IMAGE ANALYSIS FOR EVALUATION OF RHINOPLASTY EFFECT

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When evaluating facial operations in plastic surgery, a subjective evaluation of a result is used as well as an objective analysis of effect of an operation. At first, it is crucial to evaluate an esthetic optimum on the basis of parameters evaluating a facial profile; however, a design of each individual correction depends also on personal somatotype. A somatometric analysis of the digitized image and a subsequent confrontation of the gained information with the stated parameters create a methodical approach to result objectification. Application of methods of geometric morphometry is a perspective in this field.

Key words:

Image analysis, Rhinoplasty, Geometric morphometry, Facial attractiveness

1. Methods

Rated persons: 30 female patients before rhinoplasty and after the surgery, control dataset of 20 students (average age of 18 - 23 years). Clinical documentation and profile pictures, taken in the standardized manner, were used for evaluation.

Somatometric measurement: The selected somatometric points were marked for profile evaluation on the digitized pictures (Figure 1). There were 5 parameters chosen; according to literature, these parameters correlate with profile attractiveness: nasofrontal angle (NFA), nasolabial angle (NLA), nasal

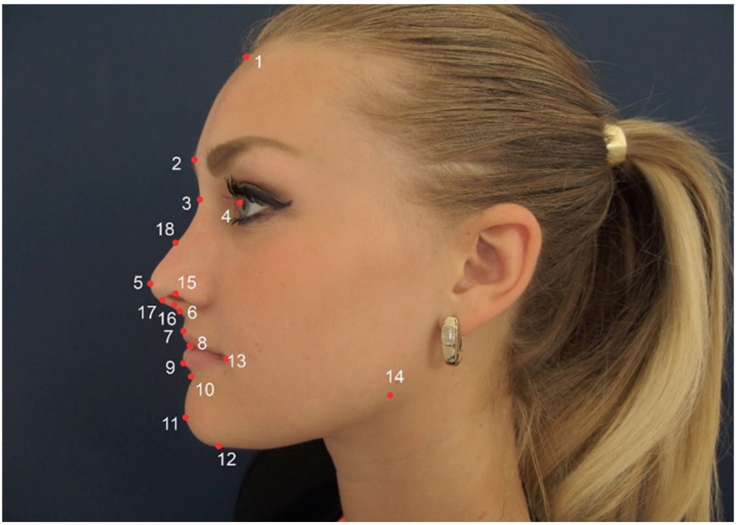

Figure 1 — Selected landmark points for profiles rating

tip projection (NTP), columellar show (CS) and nasion-cornea distance (CND). Further, the values of the stated parameters were determined within the respective proper program, which is based on the measured x-y coordinates.

Esthetic optimum rating: The rating was carried-out by three vocational groups: make-up artists, physicians and students (44 raters); gender and age of the raters were recorded also. Precondition was a different accent on perception of facial expression from psychosocial, morphological and esthetical points of view. The 7-grade Likert scale was used: very attractive, attractive, rather attractive, average, rather unattractive, unattractive and very unattractive. The points were assigned within the scale: 3, 2, 1, 0, -1, -2, -3. Averages of the summarized values for particular probands were utilized in further evaluations.

Statistical analysis: 95 % confidence intervals within the three rated groups were calculated for all the parameters. Further, there were considered the differences in values of particular persons before and after rhinoplasty. The difference in average values of particular parameters before and after the surgery was examined by a paired t-test. Due to the paired rating and interconnection of cephalometric data, the linear regression model can be used. The model examines an impact of explaining variables - a difference in values after and before the surgery on a dependent variable - the difference in score of attractiveness before and after the surgery. Data of all the considered parameters follow normal probability distribution, therefore, it is possible to use a simple multivariate linear regression (Chart 1). Multivariate linear regression with interactions was also used in order to determine which absolute values of

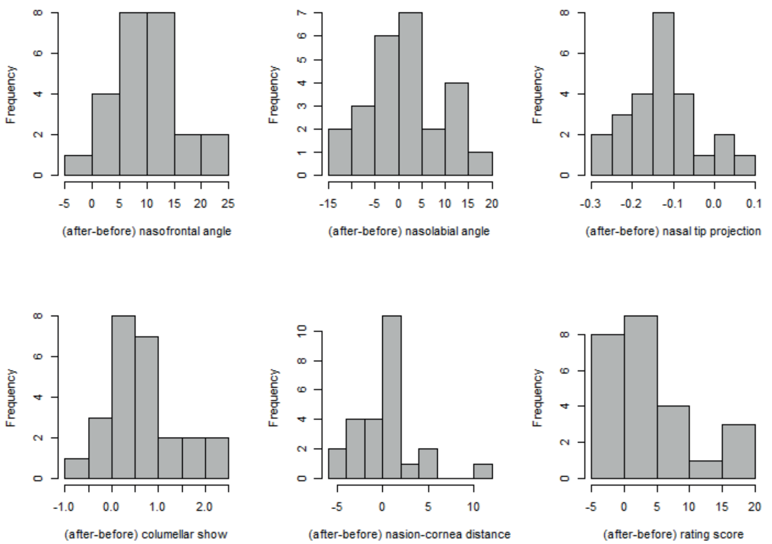

Chart 1 — Histograms of cephalometric data the parameters most influence the mentioned rating of attractiveness. All of the statistical analyses were performed using the R programming language [6].

Geometric morphometry: The pictures of faces were analyzed by methods of geometric morphometry, which is a complex of analytical methods for multidimensional statistical analysis of shape variation. The 23 anatomically defined landmarks - including 6 semi-landmarks indicating facial curves were marked on the facial photographs of profiles. The gained configurations of landmarks and semi-landmarks were superposed by means of generalized Procrustes analysis by the software tps.Relw. ver.1.53. This procedure standardizes size of objects and almost eliminates effects of rotation and position by minimizing the distance between individual landmarks. Standardized shape coordinates were further used for multivariate analysis of variance (MANOVA), where the shape data represented a dependent variable, while affiliation of the object with the group before (-1) and after (1) the surgery was a predictor variable. The result of difference between the averages of configuration profiles before and after the surgery was then visualized using the extrapolation function TPS (thin-plate spline) showing changes in shape (grid deformation) derived from average configuration of landmarks. (Figure 2)

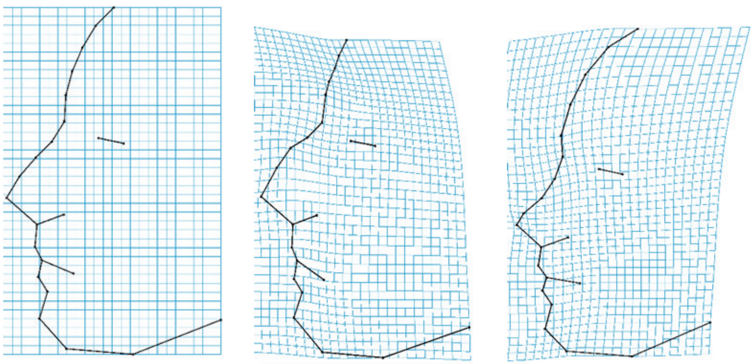

Figure 2 — Results of geometric morphometry for population average, state before rhinoplasty and state after rhinoplasty.

2. Results

Differences in confidence intervals: The differences, showed in the table bellow, were found in individual parameters of the rated groups (Table 1):

	Before surgery (95%CI)	After surgery (95% CI)	Control group (95%CI)
Nasofrontal angle [°]	136.6 – 141.4	147.1 – 151.3	139.4 – 145.7

	Before surgery (95%CI)	After surgery (95% CI)	Control group (95%CI)
Nasolabial angle [°]	107.5 – 114.3	108.5 – 117	108.3 – 117.2
Nasal tip projection	0.68 – 0.75	0.56 – 0.62	0.51 – 0.6
Collumellar show [mm]	3.1 – 3.9	3.7 – 4.5	4.2 – 5.2
Nasion-cornea distance [mm]	15.2 – 17.6	15.2 – 18.1	9.5 – 12.7

Table 1 — 95% confidence intervals of cephalometric data before and after surgery

Differences in average values: Paired t-tests comparing the parameters before and after operation were performed and Bonferroni correction for multiple testing was envisaged, alfa = 0.05/5 = 0.01 (Table 2). Average values of the parameters before and after rhinoplasty are displayed in Chart 2.

Operationeffects (before – aftersurgery)	p-value
Nasofrontalangle	$< 10^{-8}$
Nasolabialangle	0.27
Nasal tip projection	$< 10^{-6}$
Columellar show	$< 10^{-3}$
Nasion-cornea distance	0.70

Table 2 — Rhinoplastyeffects, significanceofpaired t-tests

Attractiveness rating: In the attractiveness rating, the difference in gender is applied. In average, female raters rate higher than males. The difference is significant at the significance level $p < 0.023$ (unpaired t-test). 95% confidence interval for average score is (-0.46; 0.05) in case of males and (0.05; 0.49) in case of females (see Chart 3).

Linear model: Linear model has a common shape.

$$rating_{before\text{-}after} = \beta_0 + \beta_1 \cdot NFA_{a\text{-}b} + \beta_2 \cdot NLA_{a\text{-}b} + \beta_3 \cdot NTP_{a\text{-}b} + \beta_4 \cdot CS_{a\text{-}b} + \beta_5 \cdot CND_{a\text{-}b}$$

where β_i are the coefficients of variations, a is an abbreviation for "after" and b for "before". The resulting linear model, which best fits the data, is as follows

$$rating_{before\text{-}after} = 0{,}869 + 0{,}061 \cdot NFA_{a\text{-}b} + +0{,}044 \cdot NLA_{a\text{-}b}$$

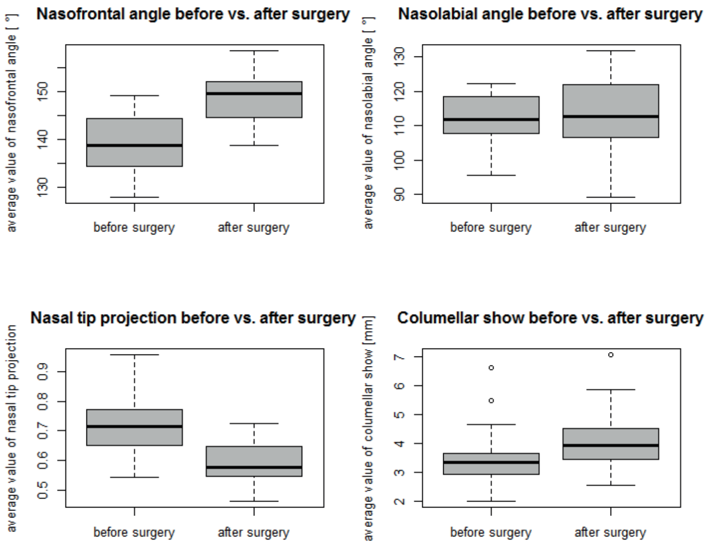

Chart 2 — Boxplots of average values of the attractiveness parameters

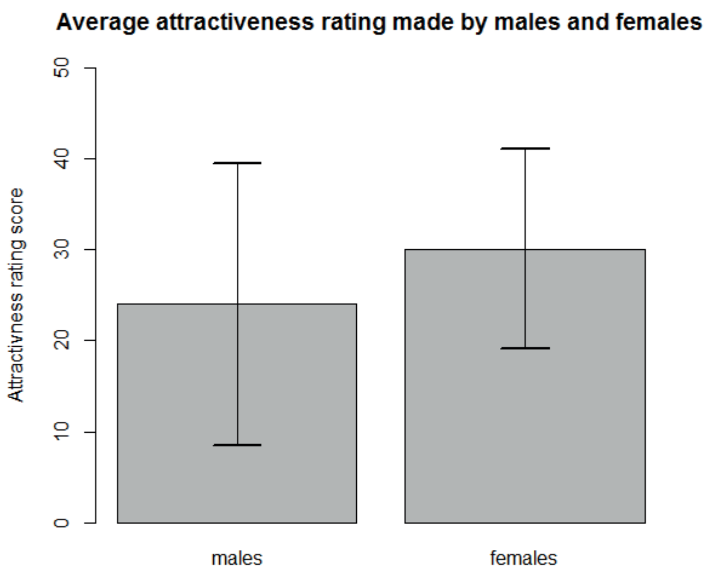

Chart 3 — Difference in attractiveness rating made by males and females.

and the other coefficients are below the significance level. The 95% confidence interval is (0.07; 1.67) forβ_0, $p <0.035$, for$\beta_1$is (0.00; 0.13), $p <0.070$, forβ_2 it is (0.00; 0.09), $p < 0.051$, respectively.
Values of standardized coefficients areβ_1= 0,46 (nasofrontal angle), β_2= 0,48 (nasolabial angle).
Coefficients of the linear model for evaluation of attractiveness are as follows (Tab. 3)

	Estimate	Std. Error	t-value	p-value
(Intercept)	-33.64718	10.92223	-3.081	0.007
Nasolabialangle	0.05081	0.01666	3.049	0.007
Nasal tip projection	47.53811	15.56234	3.055	0.007
Columellar show	3.44643	1.83881	1.874	0.078
Nasion-cornea distance	0.81234	0.41029	1.980	0.064
Nasal tip projection vs. columellar show	-5.75391	2.95230	-1.949	0.068
Nasal tip projection vs. nasion-cornea distance	-1.31208	0.69429	-1.890	0.076

Table 3 — Output of the linear regression model describing the parameters of attractiveness and their influence on attractiveness ratings

Geometric morphometry: The differences between the average configurations of geometric morphometry before and after the surgery were statistically convincing for both the left (p=0.001) and the right profile (p=0.004); the significance levels were determined by a permutation test of Goodall´s F statistic using 5000 randomizations. When comparing the average configurations before and after the surgeon´s intervention, the changes in shape of the nasal area, the character of which will be assessed bellow, are represented.

3. Discussion

From the esthetic point of view, patients assess their post operative conditions very positively in most cases. The question is, however, nature of resulting visage changes, which should be in conformity with other parts of a face [1]. This issue requires not only comparison with the esthetic ideals but also with the individual somatotype [3]. Solution of this issue presumes mainly appraisal of rhinoplasty results by attractiveness scaling methods following the facial parameters values [4]. The gained results indicate particularly the application degree of each feature rated, which may be particularly beneficial in terms of planning of operations. Employment of methods of geometric morphometry allowing objectification of multidimensional relationships seems to be very promising in this matter [5].

After the surgery, the nasofrontal angle was increasedin averagewithin the group of patients; the change compared to 95% confidence interval of angle before the surgery is significant. The growth of the average size of nasofrontal angle is expectable; many female patients arrive with a "hook nose" (gibbusnasi), which decreases the angle value prominently, and the correction then leads to blunt of the angle. Reference range for nasofrontal angle of females in common population, as specified in literature, is relatively wide, 120° - 150° [2].Nasal tip projectiondiffers significantly before and after the surgery, in cases of female patients ($p<0.05$).The mentioned projectionis to a certain extent related to size of nasofrontal angle (the sharper, i.e., smaller, nasofrontal angle, the bigger nasal prominence). The surgery led to the change of confidence interval for relative nasal prominence of female patients towards the value of 0.55-0.60, which is common in population and stated in literature [2]. Even though the columellar show (height of nostril) of female patients and control female population exceeds the standard of 2-4 mm stated in literature [2], the surgery moved the female patients closer to values of control female population. Location of nasion against tangent plane of cornea was not anyhow influenced by the surgery.

Nasal prominence is not applied in the model, what can be explained by the fact that it does not bring any new information unlike both mentioned angles (a nose with big relative prominence has a low nasofrontal and nasolabial angle); therefore, the prominence would be only a confounder. It is rather impossible to change nasion by the surgery, therefore, the difference in its distance to cornea is also not applied in the model.

According to the standardized coefficients, absolute value of facial attractiveness (in sense of rating) seems to be most influenced (both positively and/or negatively) by nasal tip projection, lesser by columellar show and nasion-cornea distance and the least by nasolabial angle. The other considered parameters do not prove enough statistical evidence for application in the model.

Visualizations gained by geometric morphometry models a theoretical shape transformation of other facial parts, which are necessarily associated to the change of nasal morphology [5]. Individual defined landmarks are not in fact independent on each other, contrarily, these elements create one holistic configuration. Change in one feature point more or less causes change in other feature points.

4. Conclusions

1. The changes of basic cephalometric data after rhinoplasty, which were compared with standard values, were described. Correction success level was documented primarily by nasal prominence reduction, or more precisely by increase in nasofrontal and nasolabial angle.

2. The relations between the cephalometric data and attractiveness rating were evaluated also. A significant quantitative dependence on level of changes of nasofrontal and nasolabial angle, in terms of computed weights was proven.
3. The method of geometric morphometry shows significant post-operative changes from the point of view of objectified combination of facial features. The level of difference of the resulting state from the standard population will be subjected to further analysis.

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