

# Voice Onset Time in Turkish-speaking Children with Repaired Cleft Lip and/or Palate: A Case-control Study

## Türkçe Konuşan Opere Dudak/Damak Yarıklı Çocuklarda Sesi Başlatma Zamanı Parametresi: Vaka-kontrol Çalışması

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**ABSTRACT Objective:** Voice onset time (VOT) may be affected by deficits in laryngeal or supralaryngeal structures. This study aimed to compare the VOT parameters between the children with repaired cleft lip and/or palate (CL/P) and their healthy peers. **Material and Methods:** Thirty-nine children with repaired CL/P ( $X \pm SD$  age; 11.51 $\pm$ 3.53 years) and 39 healthy children ( $X \pm SD$  age; 11.44 $\pm$ 3.40 years) were included in the study. Clinical data including age, gender, speaking language, hearing status, type of CL/P, presence of lip/palate repairment, results of speech-sound disorder examination, and presence of malocclusion and/or oronasal fistula were retrospectively collected. VOT values for /pa/, /ta/, and /ka/ syllables were obtained using Praat software and compared between the study group (SG) and the control group (CG). **Results:** VOT values differed significantly between the (SG) and (CG) which were prolonged in the SG for all measured /pa/ ( $p=0.015$ ), /ta/ ( $p=0.045$ ), and /ka/ ( $p=0.037$ ) syllables. In the SG, the longest VOT was observed for the /ka/, /ta/, and pa/ syllables, respectively. **Conclusion:** The presence of CL/P may have contributed to prolonged VOT values in Turkish-speaking children. Since VOT is a reliable acoustic parameter closely interacting with speech structures, clinicians should be aware of this phenomenon.

**ÖZET Amaç:** Ses üretimi ile ilgili zamansal bir ölçüm parametresi olan sesi başlatma zamanı (voice onset time-VOT), lareneal ve supralareneal yapılarıdaki yapısal sorunlardan etkilenmektedir. Bu çalışmanın amacı, opere edilmiş dudak/damak yarıklı çocukların VOT parametrelerini sağlıklı akranları ile karşılaştırmaktır. **Gereç ve Yöntemler:** Çalışmaya 39 opere dudak damak yarıklı çocuk ( $X \pm SS$  yaş; 11,51 $\pm$ 3,53 yıl) ve 39 sağlıklı çocuk ( $X \pm SS$  yaş; 11,44 $\pm$ 3,40 yıl) dâhil edilmiştir. Yaş, cinsiyet, konuşulan dil, işitme testi sonuçları, dudak/damak yarığı tipi, dudak/damak onarımı bilgileri, konuşma sesi bozukluğu değerlendirme bulguları, maloklüzyon ve oronazal fistül varlığına ilişkin klinik veriler geçmişe dönük toplanmıştır. Praat yazılımı kullanılarak /pa/, /ta/ ve /ka/ heceleri için VOT değerleri elde edilmiş ve çalışma grubu ile kontrol grubu arasında karşılaştırılmıştır. **Bulgular:** Çalışma grubunda ölçülen VOT değerleri tüm /pa/ ( $p=0,015$ ), /ta/ ( $p=0,045$ ) ve /ka/ ( $p=0,037$ ) heceleri için kontrol grubuna göre istatistiksel olarak anlamlı derecede uzun bulunmuştur. Dudak/damak yarıklı çocuklarda en uzun VOT değerleri sırasıyla /ka/, /ta/ ve pa/ heceleri için bulunmuştur. **Sonuç:** Türkçe konuşan çocuklarda dudak/damak yarıklarının VOT süresinin uzamasına neden olduğu düşünülebilir. Konuşma üretiminde kullanılan anatomik yapılar ile güvenilir bir akustik ölçüm parametresi olarak kabul edilen VOT arasında önemli bir ilişki olduğu için yapılan klinik değerlendirmelerde VOT parametresinin de göz önünde bulundurulması faydalı olabilir.

**Keywords:** Acoustic analysis; children;  
cleft lip/palate; voice onset time

**Anahtar Kelimeler:** Akustik analiz; çocuk;  
dudak/damak yarıkları; voice onset time

**TO CITE THIS ARTICLE:**

Gölaç H, Gülaçtı A, Atalık G, Bacık Tıranc Ş, Tutar H, Gündüz B. Voice Onset Time in Turkish-Speaking Children with Repaired Cleft Lip and/or Palate: A Case-Control Study. Journal of Ear Nose Throat and Head Neck Surgery, 2024;32(2):73-78.

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Peer review under responsibility of Journal of Ear Nose Throat and Head Neck Surgery.

**Received:** 13 Dec 2023

**Received in revised form:** 02 Feb 2024

**Accepted:** 18 Apr 2024

**Available online:** 30 Apr 2024

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Cleft lip and/or palate (CL/P) is among the most common craniofacial anomalies with an estimated prevalence of 0.45 in every 1,000 live births worldwide.<sup>1</sup> The etiology is still unknown, but it is largely accepted that both genetics and environmental factors such as drug use, tobacco consumption, and radiation play an essential role in the development of CL/P.<sup>2</sup> Besides the aesthetic problems, individuals with CL/P may encounter various problems in facial growth, velopharyngeal dysfunction, dental development/dentition, hearing, and articulation depending on the defect severity.<sup>3-7</sup>

Voice onset time (VOT) reflects the temporal interaction between laryngeal and supralaryngeal structures, defined as the duration (in milliseconds) between the stop burst and the onset of a vocal fold vibration.<sup>8</sup> During the stop closure period, intraoral air pressure increases until it reaches an adequate level for releasing the oral constriction. VOT is given a negative value when the vocal folds begin to vibrate before the release of the oral articulators which is particularly seen in voiced plosives. In contrast, if the release of the oral articulators precedes the vocal fold vibration, then the VOT is called positive as in voiceless plosives.<sup>9,10</sup>

Since the laryngeal and supralaryngeal aerodynamics may alter in individuals with CL/P, the investigation of VOT as a temporal aspect of speech is gaining importance in this population.<sup>11,12</sup> VOT variability has been investigated in a great number of studies using participants with various diagnoses, but relatively little research has been conducted on the CL/P population.<sup>9,11-16</sup> In a case-control study by Jiang et al., comparisons between the control group (CG) and subjects with perceived normal resonance did not reach a statistically significant level.<sup>16</sup> Despite the results of Jiang et al.'s study, there are also contradictory findings in the literature that show longer VOT values in the CL/P population compared to healthy controls.<sup>11,13-16</sup> In the earliest study, mean VOT values were found to be higher in subjects with hypernasality than those with less disordered speech.<sup>13</sup> Similarly, in another study, it was stated that malocclusion and abnormal soft palate function could result in longer VOT values in individuals with CL/P.<sup>15</sup> In a more recent study, it was noted that chil-

dren with CL/P tend to produce higher mean VOT values for all voiceless plosives than their typically-developing peers.<sup>11</sup> In another study, age was reported to have a significant effect on VOT and VOT variability in children with repaired cleft palate.<sup>12</sup> It was stated in the study that as age increased, VOT became longer and the variability of VOT became less for English voiceless stops in this population.

The general opinion in the literature shows that the VOT values are prolonged in the CL/P population.<sup>11,13-15</sup> However, a language-specific investigation of VOT should be performed because VOT is an important factor for making phonemic and phonetic distinctions among different stops in the given language.<sup>12</sup> As far as we know, there is no study investigating the VOT variability in Turkish-speaking CL/P population. Therefore, we primarily aimed to compare VOT values between the individuals with repaired CL/P and their healthy control peers for Turkish-speaking children.

## MATERIAL AND METHODS

### STUDY DESIGN AND PARTICIPANTS

The current research was conducted as a retrospective case-control study of individuals followed up at Prof. Dr. Necmettin Akyıldız Hearing, Speech, and Voice Center between April 2017 and June 2022. This study was conducted in accordance with the Declaration of Helsinki, and ethical approval was obtained from the Institutional Review Board of Gazi University (date: October 20, 2022, no: 741). Written informed consent from the parents and the children in the CG was gathered before inclusion.

A total of 71 children with repaired CL/P were examined for the present study. Data of all children including age, gender, speaking language, hearing status, type of CL/P based on Veau classification, presence of lip/palate repairment, results of speech-sound disorder examination, presence of malocclusion, and presence of oronasal fistula at the time of evaluation were retrospectively collected from the database of our center.<sup>17</sup> In addition, nasometric data of all children, which was routinely gathered by an experienced speech and language therapist within our clinical practice was also collected. For the current

study, only the voice recordings of the /pa/, /ta/, and /ka/ syllables which were collected during the nasometric evaluation were used for VOT measurements. Before the voice recordings, the nasometer device was calibrated for each individual. Children with sub-mucous cleft palate or non-repaired lip/palate, those who had problems in articulating the target syllables (/pa/, /ta/, and /ka/), compensatory misarticulations, a known syndrome, a first language other than Turkish, hearing loss, missing data on demographic and clinical variables, and those who were younger than 7 years old and older than 18 years old were excluded. After the exclusion criteria, 39 children with repaired CL/P (22 female and 17 male,  $X \pm SD$  age;  $11.51 \pm 3.53$  years) were included in the study group (SG).

The CG for the current study consisted of 39 age- and gender-matched healthy Turkish-speaking children (22 female and 17 male,  $X \pm SD$  age;  $11.44 \pm 3.40$  years) who were referred to our center for an audiological assessment. Children with hearing loss, articulation disorder, malocclusion (overbite/overjet), voice disorder, and cognitive problems were excluded from the present study.

## RECORDING STIMULI

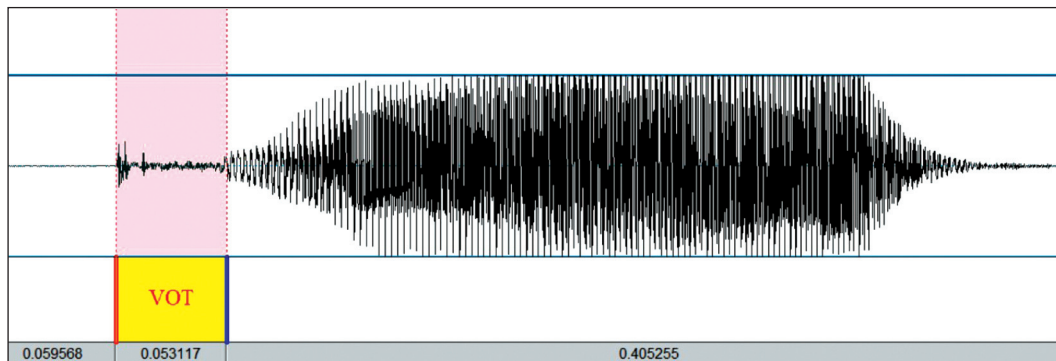
A nasometer (Rose Medical Solutions Ltd., UK) equipped with microphones that have 100-15,000 Hz frequency response and -40 dB at 1 kHz (0 dB=1 V/Pa) sensitivity was used to collect the speech samples. During the recordings, all participants were

seated on a stable and comfortable chair and the small facial contour of the acoustic separator was placed in the middle of the distance between the nose and the upper lip of each child. Five consecutive productions of the target syllables were recorded respectively (i.e., /pa-/pa-/pa-/pa-/pa/) and then saved on a desktop computer in .wav format. Recordings were completed with a sampling frequency of 44.1 kHz and 16-bit resolution in a sound-treated room with an ambient noise level of  $35 \pm 5$  dBC. Before the recordings, a speech and language therapist illustrated the procedure to all participants.

## VOT MEASUREMENTS

Praat software version 6.0.17 (Paul Boersma and David Weenink, University of Amsterdam, Netherlands) was used to obtain all VOT measurements. Among the five consecutive productions of each syllable, the first and last samples were extracted to avoid the possible effect of irregularities associated with the onset and offset of syllable production. The duration between the release of oral constriction and the beginning of the vocal fold vibration was measured in milliseconds for the remaining three trials and the average value was considered as the VOT of each participant. Figure 1 shows the details of the VOT measurements in Praat.

For the reliability of the data, VOT measurements of all 234 samples (3 samples for each child) were conducted by a primary rater (Rater 1). Twenty percent of the data were randomly selected and re-



**FIGURE 1:** Illustration of VOT measurement for /ka/ syllable in Praat. The first vertical line is the onset of the release burst for /k/ consonant, and the second is the onset of vocal fold vibration for the /a/ vowel production. VOT is the duration of the selected area between the two dashed lines. In this sample, VOT is measured as 53 milliseconds. VOT: Voice onset time.

peat measurements were performed blindly by the primary and two other raters (Rater 2 and Rater 3) to calculate intra- and inter-rater reliability.

**STATISTICAL ANALYSIS**

All data analyses were conducted with the SPSS (SPSS Inc., Chicago, IL) software version 25. The normality of the data distribution was confirmed using the visual (histogram and probability graphs) and analytical methods (Kolmogorov-Smirnov or Shapiro-Wilk tests). The demographic and clinical variables of the participants were given descriptively. To examine the intra- and inter-rater reliability of the VOT measurements, the intraclass correlation coefficient (ICC) and their 95% confidence interval (CI) were calculated using a two-way mixed effects model, average measurement, and absolute agreement. The level of reliability based on ICC values was considered “excellent” if the values were greater than 0.90, “good” if the values were between 0.75 and 0.90, “moderate” if the values were between 0.50 and 0.75, and “poor” if the values were less than 0.50.<sup>18</sup> The Mann-Whitney U test was applied to compare differences in VOT values between the CG and SG for /pa/, /ta/, and /ka/ syllables. All tests were

two-tailed and the statistical significance level was accepted as  $p < 0.05$  for the present study.

**RESULTS**

Among the SG, 7 (17.9%) children had isolated cleft palate, 22 (56.5%) had unilateral cleft lip and palate, and 10 (25.6%) had bilateral cleft lip and palate. As a coexisting deficit, only malocclusion (overbite/overjet) was present in 8 (20.5%) children, only oronasal fistula was present in 7 (17.9%) children, and both malocclusion and oronasal fistula were present in 6 (15.4%) children in the SG. The number of those who had no malocclusion or oronasal fistula was 18 (46.2%).

Intra- and inter-rater reliability results showed an “excellent” level of agreement for all the measured syllables except for the /pa/ syllable of Rater 3 which showed a “good” level of intra-rater reliability (ICC=0.884). ICC and their 95% CI in detail are given in Table 1.

When the VOT values were compared between the groups, the results for /pa/, /ta/, and /ka/ syllables in the SG were found to be significantly longer than the CG with  $p$  values of 0.015, 0.045, and 0.037, respectively (Table 2).

**TABLE 1:** Intra-rater and inter-rater reliability for voice onset time measurements.

Syllables	Intra-rater						Inter-rater					
	Rater 1			Rater 2			Rater 3			All raters		
	ICC	95% CI	<i>p</i> value	ICC	95% CI	<i>p</i> value	ICC	95% CI	<i>p</i> value	ICC	95% CI	<i>p</i> value
/pa/	0.956	0.896-0.981	<0.001	0.905	0.776-0.960	<0.001	0.884	0.730-0.950	<0.001	0.985	0.965-0.994	<0.001
/ta/	0.910	0.791-0.962	<0.001	0.961	0.906-0.984	<0.001	0.968	0.925-0.987	<0.001	0.981	0.961-0.991	<0.001
/ka/	0.947	0.875-0.978	<0.001	0.952	0.889-0.980	<0.001	0.954	0.891-0.980	<0.001	0.995	0.989-0.998	<0.001

ICC: Intraclass correlation coefficient; CI: Confidence interval.

**TABLE 2:** Comparison of the voice onset time values between the groups.

Syllables	SG (n=39)	CG (n=39)	<i>p</i> value
	Median (IQR)	Median (IQR)	
/pa/	58.00 (49.33-76.33)	50.50 (41.00-61.25)	0.015*
/ta/	62.33 (47.00-71.00)	50.00 (45.00-63.00)	0.045*
/ka/	66.33 (57.00-79.00)	58.00 (51.00-74.00)	0.037*

\*Statistically significant; SG: Study group; CG: Control group; IQR: Interquartile range.

## DISCUSSION

VOT is a reliable acoustic parameter that provides important cues about the temporal aspects of voice production. To date, VOT has been investigated in a wide range of studies conducted with various pathologies from neurogenic disorders to cochlear implantation.<sup>9,19-23</sup> However, relatively few studies have been performed to examine the VOT parameter in individuals with CL/P.<sup>11-16</sup> In the present study, we primarily hypothesized that individuals with CL/P might have longer VOT values than their healthy peers. The current findings showed that VOT values in the (SG) were prolonged in the SG for all measured syllables compared to the CG. In the SG, the longest VOT was observed for the /ka/, /ta/, and pa/ syllables, respectively.

To test our hypothesis, we compared the VOT values between the SG and the CG. The results showed significantly longer VOT values for children in the SG than those in the CG. In an early study, 5 and 6-year-old English-speaking children with and without congenital cleft palates were evaluated in the manner of speech segment durations.<sup>13</sup> The author concluded that subjects with hypernasality had significantly longer VOT values compared to those with less disordered speech. Overdriving of the speech mechanism due to structural alterations and abnormal use of the respiratory mechanism were predicted to be the leading causes of longer VOT in the CL/P population. In another study performed with eleven Persian-speaking children with repaired bilateral CL/P and 20 typically-developing peers, children with CL/P were found to have longer VOTs for all voiceless plosives (/p/, /t/, and /k/).<sup>11</sup> The authors suggested that the presence of CL/P may cause prolongation of speech segments due to a compensatory strategy to achieve better velopharyngeal closure. The present findings are consistent with the studies by Forner and Eshghi et al.<sup>11,13</sup> Alterations in the shape of supralaryngeal structures and increased respiratory effort in children with CL/P may have contributed to a greater oral air pressure in conjunction with a longer duration to generate a transglottal pressure difference which finally led to prolonged VOT in children with CL/P.

There are also contrary results in the literature. For example, in the study by Jiang et al., a significantly shorter VOT value was identified in a group of CL/P subjects with hypernasal resonance compared to those with normal nasal resonance.<sup>16</sup> In another study, no statistically significant differences in VOT values were observed between the subjects with CL/P and controls.<sup>14</sup> A possible explanation for the inconsistency between the studies may be due to the vowel combination that is used with voiceless plosives. As such, it is known that VOT can change regarding the place of plosive consonants' articulation and the height of the following vowel.<sup>24</sup> The other probable reasons for the differences between the studies could be attributed to the clinics and demographics of the included participants, as we know that both age and gender have an apparent effect on VOT variability.<sup>10,12</sup> Also, one must keep in mind that the equipment and its features used for audio-recordings are important and can directly alter the results of the measured vocal outcomes.<sup>25,26</sup> Thus, using different software and hardware in the studies may have caused inconsistencies between the study results.

## LIMITATIONS

The current study has several limitations that have to be considered. First, we only used the vowel /a/ with voiceless consonants, but it is known that the height of the vowel used directly affects VOT variability. Second, we did not collect any data using consonants (/b/, /d/, and /g/) which are known to result in negative VOT values because of their voiced characteristics. Further studies with a larger cohort of participants using different vowel combinations with both voiced and voiceless consonants may shed light on the present findings and help better understand the VOT variability in individuals with repaired CL/P.

## CONCLUSION

The results of this study suggest that the presence of CL/P may result in longer VOT values in Turkish-speaking children. Significantly prolonged VOT values were observed for /pa/, /ta/, and /ka/ syllables in children with CL/P compared to their healthy peers. Because VOT is an important parameter to differentiate voiceless and voiced consonants, clinicians

should be aware of this phenomenon to improve overall speech performance in the CL/P population.

### Acknowledgments

The authors wish to thank Reyhan KARAKUŞ for the support during data collection and to those who adhered to the present study.

### Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

### Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

### Authorship Contributions

**Idea/Concept:** Hakan Gölaç; **Design:** Hakan Gölaç, Güzide Atalık; **Control/Supervision:** Bülent Gündüz; **Data Collection and/or Processing:** Adnan Gülaçtı, Şadiye Bacık Tırank; **Analysis and/or Interpretation:** Hakan Gölaç; **Literature Review:** Hakan Gölaç, Güzide Atalık; **Writing the Article:** Hakan Gölaç; **Critical Review:** Hakan Tutar; **References and Findings:** Hakan Tutar; **Materials:** Adnan Gülaçtı, Şadiye Bacık Tırank.

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