Mathematical Modeling of the Medial Surface of the Vocal Fold for the Study of Chest and Falsetto Registers

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Introduction

Experimental data suggest that the change of laryngeal register between chest and falsetto is set by the level of activation of the thyroarytenoid muscles, with increased thyroarytenoid activation causing medial surface bulging which characterizes chest register [1]. This project explored whether medial surface bulging resulting from the activation of the thyroarytenoid muscle could cause change in the spectral slope of the acoustic output.

Methods

The geometry for the finite element model was based on the typical male geometry defined in VoxInSilico [2], a voice simulation program written by Drs Ingo Titze and Fariborz Alipour. Modeling was performed in FEBio using a transverse-isotropic Mooney-Rivlin model for the muscle tissue and Neo-Hookean models for the mucosa and ligament. The length of the vocal fold was adjusted by motion of the thyroid cartilage relative to a fixed posterior surface. The muscle tissue was divided into vocalis and muscularis portions to allow variation in fiber orientation and activation.

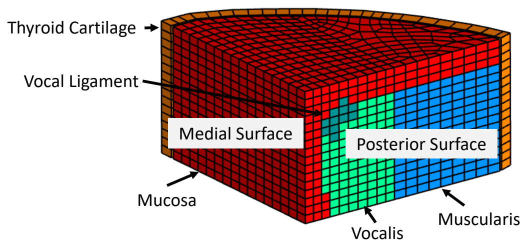

Figure 1: FE Model showing muscle divisions and vocal ligament

The FE model was solved for 50 cases of muscle activations that covered the expected range of muscle activations for the chest and falsetto registers. The displacements of the medial surface were extracted from each of those solutions. The extracted medial surface displacement data was regressed into a polynomial function of muscle activations and position on the medial surface. This 2-D polynomial was inserted into VoxInSilico to calculate the shape of the medial surface. A sample chest and falsetto case were then run in VoxInSilico and the spectral slopes of the acoustic output calculated.

Results

The expectation was that the FE model would show more bulging for the chest than for the falsetto case, and that the chest case would have a shallower spectral slope. The deformed shape of the vocal fold and the cross-section at the posterior edge are shown for the falsetto case in Figure 2 and for the chest case in Figure 3. The spectral slopes for the chest and falsetto case are shown in Table 1.

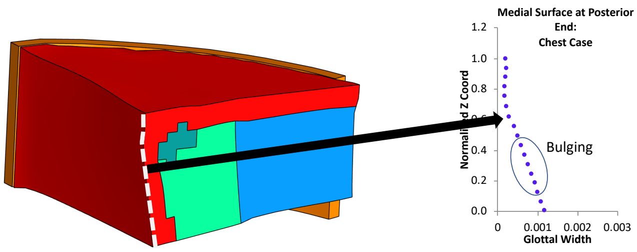

Figure 2: FE Model for chest (left) and posterior cross section plot (right) shows bulging.

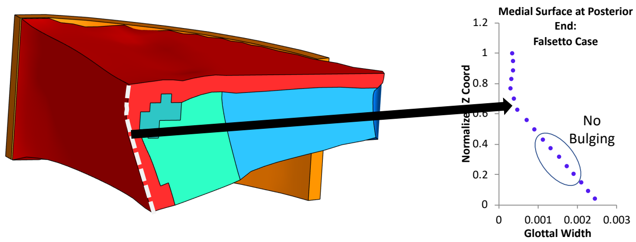

Figure 3: FE Model for falsetto (left) and posterior cross section plot (right) shows no bulging.

	Chest	Falsetto
Spectral Slope	-11.9 dB/oct	-19.2 dB/oct

Table 1: Spectral Slopes for the Chest and Falsetto Cases.

Discussion

The higher muscle activation of the chest case did result in more medial surface bulging and a shallower spectral slope. Future work will include identifying additional chest and falsetto cases to further exercise the regression model.

References

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[2] VoxInSilico (Version 7.3) [Computer Software]. Salt Lake City, UT: National Center for Voice and Speech

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