

Changes in intrinsic pitch after glossectomy: a consequence of surgery or a mechanism to enhance the intelligibility?

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0. ABSTRACT

In a former study on changes of voice quality and fundamental frequency after glossectomy we found that the mean fundamental frequency and the distance between F0 of closed vs. open vowels changed postoperatively. The general aim of our current study is to investigate whether the changed iF0 distances can be traced back to the consequences of oral surgery or to a compensatory mechanism to enhance intelligibility. Therefore the distances between F1 and F0 for the vowels /i, u, a, o, e/ are calculated for 12 patients. Our results have shown that the distances between F1 and F0 changed post-operatively, but not in relationship to the vowel categories.

1. INTRODUCTION

The intrinsic pitch of vowels (iF0) has been found to exist in all languages which have been studied [6]. There are different theories as to why for example the higher (closed) vowels such as /i/ and /u/ tend to have a higher pitch than the lower (open) vowels such as /a/. As well as the theory that biomechanical mechanisms can be made responsible for this [2], there is another theory which argues that iF0 is simply an extra, deliberate change in pitch made to enhance the differences between categories of vowels [1]. This assumption is based on the supposition that listeners do not only perceive the vowel height on the basis of F1 but much more on the auditory distance between F1 and F0. The background to this consideration is that F1 and F0 vary systematically between the various vowels which means higher vowels have a relatively low F1 and a higher F0 in comparison to lower vowels. Experiments with synthetic vowels have demonstrated that a small distance between F1 and F0 results in a high vowel being perceived whilst the opposite effect – a low

vowel – is achieved by a greater distance. It is argued that an increasing F0 would tend to fuse increasingly with F1, so that the perceptual centre of gravity would move more downwards. In the case of a constant distance one vowel only is perceived [4, 5]

Glossectomy speech appears to offer a promising new avenue for assessing the competing explanations. In a study on the effects of surgical treatment of oral cavity tumours on voice quality and fundamental frequency [7] it was possible to show that besides a post-operative increase in mean fundamental frequency and a reduction in the degree of noise of the voice, the intrinsic pitch of the vowels had increased, or rather the distance especially between /i/ and /a/ but also between /u/ and /a/.

Past studies [3] on post-operative vowel articulation have shown that after surgery on tumours of the oral cavity, the formant frequencies have also undergone changes. Since F1 is also affected by the post-operative formant changes, these changes must, with regard to the enhancement theory mentioned above, theoretically lead to an alteration in perception in terms of the vowels feature open versus closed. Therefore the possibility cannot be excluded that the patients make with the change in F0 of the vowels some sort of effort to compensate in order to emphasize the difference between the categories of vowels. The following three hypothesis show different possibilities why the F0 may have changed post-operatively:

1. With their changed F0 following surgery, the patients may have tried to ward off the changes in F1. The post-operative changes in F0 show a direction which is directly proportional to the changes in F1. (= hypothesis I)
2. The patients may have tried with their changes in F0 after surgery not only to compensate for the post-operative formant changes but also, or rather, they have in addition strengthened this effect. (= hypothesis II).

3. There may be no systematic connection between the post-operative changes in F1 and F0. It may be more likely that following surgery the patients have either a general increase or reduction in F0. The values for F1 and F0 coordinate with each other by chance and lead to a reduction and an increase in the values of distance independently of the vowel categories.
(= hypothesis III)

If either hypothesis I or II is correct, this would support the argument that with regard to F0 we are looking at an arbitrary almost compensatory mechanism, which supports the differentiation of vowels. If on the other hand hypothesis III is right, this would be an indication that the observed post-operative change in F0 is actually the result of changed muscle tension following surgery.

2. METHODS

1. Subjects

12 male patients suffering from a tumour of the floor of the mouth and/or tongue for the first time were chosen as participants for this study. They were all German native speakers and had no known neurological complications nor any pre-operative voice impairments.

All participants underwent a resection of the tumour, a reconstruction and an accompanying bilateral neck-dissection. Depending upon the progression of the illness, the neck dissection involved an increased removal of or more damage to certain supra- and infrahyoid muscles. With the exception of participants p9 and p10, they all underwent a combination of a direct closure of the defect and the insertion of a platysma flap. Participant p9 had no reconstruction at all, in the case of participant p10 a pectoral flap in combination with a platysma flap was performed.

2. Material

The participants were asked to read aloud 5 commonly used German words [Kino, Theke, Tuch, Rosi, lang], repeated 3 times

3. Procedure

The acoustic recordings were made shortly before the planned operation and 4-6 weeks postoperatively. The recordings were made with a microphone (Audiotechnica AT 4033a) on a digital audio tape (DAT-Rekorder Sony DTC ZE 700). No sound-treated room was used for this

recording, but the quality of the signal was good enough for analysis. The participants were instructed to speak at a comfortable level of loudness.

4. Data analysis

The Praat 4.0.7 speech analysis programme was used for all analyses (www.praat.org).

The vowels /i, u, e, o, a/ in the words Kino, Tuch, Theke, Rosi, lang were segmented. We try to remove the transitions of preceding or following consonants wherever possible. Also we try to ensure that these vowel segments contained no change in pitch if at all possible. All three repetitions of the words were segmented in this particular way. F0, F1 and the distance between F1-F0 were calculated for all five vowels and all three repetitions of the words. In the diagrams below all five vowels are shown whilst in the more detailed discussion only the vowels /i, u, a/ are mentioned. The psychoacoustic unit bark is used for both the first formant as well as for the fundamental frequency in this research.

4. RESULTS

F1

Five patients demonstrated a general elevation in F1 (p1, p2, p4, p5, p11), four patients a general decrease in F1 (p3, p6, p8, p10), while the remaining three patients showed an indifferent pattern (p7, p9, p13). Patient p13 had reduced post-operative values for the vowels /a, u/ and increased values for the vowel /i/. Patients p9 and p7 had differential values even within the separate vowels in the post-operative direction of movement. The scale of the changes in F1 varied from patient to patient depending upon various factors such as the extent of resection.

F0

Seven patients (p1, p2, p5, p6, p7, p11, p13) demonstrated a general rise, two patients (p3, p8) a general reduction. Three patients (p4, p9 und p10) had predominantly unchanged values; in some cases both increases and decreases in F0 could be seen. The extent of the post-operative changes in F0 varied from patient to patient depending upon various factors such as the extent of resection and neck- dissection.

F1-F0

The distance values for all vowels changed for all the patients that were examined. Three patients (p2, p4 und p5) showed a general increase in all values and half the patients had a general decrease in values (p1, p6, p8, p9, p10 und p11). The remaining patients had differential

values (p3, p7, p13). Many of the postoperative F0 changes for the vowels /i, u, a/ had increased the distance in the case of the open vowel /a/ and reduced the distance in the case of the closed vowels /i, u/ or they moved in a direction which is directly proportional to the changes in F1 (hypothesis I and hypothesis II). Several post-operative F0 changes led to a reduction in distance in the case of the open vowel /a/ and an increase in distance in the case of the closed vowels /i, u/. Three patients from our sample were selected to demonstrate these observations:

Patient p4 showed a general increase in F1, whereas the F0 values remained mainly stable. Because of this the distance values for all vowels were raised and a counter control (compensatory movements) resulting from a post-operative change in F0 did not occur (see Fig. 1).

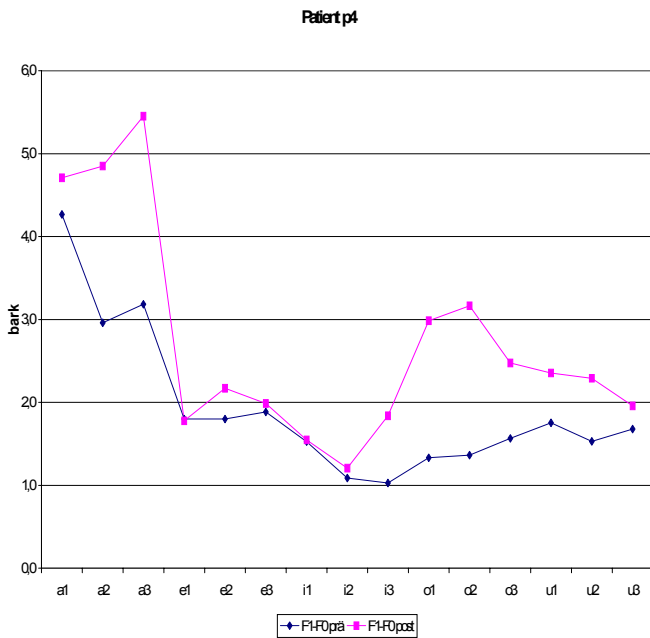


Fig. 1: Distance between F1 and F0 pre- und post-operatively for patient p4

Patient p6 demonstrated a general decrease in F1 post-operatively and a general increase in F0. Because of the post-operative changes in F0 this patient had a further reduction in the distance between F1 and F0, for the open vowel /a/ as well as for the closed vowels /i, u/ (see Fig. 2).

Patient p13 exhibited a lowering of the first formants for the vowels /a, u/ and an increase in the first formants for the vowel /i/. F0 was increased for all vowels after surgery. The post-operative changes in F0 lead to a reduction of the distance between F1 and F0 for the closed vowels /i, u/ and for the open vowel /a/ as well (see Fig.3).

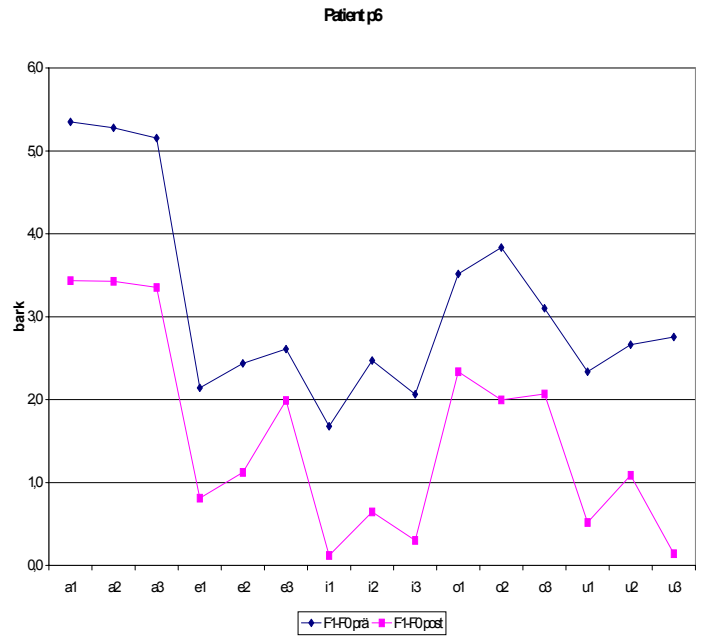


Fig. 2: Distance between F1 and F0 pre- und post-operatively for patient p6

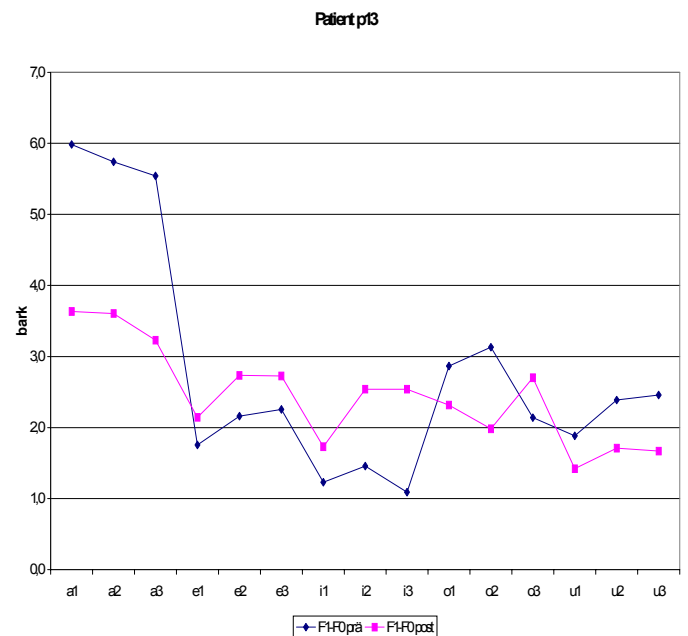


Fig. 3: Distance between F1 and F0 pre- und post-operatively for patient p13

4. DISCUSSION

With regard to the patients that we examined, it was not possible to find any systematic connection between the post-operatively changed F1 and the postoperative changes in F0. The majority of patients showed an obvious tendency in a certain direction both for the post-operative formant frequencies as well as for the post-operative changes in F0. The values for F1 and F0 seem to coordinate with each other by chance (see hypothesis III).

Although the changed postoperative F0 for the vowels /i, u, a/ caused the distance F1-F0 for the open vowel /a/ to partly increase and for the closed vowels /i, u/ to reduce it; sometimes it showed a movement directly proportional to the post-operative formant movements. Still the post-operative movements in F0 also led to a reduction of the distance in the case of the open vowel /a/ and to an increase in the distance for the closed vowels /i, u/. Seven patients demonstrated a general rise in post-operative F0. In the case of the closed vowels /i, u/ in connection with a raised F1, this leads inevitably to a direction of movement directly proportional to the formant changes or in the case of a decrease in F1 to a further reduction of the post-operative distance. Because of this sometimes a “quasi”-compensatory change in F0 takes place. Taken as a whole it is also possible to observe tendencies in the opposite direction, so that the distance for the open vowel /a/ is reduced by F0 and for the closed vowel /i, u/ is increased.

The changes in iF0 which were registered after surgery seems to be mainly a product of the post-operative change in muscle tension, as is shown by the results which are presented above.

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zimmermann_ICPhS_1249