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Aspects of Resonance: Comparison of High Speed Films and Overtone Measurements

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Abstract

A comparison has been made simultaneously of high speed films, acoustical analysis and overtone analysis with "VoceVista" and "Sygyt Ltd". The overtones software was compared with acoustical analysis. Till now formants from 1000 Hz-5000 Hz seems to be interesting using fundamental frequency of speech with 110Hz in males and 220 Hz in females. The variation of the 3 formants from 1000 Hz-5000 Hz was between 18-25% for normal persons. Glottal analysis tools from Erlangen showed no evidence of traditional acoustical voice analysis. With the new overtone analyzer (Sygyt Ltd.) we have a tool for measuring pathological voices combined with high speed films.

Keywords: Speed films; Overtone analysis; Electroglottography

Introduction

There are new apparatuses on the market-based on voice research-where the patient can benefit from advanced diagnostics of overtones.

A clinical routine with high speed films includes kymography, electroglottography and quantitative measures of the movement of the left and right vocal fold. It was showed that irregularity of the two vocal folds against each other hardly ever was the case. So airflow correction as used traditionally for correction of voices is doubted. Therefore, new approaches had to be made, especially not related to airflow. Documentation of overtones measures up to 20000 Hz (or more) with a stable and well established overtone analyzer leads to new clinical experiences – since it is made in a clinic friendly easy way – even cheap. Next is to optimize the analysis of larynx functions with among others Optical coherence tomography and Narrow Band Imaging to understand the mucosal function.

With high speed films combined with electroglottography, kymography, and overtones, nuanced evaluation of the voice is possible and to some extend evidence based. The software of high speed films includes quantitative measures of the closure of the vocal folds as well as stiffness, a calculation of maximal amplitude versus maximal speed of the vocal folds. In all 345 measurements of the voice can be made with the software that is on the market-"Glottal analyses tools" from Erlangen Germany. Acoustical analysis as well as glottal area waveforms calculations are made online on high speed films. The most used acoustical examination do not give sufficient or reliable information in pathology.

Method

The literature has been reviewed extensively for clinical aspects of resonance/overtones/harmonics: A British Library search of resonance of the human voice included search words: "voice and resonance" for the latest two years found 1610 references out of which some interesting results have been studied especially from the book by Donald Miller.

We have compared the "VoceVista" by Donald Miller with the newer software "Sygyt Ltd" which is easy to use and we have found them comparable.

In pathology there are no answers of: why one singer is better than another. Many demonstrations have been made of average formant analysis during singing of melodies – sentences - by perfect singers (Pavarotti etc.). The challenge is, with one good overtone measuring method, to explain the patient complaints of various kinds of hoarseness, in an evidence based way in the clinic.

We tried to compare the methods of overtone/harmonics analysis of "VoceVista" with "Sygyt Ltd" to find out if the two methods were comparable so that result could be used with both analyses. At least twelve subjects are needed statistically to describe the distribution of a normal material. This was also the case of the analysis of the overtones of the human voice.

In the literature the fundamental frequency (F0), in a scientifically usable way in pathology, was seldom defined in the formant analyses of singers. Therefore, we decided to compare the fundamental frequencies (F0) of voice as used in speech and harmonic overtones hereof, just to have a value for pathology. We also compared the sound analysis of the overtones of the human voice based on the fundamental frequency in speech comparing "VoceVista" with the more flexible "Sygyt Ltd".

We compared 12 normal voices of persons without voice complaints with measures of "VoceVista" and "Sygyt Ltd". 12 persons were statistically enough in a prospective cohort study to characterize a normal material and it was used to identify major differences between the two systems.

As the voices of patients are very different in nature, it is a challenge to identify the vocal problems. In order to identify the pathological problem in the clinic, a sensitive and specific measurement is needed. In the literature formant measurements over several seconds have been analyzed of famous singers without description of F0. In a clinical situation singing overtones and the measurements of them will vary extremely much and results can be understood in many ways. So to begin with, a clinical approach was made of the mean fundamental

frequency (F0). The formants as defined with "VoceVista" which measures to 5000 Hz were compared with "Sygyt Ltd." that measures to 20.000 Hz. They were made only over 1000 Hz to exclude articulation related variations.

VoceVista

Spectrogram:

Up to 5000 Hz

Fundamental frequency of speech was chosen to measure overtones:

Male: 110 Hz

Female: 220 Hz

Sygyt (Ltd.)

Spectrogram:

Up to 20000 Hz

Fundamental frequency of speech as chosen for measures to be used in pathology:

Male: 110 Hz

Female: 220 Hz

Formants

We have defined one formant as bundle of harmonic scale which combined represent the formant.

The harmonic overtone with the highest point in dB reflected in the formant was selected.

The amplitude of the selected harmonic overtones was read from the lowest to the highest point.

The first three formants over 1000 Hz were measured and the associated dB for each formant noted. Some formants less than 1000 Hz were noted in parentheses, even if they are articulation related.

Normal persons were used, 6 males and 6 females were analyzed. The fundamental frequency of speech (F0) during intonation of "ah" was defined, and a prospective cohort study of the formant placements of F0 with "VoceVista" up to 5000 Hz and "Sygyt Ltd" up to 20.000 Hz was made.

From a statistical point of view, measurements of the same millisecond (ms) was necessary to compare the formants of the two systems in a test of intonation, see Figures 1 and 2.

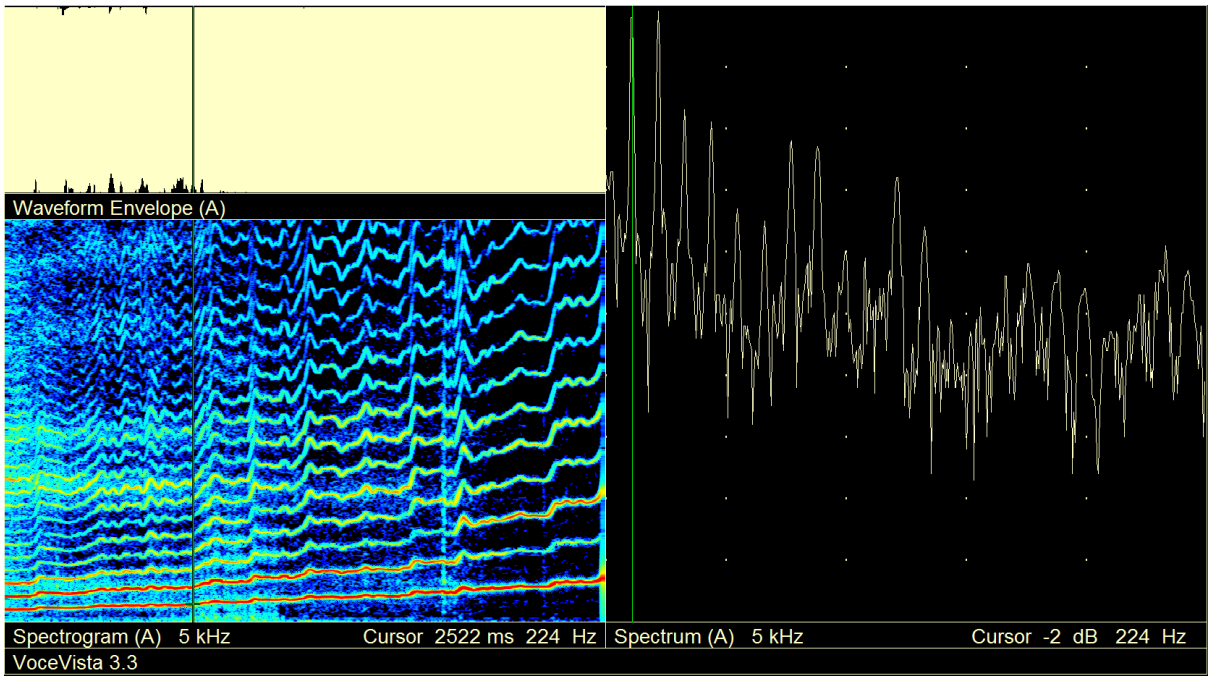

Figure 1: "VoceVista" up to 5000 Hz compared with the same sound of "Sygyt Ltd." up to 5000 Hz.

Results

"VoceVista" results of formants from 1000 up to 5000 Hz named Fx, Fy, and Fz in a prospective cohort study of 12 normal persons with the F0 nearest to 220 and 110 Hz. (Table 1).

"Sygyt Ltd." results of sound formants from over 1000 Hz up to 5000 Hz with 110 and 220 Hz as basis of overtone measures of the same 12 normal persons (Table 2).

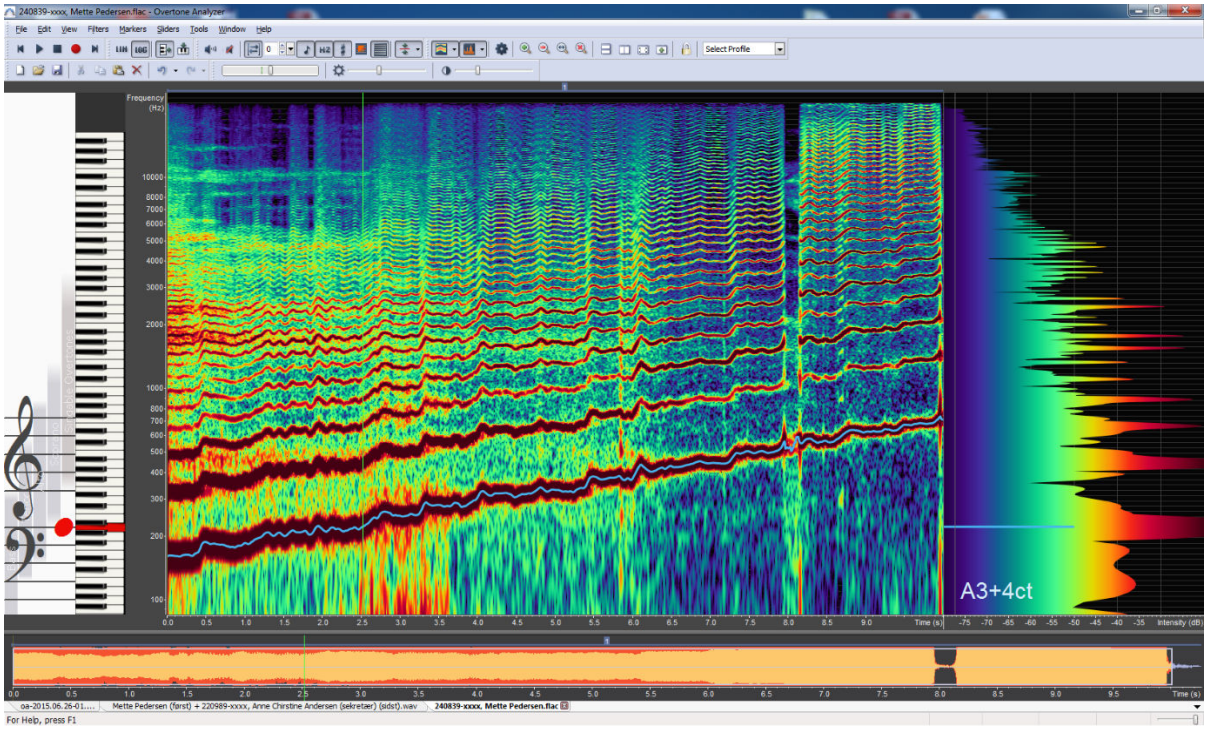

Figure 2: "Sygyt Ltd." overtone analyzer to 20000 Hz with formant detection to the hight at 220 Hz, a normal femlae's voicers.

A: "VoceVista" Results														
Nr.	**Name**	**Gender**	**Age**	**ms**	**F0 (Hz)**	**F0 (dB)**	**(Fa) (Hz)**	**Fa(dB)**	**Fx (Hz)**	**Fx (dB)**	**Fy(Hz)**	**Fy (dB)**	**Fz (dB)**	**Fz (dB)**
1	MP-A	F	75	2522	224	62			1546	38	2430	36	4662	23
2	ACA-A	F	25	14154	224	46			1558	28	2906	24	3886	16
3	LTC-A	F	40	2335	224	43			1113	38	2304	25	3525	18
4	KJH-A	F	47	2668	224	60			1552	48	2220	35	3766	25
5	SM-A	F	24	308	224	49			1762	30	2864	23	4350	14
6	NBL-A	F	25	616	224	46			1762	29	2202	24	3929	24
7	AJ-A	M	24	2551	107	48			1768	19	3321	15	4247	17
8	MSM-A	M	23	567	107	40			1624	22	2430	30	3243	30
9	BHA-A	M	22	883	107	38			1576	28	2286	20	3122	20
10	MO-A	M	28	1063	107	52			1546	35	2151	18	3327	20
11	AH-A	M	16	2320	107	42			1251	20	2290	26	3868	22
12	JJ-B	M	33	847	107	46			1095	28	3303	26	4079	24

Table 1: "VoceVista" results 12 normal persons.

B: "Sygyt" Results																
															Total Range in Hz	
Nr.	Name	Gender	Age	ms	F0 (Hz)	F0 (dB)	(Fa) (Hz)	(Fa) (dB)	Fx (Hz)	Fx (dB)	Fy (Hz)	Fy (dB)	Fz (Hz)	Fz (dB)	Lowest	Highest
1	MP-B	F	75	2520	220	58	436	55	1545	31	2433	35	4662	20	231	1126
2	ACA-B	F	25	14150	220	43	436	52	1555	24	2874	33	3881	13	174	610
3	LTC-B	F	40	2330	220	43	403	48	1114	40	2304	20	3526	16	190	874
4	KJH-B	F	47	2665	220	58	441	55	1539	42	2201	26	3762	19	151	760
5	SM-B	F	24	310	220	45	441	56	1765	25	2869	22	4333	12	211	491
6	NBL-B	F	25	620	220	51	441	49	1765	29	2201	21	3924	25	196	703
7	AJ-B	M	24	2560	110	48	333	47	1781	22	3321	23	4247	22	88	714
8	MSM-B	M	23	570	110	38	344	41	1625	21	2470	25	3246	19	98	615
9	BHA-B	M	22	880	110	44	452	59	1571	25	2255	22	3133	17	99	853
10	MO-B	M	28	1060	110	48	333	44	1550	27	2131	21	3332	22	102	538
11	AH-B	M	16	2320	110	48	333	38	1254	20	2217	24	3865	20	110	365
12	JJ-B	M	33	850	110	42	549	45	1098	24	3305	23	4107	21	107	683

Table 2: "Sygyt Ltd" results of 12 normal persons.

Comparison of "Sygyt Ltd" and "VoceVista" are presented in Table 3. The variation in % is presented: Fx (Hz) 18%, Fy(hz) 25%, Fz(Hz) 20%.

Nr.	Name	Gender	Age	F0 (Hz)	F0 (dB)	Fx (Hz)	Fx (dB)	Fy (Hz)	Fy (dB)	Fz (Hz)	Fz (dB)
1	MP-B	F	75	220	3	-19	-4	-21	2	862	-10
2	ACA-B	F	25	220	-20	-75	-11	74	10	-90	-7
3	LTC-B	F	40	220	-7	-29	-8	-884	-5	-1323	-9
4	KJH-B	F	47	220	-2	-73	9	-326	-17	-136	-9
5	SM-B	F	24	220	1	-88	-9	-115	-5	188	-5
6	NBL-B	F	25	220	1	-271	-1	-1228	1	-143	8
7	AJ-B	M	24	110	13	-42	-6	909	-7	932	2
8	MSM-B	M	23	110	8	-348	-4	-1001	5	-1152	-3
9	BHA-B	M	22	110	-6	-11	-5	-801	-3	-898	-8
10	MO-B	M	28	110	6	-610	2	-1244	1	-1523	-6
11	AH-B	M	16	110	3	-851	0	-592	5	141	3
12	JJ-B	M	33	110	-18	-3	-12	-4	-2	28	-3
Mean						1513.5	27.5	2548.9	24.33	3834.3	18.417
sd						273.796	5.9461	639.65	6.995	803.97	5.6159

cv						18.0903	21.622	25.095	28.75	20.968	30.493

Table 3: Comparing "Sygyt Ltd." and "VoceVista".

The same sound recording was analyzed of the two different software. The comparison is based on varying time points of F0 for the "Sygyt Ltd" and the "VoceVista". Notice that the coefficient of variation is 18-25%.

The fundamental frequency changes over time during the sound recording. As seen on table 4 it was essential that the results of the "Sygyt Ltd" and "VoceVista" was evaluated at the exact same millisecond for the sound recording.

Nr.	Name	Gender	Age	F0 (Hz)	F0 (dB)	Fx (Hz)	Fx (dB)	Fy (Hz)	Fy (dB)	Fz (Hz)	Fz (dB)	Fz (dB)
1	MP-B	F	75	220	-4	-1	-7	3	-1	862	0	-3
2	ACA-B	F	25	220	-3	-3	-4	-32	9	-90	-5	-3
3	LTC-B	F	40	220	0	1	2	0	-5	-1323	1	-2
4	KJH-B	F	47	220	-2	-13	-6	-19	-9	-136	-4	-6
5	SM-B	F	24	220	-4	3	-5	5	-1	188	-17	-2
6	NBL-B	F	25	220	5	3	0	-1	-3	-143	-5	1
7	AJ-B	M	24	110	0	13	3	0	8	932	0	5
8	MSM-B	M	23	110	-2	1	-1	40	-5	-1152	3	-11
9	BHA-B	M	22	110	6	-5	-3	-31	2	-898	11	-3
10	MO-B	M	28	110	-4	4	-8	-20	3	-1523	5	2
11	AH-B	M	16	110	6	3	0	-73	-2	141	-3	-2
12	JJ-B	M	33	110	-4	3	-4	2	-3	28	28	-3
Mean						1513.5	27.5	2548.42	24.5833	3834.33	3834.83	18.8333
sd						6.18098	3.54516	27.6192	5.29937	803.968	10.8195	3.98006
cv						0.40839	12.8915	1.08378	21.5568	20.9676	0.28214	21.1331
						0.75	-2.75	-10.5	-0.58333	-259.5	1.16667	-2.25
Difference in percent of mean						0%	-10%	0%	-2%	-7%	0%	-12%

Table 4: Comparing "Sygyt Ltd"-"VoceVista" at the same millisecond.

The same sound recording was analyzed for the two different softwares. As the fundamental frequency (F0) changes over time during the sound recording, it was essential that the results of the "Sygyt Ltd" and "VoceVista" were evaluated at the exact same millisecond for the sound recording.

Table 4 shows the difference in formants of F0 between the "Sygyt Ltd" and the "VoceVista" sound analysis software over 1000Hz. As can be seen for the Fx, Fy and Fz, the mean Hz were 1513, 2548 and 3834, respectively with a difference between the software of 0.75, -10.5 and -259.5 Hz. The difference in percentage of mean shows that the difference is 0, 0 and -7%, corresponding to almost identical assessment of the formants around 1500 Hz and 2550 Hz.

As "Sygyt Ltd" results of up to 20000 Hz can be measured, we tried to study the normal persons for a start for variation of the formants near 10000 Hz. With "SAS program 9,4" using "the Spearman Rank correlation coefficient test", the variation was 4,3% (Table. 5).

Nr.	Name	Gender	Age	RC (Hz)	RC (dB)	F 10k (Hz)	F 10k (dB)
1	MP-B	F	75	363	58	10125	14
2	ACA-B	F	25	365	52	10615	27
3	LTC-B	F	40	523	71	10325	21
4	KJH-B	F	47	457	41	10142	16
5	SM-B	F	24	415	49	9727	11
6	NBL-B	F	25	410	63	11138	24
7	AJ-B	M	24	205	63	10750	14
8	MSM-B	M	23	201	46	10448	15
9	BHA-B	M	22	224	49	10136	11
10	MO-B	M	28	231	48	9576	21

11	AH-B	M	16	180	14	10571	17
12	JJ-B	M	33	206	49	9969	15

Table 5: Variation of the formants near 10000 Hz with "Sygyt Ltd".

STD 441.4833

MEAN 10293.5

Coefficient of Variation (CV) 4.3%

High speed films and acoustical measurements were made simultaneously of the prospective cohort study of the 12 normal persons, and analyzed with "Sygyt Ltd". The results of formant variation made with "Sygyt Ltd" are on the same level as "VoceVista" due to the variation of F0. Table 6 presents the variation of 3 formants 1000-5000 Hz from acoustical measures made simultaneously with high speed films, with acoustical setting in the high speed software by Wolf Ltd.

Nr.	Name	Gender	Age	ms	F0 (Hz)	F0 (dB)	(Fa) (Hz)	(Fa) (dB)	Fx (Hz)	Fx (dB)	Fy (Hz)	Fy (dB)	Fz (Hz)	Fz (dB)
1	MP-A	F	75	520	327	64			1320	35	2312	34	3271	18
2	ACA-A	F	25	70	251	48			1261	33	2241	30	4025	28
3	LTC-A	F	40	1130	329	45			1401	28	2295	20	3357	9
4	KJH-A	F	47	850	142	15			1293	39	2328	24	3028	27
5	SM-A	F	24	900	307	38			1606	38	3206	25	4004	26
6	NBL-A	F	25	640	377	64			1131	23	2258	22	3411	14
7	AJ-A	M	24	120	216	56			1293	48	2371	40	3449	40
8	MSM-A	M	23	1060	158	38			1115	38	2549	29	3341	21
9	BHA-A	M	22	1210	266	47			1320	51	2904	30	4230	20
10	MO-A	M	28	440	211	49			1077	42	2373	28	4694	19
11	AH-A	M	16	430	139	42			1385	23	2500	28	3336	16
12	JJ-B	M	33	160	196	20			1040	12	1697	12	2204	19
Difference to Sygyt sound analysis of 12 normal persons														
Coefficient of variation (cv)				mean					1513.5		2548.4		3834.8	
				change mean					243.3		128.9		305.7	
				std					270.0		632.7		923.4	
				cv					18%		25%		24%	

Table 6: Variation of 3 formants from high speed films were of the same % variation.

Results/Discussion

The results show that formant measures are possible routinely. A normal material has been presented with a variation of the 3 formants over 1000 Hz of 18-25%. Since the literature is calling for more evidence based studies, we refer to measuring the formants between 1000 Hz-5000 Hz in pathology. Formant analysis with the program "Sygyt Ltd." might be a tool not only for qualified singers, but also in pathology [1,2].

From the literature we have essential documentation that evidence based voice diagnosis in pathology is lacking:

Surgical versus non-surgical interventions for vocal cord nodules:

This is a Cochrane review first published in The Cochrane Library in Issue 2, 2012 and previously updated in 2007 and 2009.

Vocal cord nodules are bilateral, benign, callous-like growths of the mid-portion of the membranous vocal folds. They are of variable size and are characterized histologically by thickening of the epithelium with a variable degree of inflammation in the underlying superficial lamina propria. They characteristically produce hoarseness, discomfort and an unstable voice when speaking or singing .

To assess the effectiveness of surgery versus non-surgical interventions for vocal cord nodules we searched the Cochrane Ear, Nose and Throat Disorders Group Trials Register; the Cochrane Central Register of Controlled Trials (CENTRAL); PubMed; EMBASE;

CINAHL; Web of Science; BIOSIS Previews; Cambridge Scientific Abstracts; ISRCTN and additional sources for published and unpublished trials. The date of the most recent search was 9 April 2012.

When searching for randomized and quasi-randomized trials comparing any surgical intervention for vocal cord nodules with non-surgical treatment or no treatment (including acoustical measures) no suitable trials were identified. No studies fulfilled the inclusion criteria. There is a need for high-quality randomized controlled trials to evaluate the effectiveness of surgical and non-surgical treatment of vocal cord nodules [3].

Reliability of objective voice measures of normal speaking voices:

The objective was to determine the reliability of objective voice measures used commonly in clinical practice. 18 healthy volunteers (nine males and nine females) were included. Measures of laryngeal efficiency and perturbation measures of fundamental frequency (F0) for both genders were made. For female cepstral peak prominence (CPP) had moderate reliability, whereas for males, the smooth CPP was reliable. Noise-to-harmonic ratios (NHRs) has the lowest consistency of all measures over the course. Additional research is needed to investigate which factors within the testing protocol and/or changes to the measurement instruments may lead to more consistent test results [4].

Evidence-based Clinical Voice Assessment: A Systematic Review.

To determine what research evidence exists to support the use of voice measures in the clinical assessment of patients with voice disorders.

Literature studies provide measurements results of selected acoustic, laryngeal imaging-based, auditory-perceptual, functional, and aerodynamic measures. There is clearly a pressing need for high-quality research that is specially designed to expand the evidence base for clinical voice assessment [5].

Conclusion

Measures of high speed films combined with overtones/harmonics with “VoceVista” and “Sygyt Ltd.” show that they are comparable up to 5000 Hz. “Sygyt Ltd” has a range up to 20.000 – 30.000 Hz. “Sygyt Ltd.” can therefore be used for formant analysis in clinical praxis for at least 10.000 Hz as it was done in the prospective cohort study of 12 normal patients.

The approach in clinical praxis must be simple-therefore we suggest using high speed films simultaneously to F0 around 110 Hz in males and 220 Hz in females analysed with “Sygyt Ltd.” as a basis for voice pathology. Formant analysis and high speed films simultaneously could give much more information of treatment effect in voice pathology.

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