Doubly-articulated fricatives are typologically rare and their existence has been disputed. Ladefoged and Maddieson (1996) argue that doubly-articulated fricatives are both articulatorily and perceptually problematic, due to the challenge of generating frication at multiple points of constriction and because the frontmost constriction will dominate the acoustic output. They suggest that all reported cases of doubly-articulated fricatives can instead be analyzed as sequences or as cases of secondary articulation. Nevertheless, the labio-coronal fricative [ɸʃ] is reported to occur in Setswana (Cole, 1985; Tlale, 2005). This paper presents an account of the labio-coronal fricative in Setswana, with implications for featural representation and the phonetics-phonology interface. Three analyses for [ɸʃ] are considered: articulatory sequence ([ɸ+ʃ]), secondary articulation ([ϕ] or [ʃʷ]), and true double articulation, with instrumental phonetic data from ultrasound, video, aerodynamic, and acoustic analysis.

Nine native speakers of Setswana participated in the study, which was conducted in two villages in Botswana. Five (two men) are speakers of the Sengwato dialect, spoken in Shoshong, and four (two men) are speakers of the Sekgatla dialect, spoken in Oodi. Participants produced three repetitions of ten words, with /s, sʷ, j, ʃ, x/ appearing word-initially before the vowels /a/ and /e/. Ultrasound data were captured using a SonoSite M-Turbo portable ultrasound machine with a C60x 5–2 MHz transducer at a scan depth of 9.2 or 11 cm. Head movement was mitigated with a chair-mounted head stabilization device and the ultrasound transducer was positioned beneath the speaker’s chin with an articulated arm mounted to a table. Tongue contours were traced at the point of maximum constriction in EdgeTrak (Li, Kambhamettu, & Stone, 2005) and modeled with polar smoothing spline ANOVA (Davidson, 2006; Mielke, 2015). Acoustic data were recorded using a Marantz solid state recorder with a headset condenser microphone and synchronized to the ultrasound signal with an Elgato Video Capture device. Acoustic measurements were made using Praat (Boersma & Weenink, 2017). Video data were recorded with a Sony camcorder at 30 fps. Lip configuration was analyzed by extracting still video images at the point of maximum constriction and calculating the ratio of vertical lip openness to horizontal lip spread. Aerodynamic data (lip airflow and intraoral pressure) were measured with a Rothenberg mask and pneumotachograph.

The first possible pattern, articulatory sequence, is ruled out by acoustic analysis, which shows that [ɸʃ] exhibits a consistent spectrum throughout its duration and is not produced as a sequence of fricatives. This pattern is presented in Figure 1. Video data reveal that [sʷ] and [ɸʃ] differ significantly in lip configuration, as observed in Figure 2. Whereas [sʷ] is produced with rounding, [ɸʃ] is produced with lip compression identical to that observed for [ϕ], without the accompaniment of lip protrusion. This finding suggests that Setswana employs two distinct types of labial constriction, compression and rounding, a cross-linguistically rare pattern previously reported only for Swedish and Norwegian (Lindau, 1978; Linker, 1982; Ladefoged & Maddieson, 1996). Ultrasound data reveal that both [ʃ] and [ɸʃ] are produced with laminal post-alveolar constriction, while [s] and [sʷ] are produced with apical alveolar constriction. Representative tongue contours produced by a speaker of Sekgatla are provided in Figure 3. Aerodynamic data show a build-up of pressure behind the lips for some, but not all, tokens of [ɸʃ], suggesting that frication may be produced at both the lingual and labial constrictions, and that [ɸʃ] is best characterized as double articulation, not as secondary articulation or articulatory sequence.
Figure 1. Waveforms, spectrographs, and spectra for [s, ŋ, ŋ, ŋ]

Figure 2. Lip configuration for [s] and [ŋ]

Figure 3. SSANOVA tongue contours

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References