# Voice Quality After Treatment of Early Glottic Carcinoma

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**Summary: Objectives.** Increasing incidence of laryngeal carcinoma and advancement in diagnostics and therapy methods, have led to constant exploration in that field. Early glottic carcinoma can be treated successfully with several procedures: cordectomy through laryngofissure, laser cordectomy, and radiotherapy. Our objective was to assess the voice quality after these different modalities of treatment.

**Study Design.** Prospective controlled study with 69 patients, treated in a 1-year period for glottic Tis and T1a carcinoma at the tertiary medical centre.

**Methods.** Nineteen of our patients were treated endoscopically with $CO_2$ laser (types III–IV cordectomy according to recommended European Laryngological Society classification of endoscopic cordectomies). Thirty-five patients underwent cordectomy through laryngofissure, 15 patients had radiotherapy. Multidimensional computer analysis of voice and speech was conducted 1, 6, and 12 months after the treatment. Three programs included 14 parameters, which were observed.

**Results.** While comparing the parameters between the groups, there were significant differences in the values of fundamental frequency (Hz), jitter (%), normalized noise energy (dB), standard deviation of fundamental frequency (Hz), percent silent time (%), and sound-pressure level in the different follow-up periods ($P < 0.05$).

**Conclusion.** In the long run, patients treated with radiotherapy show better voice quality in comparison with other two groups.

**Key Words:** Early glottic carcinoma–Voice quality–Voice and speech analysis.

## INTRODUCTION

Dysphonia, whether it is organic or functional in origin, prevents a person from being successful in social interactions and communications with others. Increasing incidence of laryngeal malignant tumors and advancement in diagnostics and therapy methods, have led to research in the name of better efficiency in therapy and rehabilitation. Laryngeal carcinoma was the fifth most common malignancy in Serbia in 2009.[1] The most important risk factors, such as smoking and consuming alcohol are avoidable. This disease is easily diagnosed in its early stages, but everyday exposure to stress, disinterest, and low sense of responsibility for personal health are causing patients to delay visiting the doctor until it is too late. In early glottic carcinoma, the average survival rate after a 5-year period is high according to some authors, over 90%. Achieving a high level of life quality is important now more than ever.

Because of the importance of preserving all laryngeal function, especially a level of voice quality that is satisfying for the patient, there are many questions about different possibilities of therapy, their appropriateness, and true value. Early glottic carcinoma can be successfully treated with classical cordectomy through laryngofissure, endoscopic cordectomy, or radiotherapy. Phoniatrics, with its methods of rehabilitation, can provide help and support to dysphonic patients after treatment. Because of the drastic nature of tumor resection, the evaluation of functional results of treatment should include fundamental vocal parameters.[2] Evaluation of laryngeal function via acoustic measurement is appealing because it is noninvasive and has the potential to provide quantitative data that may be highly descriptive of vocal fold vibrations.[3] In this study, we analyzed laryngeal function through acoustic parameters in three groups of patients with early glottic carcinoma (TisN0M0 and T1N0M0): a group treated with cordectomy through laryngofissure, a group treated with endoscopic laser cordectomy, and a group treated with radiotherapy. We compared the values of fundamental acoustic parameters in these groups in determinate periods before and after therapy and accordingly, evaluated the therapy methods. The primary aim of this study was to provide objective results regarding voice quality after each of these methods of treatment.

## MATERIALS AND METHODS

This prospective study was conducted with 69 patients treated for Tis and T1 glottic carcinoma over a 1-year time period (between November 1, 2006, and October 31, 2007) in the Institute of Otorhinolaryngology and Maxillofacial Surgery of the Clinical Centre of Serbia in Belgrade. This study was approved by the institutional review board, and all patients provided their informed consent before their inclusion in the study.

Patients were divided in three groups according to their individual indications and contraindications. Nineteen patients (Laser cordectomy [LC] group, 18 males and 1 female) were treated endoscopically with $CO_2$ laser (types II–IV cordectomies according to recommended European Laryngological Society classification for endoscopic cordectomies). Laryngofissure with cordectomy was conducted in 35 patients (Classic Cordectomy [CC] group, 33 males and 2 females), and

Accepted for publication April 12, 2011.
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Journal of Voice, Vol. ■, No. ■, pp. 1-9
0892-1997/$36.00

doi:10.1016/j.jvoice.2011.04.004

radiotherapy was performed in 15 patients (Radiotherapy [RT] group, all male).

Patients were staged using the TNM clinical classification of the International Union Against Cancer[4] as TisN0 and T1N0, based on clinical examination, laryngomicroscopy, and pathohistology. Endoscopic cordectomies were conducted with a Sharplan Lumenis 40C $CO_2$ laser (Sharplan Lasers Inc. London, UK), with a Carl Zeiss Surgical OPMI Sensera optical microscope (Carl Zeiss Meditec Inc. Dublin, CA), and in patients under general endotracheal anesthesia. The open surgical approach involved laryngofissure with cordectomy with general endotracheal anesthesia. Radiotherapy was conducted at the Institute of Oncology and Radiology of Serbia, and the patients who were primarily irradiated received 60 Gy midline doses split up in fractions of 2 Gy, five fractions each week.

Multidimensional voice and speech analysis was performed with *Tiger DRS* software (Tiger DRS, Inc. Seattle, WA), in every patient 1, 6, and 12 months after the treatment. Intensive voice therapy lasted at least 2 weeks and was conducted in every patient 5–8 weeks after the treatment. The following programs were included:

1. Vocal assessment, where we determined the acoustic parameters by analyzing vocal results, as patients pronounced continuous vocal /a/—fundamental frequency (F0, Hz), jitter, shimmer, fundamental frequency tremor (F0 tremor, Hz), amplitude tremor (Amp tremor, Hz), and normalized noise energy (NNE, dB).
2. Real analysis, where we determined the acoustic parameters while patients pronounced continuous vocal /a/ and analyzed the voice signal emitted from five standard sentences—average fundamental frequency (Ave F0, Hz), standard deviation of fundamental frequency (SD F0, Hz), average intensity (Ave Int, dB), standard

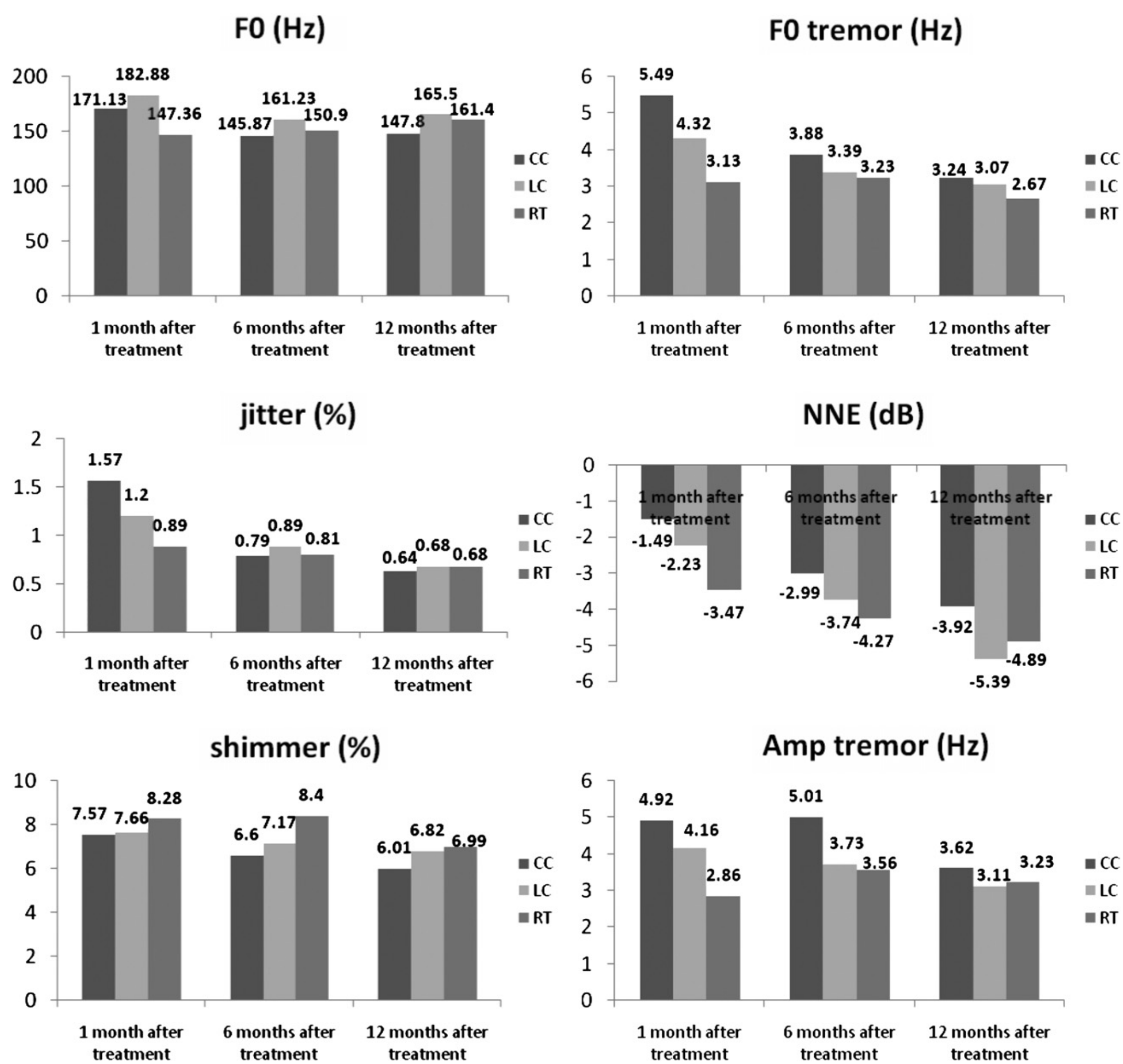


**FIGURE 1.** Average values of parameters for vocal assessment program (all groups).

deviation of intensity (SD Int, dB), and percent silent time.
3. Phonetogram, where we determined the acoustic parameters while patients read a standardized text—fundamental frequency (F0 range, Hz), sound-pressure level (SPL) and area.

For the signal in the real analysis program we used original sentences. For the phonetogram program, we used original text, written to best reflect the Serbian language phonetically and in terms of syntax. These were created and tested at the Institute of Philology and Institute of Engineering, and presented in 2005. The recording was conducted directly by setting the frequency and amplitude ranges according to the patient's gender, in a room where ambient noise was less than 50 dB. The recommended distance of the microphone to the mouth was 30 cm, at an angle of 45°–60°, to reduce aerodynamic noise during speech.

For statistical analysis, we used the *SPSS* 11.5 program (IBM Corporation, New York, NY). If the distribution was normal for variables, post hoc Bonferroni multiple comparison tests and Student $t$ tests were used. If not, the Wilcoxon signed rank test, and the Mann-Whitney test were used. We considered $P$ values less than 0.05 significant and less than 0.01 strongly significant.

## RESULTS

Average values of the acoustic parameters were analyzed in the vocal assessment program for all three groups of patients (Figure 1). Changes in values of each parameter of the vocal assessment program in all three groups were compared using Student $t$ test and the Wilcoxon signed rank test, depending on the distribution of data. Statistical significance for different periods of measurement is shown in Table 1. There was a significant change in decreasing F0 between 1 and 6 months after the treatment and voice therapy ($t = 5.03$; $P < 0.01$), as well as when comparing the values of F0 at 1 and 12 months after the treatment ($t = 4.87$; $P < 0.01$) in the CC group. The same was recorded in the LC group, but in the RT group there was a significant difference in values of F0, between the periods of 6 and 12 months after the treatment ($t = 6.25$; $P < 0.01$). Values of jitter were strongly significantly lower in all three groups after 6 months, and that improvement continued 12 months after the treatment. Values of shimmer significantly improved in the CC group ($z = -2.82$; $P < 0.05$) and LC group ($z = -1.99$; $P < 0.05$), but in the RT group, values decreased with time, but without significant differences. NNE improved significantly in all three groups of patients 6 and 12 months after the treatment (Table 1).

The differences between the mean values of parameters in the vocal assessment program among different groups were compared using the Bonferroni multiple comparisons and Mann-Whitney tests (Table 2). There was a significant difference in F0 values between the LC group and RT group ($P < 0.01$); jitter values also differed between the RT group and the other two groups (z = −2.65, $P < 0.05$ for CC group and $z = -2.06$, $P < 0.01$ for LC group). NNE values differed between the group treated with radiotherapy and the other two groups ($P < 0.01$), 1 month after the treatment. Six and 12 months after the treatment, there were few differences among the groups. Average values of the acoustic parameters analyzed in the real analysis program, for all three groups of patients, are shown in Figure 2.

In the real analysis program (Table 3), Ave F0 was significantly lower in the CC group ($t = 4.23$; $P < 0.01$) and in the LC group ($t = 4.16$; $P < 0.01$) 6 months after the treatment than 1 month after the treatment. Twelve months later, the treatment values of Ave F0 were increased significantly in the LC group ($t = -4.06$; $P < 0.01$) and RT group ($t = -4.50$; $P < 0.01$). Values of Ave Int were significantly increased 6 and 12 months after the treatment for all groups ($P < 0.01$). Values of SD F0 were significantly increased in the CC group and LC group 6 months after treatment ($P < 0.01$) but significantly decreased in all three groups 12 months after the treatment ($P < 0.01$). Percent silent time was significantly lower only in the CC group after voice therapy ($t = 2.65$; $P < 0.01$) but was significantly lower in the CC ($t = 5.06$; $P < 0.01$) and LC group ($t = 5.75$; $P < 0.01$) 12 months after the treatment.

There was a significant difference when comparing average values of SD F0 between the RT group and the other two groups ($P < 0.01$), as well as for percent silent time in the RT group and other two groups ($P < 0.01$) 1 month after the treatment (Table 4). After 6 months, there was little difference between the CC and LC group, except in the value of Ave Int 6 months after the treatment ($P < 0.01$) and Ave F0 12 months after the treatment ($P < 0.05$). There was a significant difference between the value of percent silent time in the RT group and two other groups, 6 months after the treatment ($P < 0.01$).

Average values of the acoustic parameters analyzed using the phonetogram program for all three groups of patients are shown in Figure 3. There was a significant increase in the range of F0 values in the CC group ($z = -2.70$; $P < 0.01$) and RT group ($z = -2.87$; $P < 0.01$) 6 months after the treatment. This trend was also true for the LC group ($z = -2.84$, $P < 0.01$) and RT group 12 months after the treatment ($z = -3.42$; $P < 0.01$). Values of SPL also increased for all groups throughout the time frame (Table 5).

For the phonetogram program, Bonferroni multiple comparisons revealed a significant difference between the SPL values in the RT group and two other groups 6 months after the treatment ($P < 0.01$ for the CC group; $P < 0.05$ for the LC group). When comparing the mean values of other parameters measured by the phonetogram program, there were not many statistically significant differences (Table 6).

## DISCUSSION

### Vocal assessment

In the CC and LC groups there was a significant decrease in F0 between 1 and 6 months after the treatment and voice therapy; this decrease was also observed when comparing the values of F0 1 and 12 months after the treatment. In the RT group, there was a significant difference in F0 values not after voice therapy, but later, between 6 and 12 months after the treatment.

**TABLE 1.**
**Statistical Significance Comparing the Difference of Average Values for Parameters of Vocal Assessment Program**

| | F0 (Hz) | | | Jitter (%) | | | Shimmer (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Student *t* Test | | | Wilcoxon Signed Rank Test | | | Wilcoxon Signed Rank Test | | |
| Patient Group | CC | LC | RT | CC | LC | RT | CC | LC | RT |
| 1–6 Months after | 25.26* $t = 5.03$ | 21.65* $t = 6.53$ | −3.54 $t = -0.67$ | $z = -4.32$* | $z = -2.29$† | $z = -0.72$ | $z = -2.82$† | $z = -1.99$† | $z = -1.42$ |
| 1–12 Months after | 23.33* $t = 4.87$ | 17.37* $t = 6.25$ | 14.04† $t = -2.86$ | $z = -4.92$* | $z = -3.34$* | $z = -1.99$† | $z = -3.49$† | $z = -1.01$ | $z = -0.62$ |
| 6–12 Months after | −1.93 $t = -0.88$ | −4.28 $t = -1.75$ | 10.50* $t = -3.59$ | $z = -3.79$* | $z = -3.70$* | $z = -3.41$* | $z = -3.81$† | $z = -0.22$ | $z = -3.07$ |

*$P < 0.01$; †$P < 0.05$.

Wedman et al[5] recorded average F0 in patients treated with laser cordectomy 144 Hz, and in patients treated with radiotherapy 137 Hz, 2 years after treatment. In patients followed by Honocodeevar-Boltežar and Žargi,[6] a year after radiotherapy, average F0 values were 163.32 Hz, which is close to ours. Vilaseca et al[7] had similar values of F0 for type I–III laser cordectomies in their follow-up period of 6–18 months. Policarpo et al[8] recorded lower average values of F0 in patients treated with laser cordectomy, compared with those treated with radiotherapy, which is very similar to findings reported by Krengli et al.[9] Ledda et al[10] reported that in 31 patients treated with type III laser cordectomy, average F0 was 168.2 Hz. In 13 patients treated with type IV cordectomy, this value was 169.1 Hz after 5.5 years of follow-up. Additionally, Haddad et al[11] stated that the average F0 in patients treated with laser cordectomy was 167.51 Hz, during a follow-up period between 3 and 36 months, which is close to the values in our LC group.

The voice changes significantly because of the removal of the vibrating tissue of the vocal cord in patients treated with open cordectomy and laser cordectomy, with lower mass leading to higher fundamental frequencies. In addition, patients often compensate with hyperconstriction and building tension, which results in increasing the fundamental frequency.[11] Voice therapy is helpful in removing the tension and hyperconstriction, and thereby decreasing the fundamental frequency. Removed vocal cord tissue is replaced by scar tissue, which has lower mobility and elasticity, qualities essential for vibration. However, the low mass of the scar tissue does not always involve insufficient vocal fold vibration.[5] The voice will be better if a smaller portion of the vocal muscle is removed, leaving a bigger portion of functional muscle.[12] In patients treated with radiotherapy, tumor tissue is replaced with less labile tissue. Some authors emphasize that the fundamental frequency is lower after radiation,[13] because of radiation edema of the mucosa, and this is consistent with our findings that F0 in the RT group was lower a month after the treatment in comparison with the other two groups.

Values of jitter and shimmer were lower in all three groups after 6 months and that improvement continued 12 months after

**TABLE 2.**
**Comparison of Differences Between Mean Values of Vocal Assessment Program Among Different Groups of Patients**

| | | F0 (Hz) | Jitter (%) | Shimmer (%) | F0 Tremor (Hz) | NNE (dB) | Amp Tremor (Hz) |
|---|---|---|---|---|---|---|---|
| Patient Group | | Multiple Comparisons Bonferroni | Mann-Whitney Test | Mann-Whitney Test | Multiple Comparisons Bonferroni | Multiple Comparisons Bonferroni | Mann-Whitney Test |
| 1 Month after treatment | CC-LC | −11.75 | $z = -1.45$ | $z = -0.46$ | 1.17 | 0.78 | $z = -0.16$ |
| | CC-RT | 23.77 | $z = -2.65$* | $z = -0.59$ | 2.36† | 1.98† | $z = -1.52$ |
| | LC-RT | 35.52* | $z = -2.06$† | $z = -0.69$ | 1.19 | 1.24† | $z = 0.07$ |
| 6 Months after treatment | CC-LC | −15.36 | $z = -1.09$ | $z = -1.36$ | 0.49 | 0.74 | $z = -1.61$ |
| | CC-RT | −5.03 | $z = -0.07$ | $z = -1.66$ | 0.65 | 1.27† | $z = -1.32$ |
| | LC-RT | 10.33 | $z = -0.87$ | $z = -0.47$ | 0.16 | 0.53 | $z = 0.22$ |
| 12 Months after treatment | CC-LC | −17.70 | $z = -0.69$ | $z = -1.53$ | 0.17 | 1.47† | $z = -1.66$ |
| | CC-RT | −13.60 | $z = -0.44$ | $z = -1.64$ | 0.57 | 0.97 | $z = -0.32$ |
| | LC-RT | 4.10 | $z = -0.40$ | $z = -0.21$ | 0.39 | −0.50 | $z = 0.74$ |

*$P < 0.01$; †$P < 0.05$.

| F0 Tremor (Hz) | | | NNE (dB) | | | Amp Tremor (Hz) | | |
|---|---|---|---|---|---|---|---|---|
| Student *t* Test | | | Student *t* Test | | | Wilcoxon Signed Ranks Test | | |
| CC | LC | RT | CC | LC | RT | CC | LC | RT |
| 0.96* $t=3.17$ | 0.93† $t=3.94$ | −0.10 t = −0.24 | 1.50* $t=6.32$ | 1.51* $t=5.51$ | 0.80† $t=2.87$ | $z=-0.15$ | $z=-1.65$ | $z=-3.08$* |
| 1.56* $t=3.78$ | 1.25† $t=6.04$ | 0.46 $t=1.04$ | 2.43* $t=10.41$ | 3.16* $t=9.21$ | 1.20* $t=4.35$ | $z=-2.52$* | $z=-3.54$* | $z=-2.50$† |
| 0.60† $t=2.66$ | 0.32† $t=2.15$ | 0.56† $t=24.85$ | 0.92* $t=5.65$ | 1.65* $t=7.38$ | 0.61* $t=4.79$ | $z=-2.83$* | $z=-1.85$ | $z=-3.41$* |

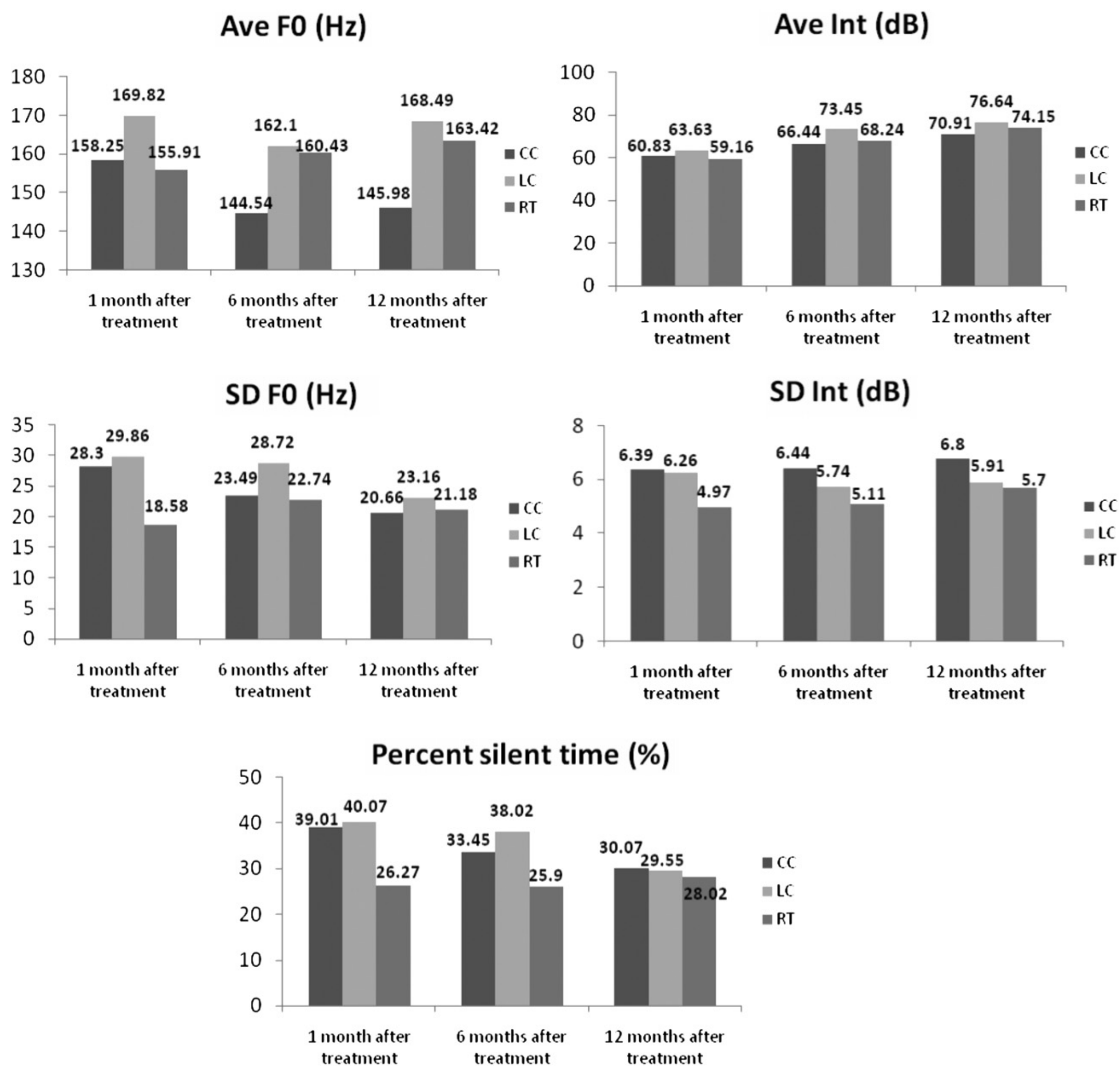


**FIGURE 2.** Average values of parameters for real analysis program (all groups).

**TABLE 3.**
**Statistical Significance Comparing Average Values of Parameters of Vocal Assessment Program for all Groups**

| | Ave F0 (Hz) | | | SD F0 (Hz) | | | Ave Int (dB) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Student *t* Test | | | Student *t* Test | | | Student *t* Test | | |
| Patient Group | CC | LC | RT | CC | LC | RT | CC | LC | RT |
| 1–6 Months after | 13.71* | 7.72* | −4.52 | 4.81† | 1.14 | −4.15* | −5.60* | −9.82* | −9.08* |
| | $t = 4.23$ | $t = 4.16$ | $t = -1.62$ | $t = 2.27$ | $t = 0.83$ | $t = 5.72$ | $t = -4.39$ | $t = -7.60$ | $t = -6.81$ |
| 1–12 Months after | 12.27 | 1.34 | −7.51† | 7.64* | 6.70* | −2.60* | −10.08* | −13.00* | −14.98* |
| | $t = 2.33$ | $t = 0.70$ | $t = -2.90$ | $t = 3.77$ | $t = 5.72$ | $t = -4.06$ | $t = -7.12$ | $t = -7.58$ | $t = -10.99$ |
| 6–12 Months after | −1.44 | −6.38* | −2.99* | 2.83* | 5.56* | 1.55† | −4.48* | −3.19* | −5.90* |
| | $t = -0.31$ | $t = -4.06$ | $t = -4.50$ | $t = 3.08$ | $t = 5.08$ | $t = 2.20$ | $t = -5.70$ | $t = -3.97$ | $t = -2.94$ |

*$P < 0.01$; †$P < 0.05$.

the treatment. Average values of jitter and shimmer in different studies were higher than in our patients,[5,7–9,11] except for one study conducted by Haddad et al,[11] where jitter was 0.76% in patients treated with laser cordectomy over a follow-up period of 3–36 months after the therapy. Dagli et al[14] reported higher F0, higher values of jitter, and no difference in values of shimmer, probably as a result of fibrosis of the vocal folds in patients treated with radiotherapy. The stiffness of the vocal folds may require more effort for voice production.

Although the changes in Amp tremor did not differ significantly between the groups, there were significant changes with the groups. Voice therapy helps in decreasing values of this parameter, especially later, during the recovery, in the CC and LC groups.

Uloza et al[15] report that NNE is a more universal and complex parameter during acoustic voice examinations than jitter and shimmer. In our case, this parameter was more sensitive than jitter and shimmer. Values of NNE improved significantly in all three groups of patients 6 and 12 months after the treatment. Glottic gap was significantly reduced, according to the values of NNE, in all groups of our patients, 6 and 12 months after voice therapy. In the RT group, 12 months after the treatment there were no significant changes in NNE compared with the other two groups, which can be interpreted as a result of the structural changes in the vocal folds, rather than the shortage of vocal fold tissue. Additionally, in the LC group values of NNE after 12 months were significantly lower compared with the CC group. The voice was perceived to be less breathy, meaning that the glottic occlusion was better in these patients. The parameters of F0 tremor and Amp tremor in our study were not sensitive enough to distinguish differences in voice quality between the groups of patients examined.

## Real analysis

Average F0 values were high a month after the treatment, only to be significantly lowered in the CC and LC groups 6 months after the treatment. In the RT group, values were significantly increased 12 months after the treatment. Values of SD F0 were significantly increased in the CC group and LC group 6 months after the treatment and significantly decreased in all three groups 12 months after the treatment. Deviations of F0 and intensity early after the treatment can be explained by removing part or all of the vocal cord, resulting in glottic insufficiency, which is not yet compensated for by the patients. During phonation the air is "passed'' through the glottic gap, over which the patient does not have any control. This results in increased intensity and variations in intensity. After treatment the Ave intensity of the voice was lowered, so the aim of voice therapy was to increase these values. Twelve months later the treatment values of Ave F0 were increased significantly in the LC and RT groups. Values of Ave Int were significantly increased 6 and 12 months after the treatment for all groups.

Percent silent time was significantly lower only in the CC group after 6 months, but 12 months after the treatment, it was significantly lower in the CC and LC groups. In the RT group, there were not significant changes in the values of this parameter. Percent silent time was significantly lower in the RT group as compared with the CC and LC groups 6 and 12 months after the treatment. McGuirt et al[12] reported a reduction of voiced elements in the vocal samples in irradiated patients and that the signal was normalized in the analysis of complete sentences, which is in agreement with our results. Diffuse stiffness and irregular vibration of the vocal cords are observed after radiotherapy because of structural changes in the vocal folds.[16–18] Koufman and Blalock[19] show that after radiotherapy, organic lesions of the larynx (radiomucositis) may result in altered biomechanical functions of the larynx, creating maladaptive compensatory mechanisms, which do not change even after the organic lesion is removed. Honocodeevar-Boltežar and Žargi[6] conducted a study with patients who had not undergone voice therapy after radiotherapy, but they did not exclude the possibility that voice therapy will help in forming better compensatory maneuvers using the vocal cords, as well as improve voice quality. In our study, no parameter revealed a significant difference among all three groups 12 months after the treatment.

## Phonetogram

Vocal intensity refers to the acoustic energy of speech, and it is typically quantified with the SPL.[20] Increased F0 values cause the speech pressure waveform to contain more high-amplitude

| SD Int (dB) | | | Percent Silent Time (%) | | |
|---|---|---|---|---|---|
| Student *t* Test | | | Student *t* Test | | |
| CC | LC | RT | CC | LC | RT |
| −0.51 | 0.52* | −0.14 | 5.56* | 2.04 | 0.37 |
| *t* = −0.12 | *t* = 3.06 | *t* = −0.37 | *t* = 2.65 | *t* = 1.16 | *t* = 0.18 |
| −0.41 | 0.35 | −0.72 | 8.94* | 10.51* | −1.74 |
| *t* = −1.19 | *t* = 1.36 | *t* = 2.03 | *t* = 4.15 | *t* = 6.35 | *t* = −0.69 |
| −0.36 | −0.17 | −0.58* | 3.38* | 8.47* | −2.11 |
| *t* = −2.03 | *t* = −1.1 | *t* = −13.55 | *t* = 5.06 | *t* = 5.75 | *t* = −1.13 |

fluctuations, which increase SPL—a phenomenon called "pulse repetition."[21] Alku et al[22] show that by elevating F0 and producing a loud voice, the number of glottic occlusions is increased in time, which induces rapid fluctuations in the speech pressure waveform and raises vocal intensity. Because of the newly developed glottic insufficiency, patients increase glottic pressure in an effort to achieve the same level of voice quality they had before the treatment. Improved glottic closure is achieved after voice therapy. There is a significant increase in the range of F0 values in CC and RT groups 6 months after the treatment; this trend continued for the LC and RT groups 12 months after the treatment. Values of SPL increased for all groups throughout the examined time frame.

There are many irregularities in the results acquired using Phonetogram. This can be explained by local changes after treatment, such as changes in vocal fold mass, the accumulation of scar tissue, and the loss of vocal cord elasticity. This results in complex vibration modes. The results obtained in our investigation do not necessarily indicate which method of treatment allows superior voice quality. When we observe these parameters only within the groups, it could be said that the most sensitive parameter is frequency range, whereas the least sensitive is the total surface area of the Phonetogram. The values for total surface area can vary depending on the shape of the Phonetogram, increasing minimal and decreasing maximal vocal intensity and frequency. Comparing the mean values of the phonetogram program parameters between the groups did not reveal many statistically significant differences.

Data in the literature explaining the exact influence of voice therapy on phonetogram is scarce. Spreyer et al[23] conducted a study on patients with chronic dysphonia of different etiology, but without carcinoma. In their patients after, conducting phoniatric rehabilitation, values of minimal frequency and intensity of the voice were lowered; surface area beneath speech intensity was increased; and consequently, the total surface area of the phonetogram was increased. After 6 months of therapy, when control recordings were done, significant changes in the phonetogram were still observed. There was an improvement in higher frequencies and the total surface area of the phonetogram was enlarged. The authors explain these results by putting

**TABLE 4.**
**Comparison of Differences Between Mean Values of Real analysis Program Among Different Groups of Patients**

| Patient Group | | Ave F0 (Hz) Multiple Comparisons Bonferroni | SD F0 (Hz) Multiple Comparisons Bonferroni | Ave Int (dB) Multiple Comparisons Bonferroni | SD Int (dB) Multiple Comparisons Bonferroni | Percent Silent Time (%) Multiple Comparisons Bonferroni |
|---|---|---|---|---|---|---|
| 1 Month after treatment | CC-LC | −11.57 | −1.56 | −2.80 | 0.12 | −1.06 |
| | CC-RT | 2.34 | 9.72* | 1.67 | 1.41† | 12.74* |
| | LC-RT | 13.91 | 11.27* | 4.47 | 1.29 | 13.79* |
| 6 Months after treatment | CC-LC | −17.56 | −5.22 | −7.01* | 0.70 | −4.57 |
| | CC-RT | −15.89 | 0.75 | −1.81 | 1.33 | 7.55* |
| | LC-RT | 1.67 | 5.98 | 5.20 | 0.63 | 12.12* |
| 12 Months after treatment | CC-LC | −22.51† | −2.50 | −5.72 | −0.89 | 0.52 |
| | CC-RT | −17.45 | −0.53 | −3.23 | 0.21 | 2.05 |
| | LC-RT | 5.06 | 1.98 | −2.49 | 0.21 | 1.54 |

*$P < 0.01$; †$P < 0.05$.

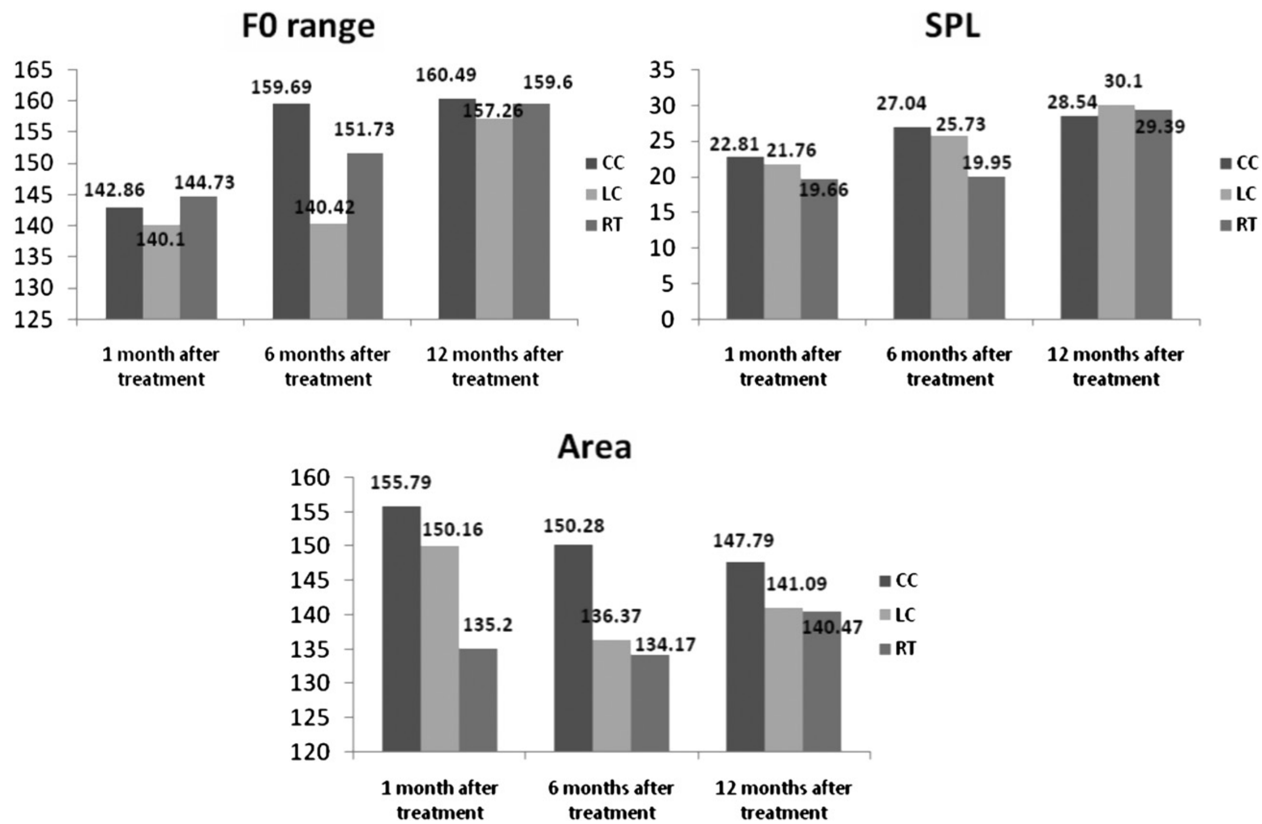


**FIGURE 3.** Average values of parameters for phonetogram program (all groups).

the emphasis on phonation in the chest register during phonation. In addition, voice relaxation exercises stimulate voice production of lower frequencies, which also happens in our patients. In our patients, speech therapists tried to stabilize the frequency, which is usually too high after cordectomies, and to increase frequency range. Speyer et al[23] suggest that the enlargement of the total surface area of the phonetogram is a result of the patient's awareness during vocal hygiene instruction given by the therapist. After the therapy is complete, compliance with these instructions weakens with time. However, the groups of patients were different, so the area of the phonetogram 12 months after the treatment was decreased compared with the one recorded after 6 months. Variation in total surface area was lowest in the RT group.

According to our results, patients treated with radiotherapy react poorly to voice therapy, compared with the CC and LC groups. There is, certainly, a slower improvement of some parameters in the RT group over a shorter period of follow-up. It is possible for voice therapy to remove hyperkinesis during speech, but the structure changes in the vocal fold tissue, individual response to voice therapy, inflammatory response to radiation in the beginning of the treatment, and creation of fibrotic

**TABLE 5.**
**Statistical Significance Comparing Average Values of Parameters of Phonetogram Program for all Groups**

| Months After Treatment | F0 Range | | | SPL | | | Area | | |
|---|---|---|---|---|---|---|---|---|---|
| | Wilcoxon Signed Ranks Test | | | Student *t* Test | | | Student *t* Test | | |
| | CC | LC | RT | CC | LC | RT | CC | LC | RT |
| 1–6 | $z=-2.70$* | $z=-0.78$ | $z=-2.87$* | −4.23*<br>$t=-3.99$ | −3.97*<br>$t=-3.06$ | −0.29<br>$t=-0.66$ | 5.51<br>$t=0.135$ | 14.78*<br>$t=5.16$ | 1.03<br>$t=-0.24$ |
| 1–12 | $z=-2.85$* | $z=-3.16$* | $z=-3.41$* | −5.73*<br>$t=-4.00$ | −8.34†<br>$t=-2.71$ | −9.73*<br>$t=-4.33$ | 7.99<br>$t=1.23$ | 10.06†<br>$t=2.42$ | −5.27<br>$t=-1.40$ |
| 6–12 | $z=-1.58$ | $z=-2.84$* | $z=-3.42$* | −1.50<br>$t=-1.37$ | −4.36<br>$t=-1.61$ | −9.45*<br>$t=-4.06$ | 5.48<br>$t=1.85$ | −4.72<br>$t=-1.54$ | −6.31†<br>$t=-2.73$ |

* $P<0.01$; † $P<0.05$.

**TABLE 6.**
**Comparison of Differences Between Mean Values of Phonetogram Program Among Different Groups of Patients**

| Patient Group | | F0 Range | SPL | Area |
|---|---|---|---|---|
| | | Mann-Whitney Test | Multiple Comparisons Bonferroni | Multiple Comparisons Bonferroni |
| 1 Month after treatment | CC-LC | −1.01 | 1.05 | 5.631 |
| | CC-RT | −0.48 | 3.15 | 20.589 |
| | LC-RT | −0.99 | 2.10 | 14.958 |
| 6 Months after treatment | CC-LC | −2.51* | 1.31 | 16.903 |
| | CC-RT | −0.86 | 7.10† | 19.110 |
| | LC-RT | −2.25* | 5.78* | 2.207 |
| 12 Months after treatment | CC-LC | −0.41 | −1.56 | 6.701 |
| | CC-RT | −0.15 | −0.85 | 7.321 |
| | LC-RT | −0.33 | 0.70 | 0.620 |

*$P < 0.05$; †$P < 0.01$.

tissue later during recovery play an important role in voice production. We can conclude that patients treated with radiotherapy demonstrate superior voice quality in comparison with the other two groups.

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