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ORIGINAL ARTICLE

Soft tissue outcome after mandibular advancement—an anthropometric evaluation of 171 consecutive patients

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Abstract
Objectives There is an ongoing discussion in the literature about preoperative planning and postoperative evaluation of orthognathic surgery and its impact on facial appearance and aesthetics.
Materials and Methods We present an anthropometric and cephalometric evaluation of orthognathic surgery results based on reference anthropometric data. In 171 Class II patients, mandibular advancement by bilateral sagittal split osteotomy was performed. Preoperative as well as 3 and 9 months postoperative standardized frontal view and profile photographs and lateral cephalograms were evaluated in a standardized manner by use of 21 anthropometric indices. In cephalograms, SNA and SNB angle as well as Wits appraisal were investigated. Results of anthropometric and cephalometric measurements were correlated.
Results Lower vermilion contour, vermilion and cutaneous total lower lip height, nose–lower face height, nose–face height, upper face–face height, upper lip– and chin–mandible height index showed significant pre- to postoperative changes as well as SNB angle and Wits appraisal. Furthermore, medial–lateral cutaneous upper lip height, vermilion and cutaneous total lower lip height and philtrum–mouth width index presented significant correlations to cephalometric measurements.
Conclusions The investigated anthropometric indices and cephalometric measurements presented reproducible results related to surgery. The correlation of cephalometric to anthropometric measurements has been proven useful for preoperative planning and postoperative evaluation of orthognathic surgery patients.
Clinical relevance The presented anthropometric measurements and their observed correlation to cephalometric measurements could lead to a better prediction and optimized planning of the soft tissue result in orthognathic surgery patients and thereby improve the aesthetic outcome.

Keywords Mandibular advancement · Class II · Orthognathic surgery · Anthropometry

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Introduction

The desire to improve facial aesthetics and appearance is, among others, an important reason in seeking orthognathic treatment [1, 2]. Orthognathic surgery requires both jaws and teeth to be manipulated in three dimensions to obtain the best aesthetic and functional result [3, 4].

In order to achieve excellent results, it is indispensable to perform an objective and quantitative planning and evaluation of the treatment quality.

To date, evaluation of postoperative aesthetic results after orthognathic surgery mainly consists of the investigation of subjective measurements of patients', surgeons' and/or observers' satisfaction [5]. However, this type of evaluation is subjective and requires a complete understanding of the aesthetic morphology of the face.

In orthognathic surgery, both bony and soft tissue, undergo considerable changes, while the judgement of aesthetic outcomes after orthognathic surgery mainly depends on the evaluation of soft tissue changes [6].

These soft tissue changes may be quantified by facial anthropometric measurements described by Farkas [7, 8]. Normative anthropometric measurements of the face are related to attractiveness [9]. The usefulness of these normative values has been widely recognized. They have already proven useful in the field of aesthetic surgery [10, 11], as well as in planning changes of facial proportions by orthodontics [7, 12].

We feel that photo-assisted anthropometric measurements of the face may help to adequately rate and quantify outcomes after orthognathic surgery.

Currently, most studies report pre- to postoperative facial changes by cephalometric measurements on lateral cephalograms [13, 14].

Here, we compared the results of the anthropometric measurements to cephalometric measurements. Comparing results of anthropometric measurements to an evaluation of lateral cephalograms helps to achieve a highly reliable and valid evaluation after orthognathic surgery [15].

In a group of 171 Class II patients undergoing bilateral sagittal split osteotomy for mandibular advancement, preoperative anatomic landmarks and facial relationships were measured on standardized photographs. Cephalometric measurements of SNA and SNB angle, as well as Wits appraisal were performed as well. Changes resulting from surgery were measured 3 and 9 months postoperatively and compared to the preoperative values. In addition, we investigated possible correlations between anthropometric and cephalometric measurements.

Patients and methods

All patients were operated between January 2006 and March 2011 at the Department of Cranio-Maxillofacial Surgery at the University Hospital Jena, Germany. They all exhibited a bilateral dentition of at least first molar to first molar. They all underwent orthodontics and orthognathic surgery, but no genioplasty or rhinoplasty. Patients with congenital deformities, such as cleft lip and/or palate, were excluded.

After presurgical orthodontic treatment, the planned postoperative position of the mandible was determined on dental casts and cephalograms.

Bilateral sagittal split osteotomy was performed in a standardized manner as described before [16, 17].

A photo- and radiographic description of an exemplary patient is shown in Fig. 1.

Objective Rating Scheme

Coloured frontal view and profile photographs were taken the day before surgery, as well as 3 and 9 months postoperatively by a professional photographer with a Nikon D 80 camera (objective, Nikon AF Micro Nikkor 105 mm 1:2.8 D; aperture, f13; Nikon Corp, Tokyo, Japan) in a standardized manner as described elsewhere [18]. Only photographs in which patients' face was clearly at rest and in which the interpupillary axis was at the same level as the camera lens were selected to avoid photographic distortion. Photographic analysis was performed using the Adobe Photoshop CS2 (Adobe Inc, San Jose, CA) software tool.

Based on anthropometric values described by Farkas [7, 8] predefined anatomic landmarks (Table 1) and distances (Table 2) were used to calculate the following indices (see Table 3) in the frontal view photographs (see also Fig. 2): (1) upper lip height–mouth width index, representing the relation between upper lip height (ULH, sn–sto) and mouth width (MW, ch–ch). (2) Philtrum-–mouth width index, the philtrum width (cph–cph), as percentage of the MW (ch–ch). (3) Medial–lateral cutaneous upper lip height index representing the cutaneous upper lip height (CULH, sn–ls), as percentage of the lateral upper lip height (sbal–ls′). (4) Upper vermilion contour index, the MW as percentage of the upper vermilion arc (UVA, ch–ls–ch). (5) Lower vermilion contour index, the MW as percentage of the lower vermilion arc (LVA, ch–li–ch). (6) Vermilion arc index, the LVA as percentage of the UVA

In the profile photographs, the following data were recorded (see also Fig. 3): (1) vermilion–total upper lip height index represented by the upper vermilion height (UVH, ls–sto), as percentage of the ULH (sn–sto). (2) CULH (sn–ls) as percentage of the ULH (sn–sto). (3) Vermilion height index, represented by the UVH (ls–sto), as percentage of the lower vermilion height (LVH, sto–li). (4) Vermilion total lower lip height index, the LVH (sto–li) as percentage of the lower lip height (LLH, sto–sl). (5) Cutaneous–total lower lip height index represented by the cutaneous lower lip height (CLLH, li–sl), as percentage of the LLH (sto–sl). (6) Nasal tip protrusion–nose height index, the nasal tip protrusion (sn–prn), as percentage of the nose height (NH, n–sn). (7) Ala length–nose height index, representing the ala length (ac–prn), as percentage of the NH (n–sn) (8) Nasal bridge index, the nasal bridge length (n–prn) as percentage of the NH (n–sn). (9) Nose–upper face height index, the NH (n–sn), as percentage of the upper face height (UFH, n–sto). (10) Nose–lower face height index, the NH (n–sn), as percentage of the lower face height (sn–gn). (11)

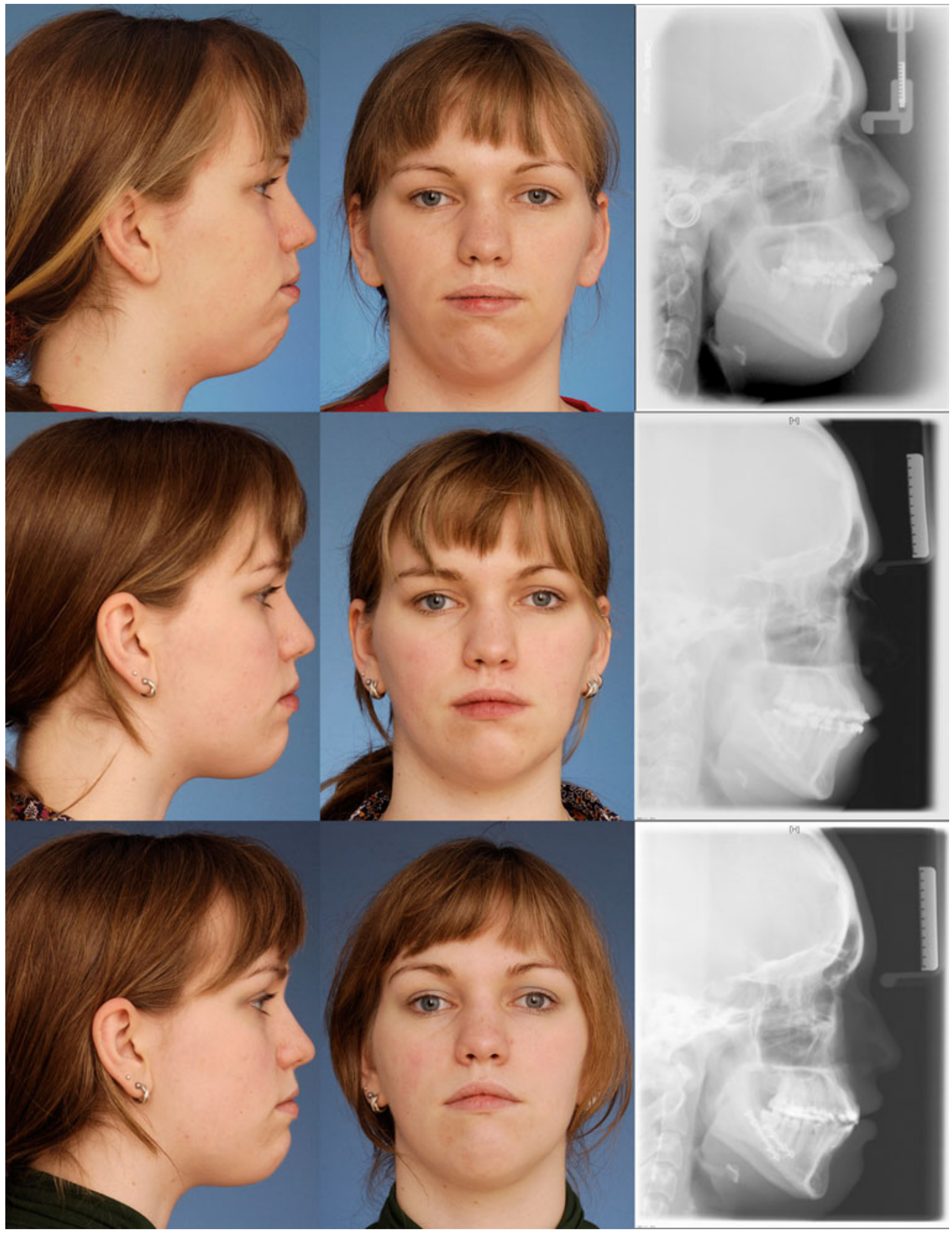

Fig. 1 Standardized photographs and lateral cephalograms of a 21-year-old woman undergoing mandibular advancement. Preoperative situation above, in the middle the situation 3 months postoperative and below 9 months postoperative

Nose–face height index, the NH (n–sn), as percentage of the face height (FH, n–gn). (12) Upper lip–nose height index, the ULH (sn–sto), as percentage of the NH (n–sn). (13) Upper face–face height index, the UFH (n–sto), as percentage of the face height (n–gn). (14) Upper lip–mandible height index, representing the ULH (sn–sto), as percentage of the mandible height (MH, sto–gn). (15) Chin–mandible height index, the chin height (CH, sl–gn), as percentage of the MH (sto–gn).

Furthermore, lateral cephalograms were taken preoperatively as well, as 3 and 9 months postoperatively in a standardized manner using a cephalostat in norma lateralis. SNA and SNB angle as well as Wits appraisal as established

Table 1 Used anthropometric landmarks based on the investigations by Farkas and Munro

N	Nasion
Sn	Subnasale
Sbal	Lateral subalare
Ac	Alar curvature point
Prn	Pronasale
Ch	Cheilion
Cph	Crista philtre
Sto	Stomion
Ls	Labiale superius
Ls′	Labiale superius lateralis
Li	Labiale inferius
Sl	Sublabiale
Gn	Gnathion

Table 2 Used anthropometric distances based on the investigations by Farkas and Munro

NH	Nose height, n–sn
NTP	Nasal tip protrusion, sn–prn
AL	Ala length, ac–prn
MW	Mouth width, ch(l)–ch(r)
PW	Philtrum width, cph(l)–cph(r)
ULH	Upper lip height, sn–sto
CULH	Cutaneous upper lip height, sn–ls
UVH	Upper vermilion height, ls–sto
UVA	Upper vermilion arc, ch(l)–ls–ch(r)
LULH	Lateral upper lip height, sbal–ls′
LLH	Lower lip height, sto–sl
LVH	Lower vermilion height, sto–li
LVA	Lower vermilion arc, ch(l)–li–ch(r)
CLLH	Cutaneous lower lip height, li–sl
FH	Face height, n–gn
UFH	Upper face height, n–sto
LFH	Lower face height, sn–gn
MH	Mandible height, sto–gn
CH	Chin height, sl–gn

cephalometric measurements in the judgement of orthognathic surgery were raised.

Statistical Analysis

An univariate ANOVA was conducted to evaluate effects of time (preoperative, 3 and 9 months postoperative) on all variables. In case of a significant effect of time for a variable, post hoc comparisons with Bonferroni correction were applied. Furthermore pre- to postoperative differences of SNA and SNB angle and Wits appraisal were linearly correlated to corresponding differences of all anthropometric measurements using the Spearman method.

Results

All 171 white Caucasian patients, 104 (60.8 %) women and 67 (39.2 %) men included in this study underwent bilateral sagittal split osteotomy for mandibular advancement. Average age was 32.27±9.85 years at time of surgery.

A comparison of the cephalometric and photographic measurements is shown in Table 4.

SNB angle ($p<.001$) and Wits appraisal ($p<.001$) showed significant changes in the comparison of pre- to postoperative values three as well as 9 months after surgery.

Photo-assisted anthropometric measurements yielded significant pre- to postoperative changes 3 months after surgery on the following indices: lower vermilion contour ($p=.002$), vermilion total lower lip height ($p<.001$), cutaneous total lower lip height ($p<.001$), nose–lower face height ($p<.001$), nose–face height ($p=.002$), upper face–face height (<.001), upper lip–mandible height (<.001) and chin–mandible height ($p<.001$).

Table 3 List of the names and descriptions of the applied anthropometric indices described by Farkas

Dimension	Name of index	Description
En face indices	Upper lip height–mouth width index	Subnasale–stomion/cheilion(I)–cheilion(r)
	Philtrum–mouth width index	Crista philtre(r)–christa philtre(I)/cheilion(I)–cheilion(r)
	Medial–lateral cutaneous upper lip height index	Subnasale–labiale superius/subalare–labiale superius lateralis
	Upper vermilion contour index	Cheilion(r)–cheilion(I)/cheilion(r)–labiale superius lateralis
	Lower vermilion contour index	Cheilion(r)–cheilion(I)/cheilion(r)–labiale inferius–cheilion
	Vermilion arc index	Cheilion(r)–labiale inferius–cheilion(I)/cheilion(r)–labiale superius–cheilion
Profile indices	Vermilion total upper lip height index	Labiale superius–stomion/subnasale–stomion
	Cutaneous total upper lip height index	Subnasale–labiale superius/subnasale–stomion
	Vermilion height index	Labiale superius–stomion/stomion–labiale inferius
	Vermilion total lower lip height index	Stomion–labiale inferius/stomion–sublabiale
	Custaneous total lower lip height index	Labiale inferius–sublabiale/stomion–sublabiale
	Nasal tip protrusion–nose height index	Subnasale–pronasale/nasion–subnasale
	Ala lenght–nose height index	Alar curvature point–pronasale/nasion–subnasale
	Nasal bridge index	Nasion–pronasale/nasion–subnasale
	Nose–upper face height index	Nasion–subnasale/nasion–stomion
	Nose–lower face height index	Nasion–subnasale/subnasale–gnathion
	Nose–face height index	Nasion–subnasale/nasion–gnathion
	Upper lip–nose height index	Subnasale–stomion/nasion–stomion
	Upper face–face height index	Nasion–stomion/stomion–gnathion
	Chin–mandible height index	Sublabiale–gnathion/stomion–gnathion

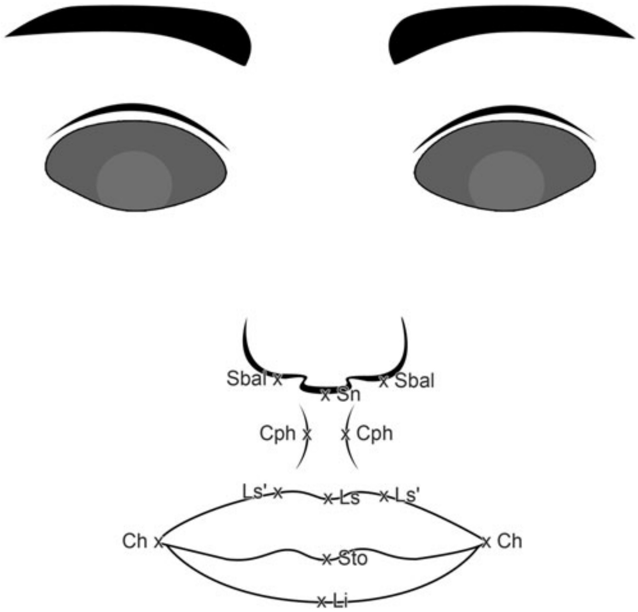

Fig. 2 Schematic frontal view image with description of the used anthropometric distances. Mouth width (*ch–ch*), philtrum width (*cph–cph*), upper lip height (*ls–sn*), lateral upper lip height (*sbal–ls'*), upper vermilion arc (*ch–ls–ch*), and lower vermilion arc (*ch–li–ch*)

Nine months after surgery, the indices of lower vermilion contour (p=.002), vermilion total lower lip height (p<.001), cutaneous total lower lip height (p<.001), nose–lower face height (p<.001), nose–face height (p=.005), upper face–face height (<.001), upper lip–mandible height (<.001) and chin–mandible height (p<.001) yielded significant changes as compared to the preoperative values.

The differences of pre- to 3 months postoperative of SNB angle and medial–lateral cutaneous upper lip height index were significantly correlated (Rho=−0.223, p=.003). Pre- to 9 months postoperative SNB angle showed a significant correlation to vermilion total lower lip height index (Rho=−0.167, p=.029) and cutaneous total lower lip height index (Rho=0.169, p=.027). In the comparison of the preoperative to the 3 months postoperative values Wits appraisal showed a significant correlation to philtrum–mouth width index (Rho=0.178, p=.02). The same correlation holds true 9 months postoperatively (Rho=0.173, p=.024).

All other investigated anthropometric parameters did not show significant pre- to postoperative changes or significant correlations.

Fig. 3 Schematic profile-view image with description of the used anthropometric distances. Nose height, *n–sn*; nasal tip protrusion, *sn–prn*; ala length, *ac–prn*; upper vermilion height, *ls–sto*; lower vermilion height, *sto–li*; cutaneous upper lip height, *sn–ls*; cutaneous lower lip height, *li–sl*; upper vermilion height, *ls–sto*; lower vermilion height, *sto–li*; total upper lip height, *ls–sto*; total lower lip height, *sto–sl*; face height, *n–gn*; upper face height, *n–sto*; lower face height, *sn–gn*; mandible height, *sto–gn*; chin height, sl–gn

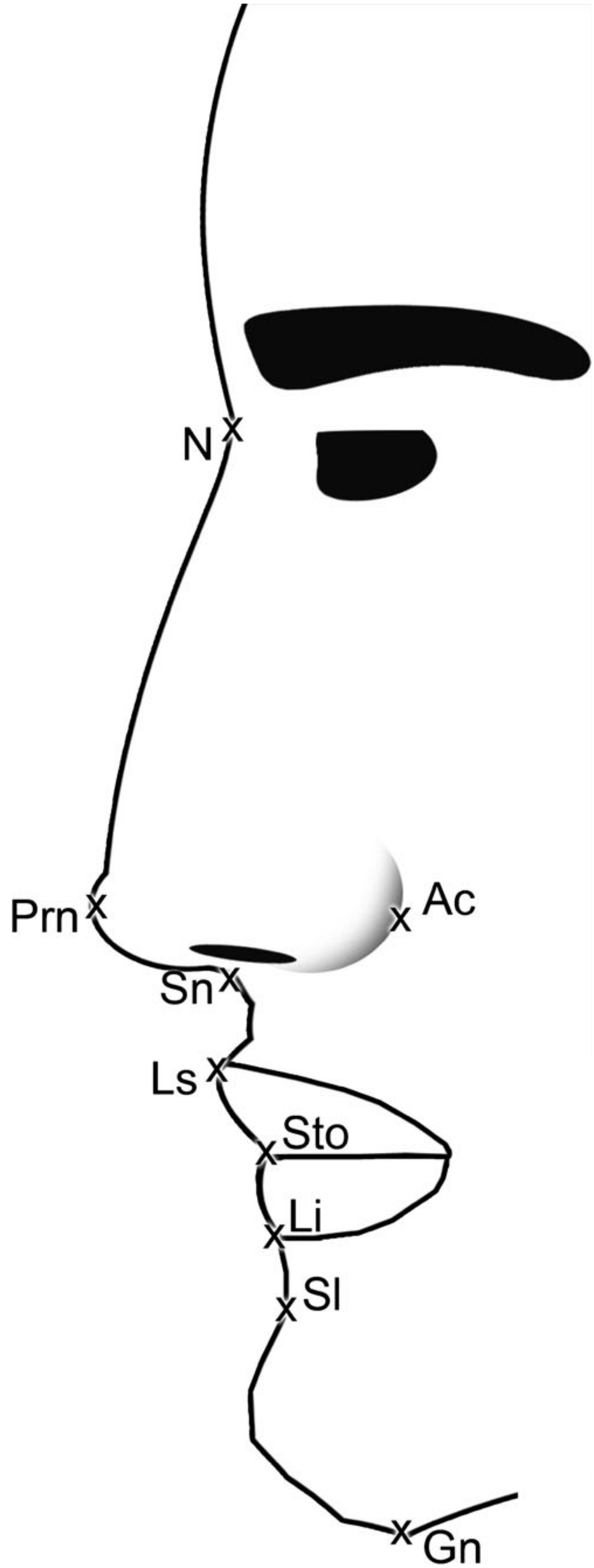

Table 4 Comparison of the results of anthropometric and cephalometric measurements preoperative and three as well as 9 months postoperative

	Preoperative	3 months postoperative	9 months postoperative	Sign.	Sign. pre-to 3 months postoperative	Sign. pre-to 9 months postoperative
SNA (°)	83.93±4.100	83.71±4.06	83.21±7.0	0.137		
SNB (°)	77.74±4.46	80.27±4.35	80.28±4.27	<0.001	<0.001	<0.001
Wits appraisal (mm)	8.15±4.81	2.25.±3.03	2.01±3.09	<0.001	<0.001	<0.001
Upper lip height–mouth width index (%)	42.53±6.48	42.68±6.57	42.94±7.06	0.361		
Philtrum–mouth width index (%)	21.03±3.11	20.83±3.31	21.02±3.30	0.545		
Medial–lateral cutaneous upper lip height index (%)	90.37±9.51	89.90±9.52	89.77±8.50	0.505		
Upper vermilion contour index(%)	94.25±3.59	94.44±3.60	94.53±3.60	0.178		
Lower vermilion contour index (%)	93.28±3.99	93.75±4.11	93.87±3.93	0.002	0.002	0.002
Vermilion are index (%)	100.60±5.90	100.35±6.41	100.14±5.99	0.408		
Vermilion total upper lip height index (%)	31.95±6.44	31.39±6.95	31.51±7.52	0.162		
Cutaneous total upper lip height index (%)	67.06±6.45	67.70±6.98	67.54±7.51	0.118		
Vermilion height index (%)	85.51±26.59	87.34±24.90	87.30±25.11	0.493		
Vermilion total lower lip height index (%)	57.22±16.03	48.72±12.37	48.76±11.85	<0.001	<0.001	<0.001
Cutaneous total lower lip height index (%)	41.84±16.01	50.35±12.37	50.29±11.84	<0.001	<0.001	<0.001
Nasal tip protrusion–nose height index (%)	38.46±3.82	38.70±4.64	38.36±3.84	0.442		
Ala lenght–nose height index (%)	57.37±5.40	57.19±5.24	57.35±5.45	0.690		
Nasal bridge index (%)	36.80±7.75	34.19±8.77	34.30±8.55	0.330		
Nose–upper face height index (%)	68.84±2.72	68.95±3.06	69.00±2.95	0.428		
Nose–lower face height index (%)	75.86±810	74.61±7.97	74.60±7.78	<0.001	<0.001	<0.001
Nose–face height index (%)	42.65±2.57	42.28±2.58	42.32±2.49	<0.001	0.002	0.005
Upper lip–nose height index (%)	43.91±5.67	43.82±6.66	43.67±6.04	0.683		
Upper face–face height index (%)	61.71.±2.46	61.12±2.19	61.05±2.14	<0.001	<0.001	<0.001
Upper lip–mandible height index (%)	50.28±6.35	48.69±5.92	48.53±5.96	<0.001	<0.001	<0.001
Chin–mandible height index (%)	64.07±5.26	61.78±4.34	62.06±4.16	<0.001	<0.001	<0.001

Discussion

Discussion of the Method

Two-dimensional analysis of the hard and soft tissue using cephalograms is the most commonly used method in clinical routine for planning and evaluating orthognathic surgery [19, 20]. Three-dimensional models based on video imaging [13], laser scan [6, 19], photography or CT-scan [21, 22] are also in use, but because of high costs and difficult application are not applied in clinical routine.

Overall, soft tissues show more significant changes after orthognathic surgery than the underlying hard tissues. The judgement of the aesthetic result mainly depends on changes of the soft tissues [6]. Most of the measurements currently in use for evaluation of soft tissue changes make use of defined cephalometric and anthropometric landmarks such as nasal tip, subnasale point, labrale superius and inferius, pogonion or menton [14, 20, 23]. Corresponding landmarks on cephalograms and two- or three-dimensional models are compared pre- to postoperatively. Pre- and postoperative changes have been reported in millimeters [4, 6, 13, 14, 24].

No three-dimensional models such as cone-beam-CT or three-dimensional photography were applied the presented study sample. These techniques have been proven useful in the planning and evaluation of orthognathic surgery as well, but it was the intention of the authors to focus on established two-dimensional cephalometric and anthropometric measurements, which are currently most widely used in the daily clinical routine [19, 20]. Even though the modern facial anthropometry bases on wide parts on the anthropometric relations described by Farkas, there is a lack of knowledge in the present literature regarding the systematic application of the anthropometric indices described by Farkas [7, 8] in the evaluation of orthognathic surgery. It has been pointed out that a better prognosis of postoperative soft tissue projection will potentially become available, if a correlative function of bony movement and subsequent soft tissue impact could be identified for different landmarks [15].

We feel that an evaluation of the pre- to postoperative changes by anthropometric indices as described by Farkas [7, 8] may adequately reflect the surgical outcome. These indices are able to describe the relation of different anthropometric landmarks and distances in one single term. Facial attractiveness is related to them [9, 25]. The application of the given indices on photographic measurements as we performed here has been shown to be entirely valid, as long as the selected anthropometric landmarks are readily identifiable and the correct standardized photographic technique has been used [1, 5].

The selection criteria for the 21 anthropometric indices consisted in the reliable identification of their corresponding anthropometric landmarks on standardized photographs, as well as their potential changes by orthognathic surgery [5]. The selected anthropometric landmarks are given in Table 1, distances in Table 2 and indices in Table 3.

Subnasale and nasion are fundamental reference points for aesthetic surgery and orthodontics [25]. Together they define the nose height. The pronasale is a basic reference point in the estimation of the facial convexity. Together with the nasion, it defines the nasal bridge length and together with the alar curvature point it defines the alar length.

It has been described before, that the upper and lower lip are very inaccurate in predicting soft tissue outcome [13, 23]. Therefore, the morphology of upper and lower lip was evaluated in detail. Philtrum–mouth width index describes the relation between philtrum and mouth width. Knowledge about the composition of the philtrum is important as it divides the upper lip in two lateral and one medial aesthetic subunit. Upper lip height mouth width index describes the vertical extension of the upper lip to the horizontal extension of the mouth width. Together with the medial lateral cutaneous upper lip height index it represents the relation of mouth width, upper lip, and nose to each other.

The vermilions are the major feature of both upper and lower lips. They represent the mucocutaneous junction between internal mucosa and external skin of the oral region. Therefore, considerations of their dimension and their composition are highly relevant for surgery in this region. On the profile photographs, the vermilion total upper and lower lip height indices describe the relation of the vermilion in the context of the overall height of upper and lower lip. The cutaneous total upper and lower lip height indices describe the relation of the cutaneous fraction of the lips to the overall height of upper and lower lip. A disturbance of the balance between these parts of the lips, which can often be observed in Class II patients, has major implications for the whole appearance of the face and may be corrected by orthognathic surgery.

In order to quantify the downward rotation of the mandible in mandibular advancement, the chin, mandible and lower face height were measured and interactions between these distances and the upper face were investigated.

Comparing results of anthropometric measurements to an evaluation of lateral cephalograms helps to underline the validity of the performed anthropometric measurements [15]. Therefore, in order to adequately rate the results of the anthropometric measurements, SNA and SNB angle as well as Wits appraisal as established cephalometric measurements to determine the incorporation of maxilla and mandible in the cranial base were investigated and correlated to the results of the anthropometric measurements [26, 27].

Discussion of the Results

In the cephalometric measurements SNB angle and Wits appraisal showed similar levels to those reported in Class II patients undergoing mandibular advancement [28]. The significant pre- to postoperative increase of SNB angle as well as decrease of Wits appraisal is a typical result of advancement surgery.

Regarding the photo-assisted anthropometric measurements of the vermilion, vermilion total lower lip height, cutaneous total lower lip height and lower vermilion contour index changed significantly 3 months as well as 9 months postoperatively. The significant decrease of the lower vermilion contour and vermilion total lower lip height index as well as the significant increase of the cutaneous total lower lip height index indicate that the cutaneous part of the lower lips increased significantly more vertically than the lower vermilion height. After mandibular advancement, often a fuller aspect of the lips can be observed. It seems that the fuller aspect of the lips after mandibular advancement leads to broader look of the mouth width indicated by the significant increase of the lower vermilion contour index. These results confirm the current literature. As shown on various previous analyses the movement of labiale inferius and inferior labial sulcus due to the forward and downward rotation of the mandible is a predictable result of mandibular advancement [29]. It significantly reduces the eversion of the lower lip [29] and thereby leads to the aforementioned typical morphologic changes of the lips, particularly a vertical enlargement of the cutaneous part of the lower lips.

The significant decreases of nose–lower face height, nose–face height, upper face–face height, upper lip–mandible height and chin–mandible height index all reflect the vertical enlargement of the lower face due to mandibular advancement and the consecutive for- and downward rotation of the mandible. Mandible and chin projection increase after correction of Class II deformity [26]. In cases of excessive downward rotation of the chin and subsequent increase of the lower face height, a correction by genioplasty may be warranted [30].

In order to augment the validity of our data the results of cephalometric an anthropometric measurements were correlated [15].

A significant correlation between SNB angle and medial–lateral cutaneous total lower lip height index was identified 3 months postoperatively. Possibly, due to the process of adaptation of the soft tissues, this correlation was no longer detectable 9 months after surgery.

Nine months after surgery, vermilion total lower lip height index presented a negative, and cutaneous total lower lip height index a positive correlation to SNB angle. This confirms the validity of the postoperative changes in the morphology of the lower lips described above. These findings are of significant importance as the lips and especially the upper and lower vermilion are considered to show unpredictable results in mandibular advancement surgery [31]. However, our results indicate that there is indeed a correlation between bony movement reflected by the SNB angle and the resulting soft tissue change in the lower lips.

With reference to the lower face height, none of the applied indices showed a significant correlation to the cephalometric measurements. Previous linear measurements of the pre- to postoperative movement of chin and/or pogonion showed a correlation to the underlying bony movement [15, 29, 32–34].

Conclusion

The application of anthropometric landmarks and measurements described by Farkas [7] leads to valid and reproducible results. The evaluation of the effect of orthognathic surgery on the facial appearance by using anthropometric data extracted from standardized photographs helps to accurately analyze postoperative results. The described correlations between cephalometric and anthropometric measurements endorse the value of both landmarks and measurements with regards to preoperative planning, surgical procedure and final surgical result.

Conflict of Interest Statement The authors declare that they have no conflict of interest. There were no sources of funding.

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