic tones (Punjabi: Hussain et al. 2019), breathy vowels (Gujarati: Esposito and Khan 2012), or both (Western Kammu varieties: Kingston 2011). Dardic languages perhaps belong to the type (a) languages discussed by Esposito and Khan (2020). As phonetic data of Dardic languages are still scarce, a cross-linguistic acoustic/articulatory study is needed to further investigate the relationships among F0, phonation, and width of the vocal cords during the production of various laryngeal categories and places of articulation. Acoustic-phonetic data would also be needed to investigate tonogenesis and phonationgenesis in Shina and neighbouring Dardic languages.

The findings of this study will contribute to the phonetic documentation of endangered Dardic languages. The study also has some limitations. Acoustic data were collected from five male speakers of Shina. Future studies with a larger sample of speakers (both males and females), different age groups (younger, middle-aged, and older), and dialects of Shina (Astor, Gilgit, and Gurez) can complement the findings of the current study. Articulatory experiments using electroglottography (EGG) can also help inform the correlations among various acoustic and articulatory measures.

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**Institutional Review Board Statement:** The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the IRB of the North Carolina State University, Raleigh (Protocol Number 7745).

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** The data presented in this study are available on request from the corresponding author.

**Conflicts of Interest:** The author declares no conflict of interest.

### Appendix A

**Table A1.** List of nonsense words of Shina. The target stops occurred in word-initial position, followed by a neutral vowel /a/.

Place	Laryngeal	IPA
Bilabial	Voiceless Unaspirated	/pa/
	Voiceless Aspirated	/p <sup>h</sup> a/
	Voiced Unaspirated	/ba/
Dental	Voiceless Unaspirated	/t̪a/
	Voiceless Aspirated	/t̪ <sup>h</sup> a/
	Voiced Unaspirated	/d̪a/
Retroflex	Voiceless Unaspirated	/ʈa/
	Voiceless Aspirated	/ʈ <sup>h</sup> a/
	Voiced Unaspirated	/ɖa/
Palatal	Voiceless Unaspirated	/tʃa/
	Voiceless Aspirated	/tʃ <sup>h</sup> a/
	Voiced Unaspirated	/dʒa/
Velar	Voiceless Unaspirated	/ka/
	Voiceless Aspirated	/k <sup>h</sup> a/
	Voiced Unaspirated	/ga/

**Table A2.** Pairwise comparisons: three laryngeal categories are compared across five places of articulation.

Place	Comparisons	F0			H1*-H2*		
		Est.	t	p	Est.	t	p
Bilabial	Voiced Unaspirated vs. Voiceless Aspirated	-6.83	-8.45	<0.001	-1.90	-3.64	=0.033
	Voiced Unaspirated vs. Voiceless Unaspirated	-5.96	-10.03	<0.001	-1.72	-5.02	=0.004
	Voiceless Aspirated vs. Voiceless Unaspirated	0.87	1.76	=0.227	0.18	0.63	=0.805
Dental	Voiced Unaspirated vs. Voiceless Aspirated	-10.14	-12.76	<0.001	-3.18	-6.10	=0.004
	Voiced Unaspirated vs. Voiceless Unaspirated	-9.00	-15.64	<0.001	-2.27	-6.63	=0.001
	Voiceless Aspirated vs. Voiceless Unaspirated	1.14	2.31	=0.097	0.92	3.22	=0.023
Retroflex	Voiced Unaspirated vs. Voiceless Aspirated	-1.60	-2.01	=0.194	-0.66	-1.26	=0.473
	Voiced Unaspirated vs. Voiceless Unaspirated	-0.75	-1.30	=0.429	-0.33	-0.93	=0.640
	Voiceless Aspirated vs. Voiceless Unaspirated	0.84	1.70	=0.250	0.34	1.16	=0.502
Palatal	Voiced Unaspirated vs. Voiceless Aspirated	2.55	3.08	=0.043	0.76	1.42	=0.393
	Voiced Unaspirated vs. Voiceless Unaspirated	4.46	7.14	<0.001	0.99	2.72	=0.057
	Voiceless Aspirated vs. Voiceless Unaspirated	1.91	3.81	=0.007	0.22	0.79	=0.720
Velar	Voiced Unaspirated vs. Voiceless Aspirated	-2.61	-3.27	=0.041	-0.48	-0.92	=0.653
	Voiced Unaspirated vs. Voiceless Unaspirated	-1.55	-2.69	=0.058	-0.29	-0.84	=0.691
	Voiceless Aspirated vs. Voiceless Unaspirated	1.06	2.13	=0.129	0.19	0.67	=0.784
Place	Comparisons	H1*-A1*			H1*-A2*		
		Est.	t	p	Est.	t	p
Bilabial	Voiced Unaspirated vs. Voiceless Aspirated	-1.11	-5.62	=0.002	-1.87	-4.53	=0.009
	Voiced Unaspirated vs. Voiceless Unaspirated	-0.96	-7.57	<0.001	-1.67	-6.03	<0.001
	Voiceless Aspirated vs. Voiceless Unaspirated	0.15	1.07	=0.551	0.19	0.74	=0.743
Dental	Voiced Unaspirated vs. Voiceless Aspirated	-2.08	-10.76	<0.001	-3.07	-7.54	=0.001
	Voiced Unaspirated vs. Voiceless Unaspirated	-1.60	-13.25	<0.001	-2.18	-8.06	<0.001
	Voiceless Aspirated vs. Voiceless Unaspirated	0.48	3.42	=0.014	0.89	3.45	=0.012
Retroflex	Voiced Unaspirated vs. Voiceless Aspirated	-0.32	-1.66	=0.292	-0.49	-1.19	=0.501
	Voiced Unaspirated vs. Voiceless Unaspirated	-0.15	-1.22	=0.454	-0.21	-0.78	=0.723
	Voiceless Aspirated vs. Voiceless Unaspirated	0.17	1.21	=0.470	0.27	1.05	=0.559

Table A2. Cont.

Place	Comparisons	H1*-A1*			H1*-A2*		
		Est.	t	p	Est.	t	p
Palatal	Voiced Unaspirated vs. Voiceless Aspirated	0.39	1.92	=0.198	0.50	1.17	=0.506
	Voiced Unaspirated vs. Voiceless Unaspirated	0.82	5.99	<0.001	0.87	2.90	=0.029
	Voiceless Aspirated vs. Voiceless Unaspirated	0.43	3.02	=0.027	0.37	1.41	=0.363
Velar	Voiced Unaspirated vs. Voiceless Aspirated	-0.40	-2.08	=0.171	-0.51	-1.26	=0.466
	Voiced Unaspirated vs. Voiceless Unaspirated	-0.25	-2.01	=0.136	-0.32	-1.16	=0.504
	Voiceless Aspirated vs. Voiceless Unaspirated	0.16	1.12	=0.521	0.20	0.78	=0.724
Place	Comparisons	H1*-A3*			CPP		
		Est.	t	p	Est.	t	p
Bilabial	Voiced Unaspirated vs. Voiceless Aspirated	-1.87	-4.53	=0.009	-2.77	-4.46	=0.020
	Voiced Unaspirated vs. Voiceless Unaspirated	-1.67	-6.03	<0.001	-2.50	-4.72	=0.015
	Voiceless Aspirated vs. Voiceless Unaspirated	0.19	0.74	=0.743	0.27	1.53	=0.298
Dental	Voiced Unaspirated vs. Voiceless Aspirated	-3.07	-7.54	=0.001	-3.16	-5.09	=0.012
	Voiced Unaspirated vs. Voiceless Unaspirated	-2.18	-8.06	<0.001	-2.77	-5.25	=0.010
	Voiceless Aspirated vs. Voiceless Unaspirated	0.89	3.45	=0.012	0.39	2.16	=0.102
Retroflex	Voiced Unaspirated vs. Voiceless Aspirated	-0.49	-1.19	=0.501	-0.55	-0.89	=0.675
	Voiced Unaspirated vs. Voiceless Unaspirated	-0.21	-0.78	=0.723	-0.28	-0.53	=0.860
	Voiceless Aspirated vs. Voiceless Unaspirated	0.27	1.05	=0.559	0.27	1.48	=0.319
Palatal	Voiced Unaspirated vs. Voiceless Aspirated	0.50	1.17	=0.506	0.16	0.25	=0.966
	Voiced Unaspirated vs. Voiceless Unaspirated	0.87	2.90	=0.029	0.47	0.88	=0.674
	Voiceless Aspirated vs. Voiceless Unaspirated	0.37	1.41	=0.363	0.32	1.76	=0.207
Velar	Voiced Unaspirated vs. Voiceless Aspirated	-0.51	-1.26	=0.466	-0.72	-1.17	=0.526
	Voiced Unaspirated vs. Voiceless Unaspirated	-0.32	-1.16	=0.504	-0.39	-0.75	=0.751
	Voiceless Aspirated vs. Voiceless Unaspirated	0.20	0.78	=0.724	0.33	1.84	=0.182

## Notes

- <sup>1</sup> Strand (2001a) also listed several words with aspirated stops. More research is needed to investigate the number of laryngeal contrasts in Bateria.
- <sup>2</sup> Kashmiri also contrasts palatalized stops in addition to plain stops (Koul 2003; Wali and Koul 1997).
- <sup>3</sup> These two languages are shown here because of their relevance for the three laryngeal categories of Shina.

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