Three-Dimensional Cephalometric Analysis of Orbital Morphology Modification for Midface Correction Surgery

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Abstract

Objectives The aim of this study was to create an evidence-based three-dimensional cephalometric analysis of orbits in order to perform time-efficient measurements of postoperative orbital morphology changes.

Materials and Methods The authors used 23 (11 bilateral and 1 unilateral) anatomical landmarks. Based on these, 6 planes, 12 angular and 16 linear measurements were determined. A three dimensional analysis was performed twice by two observers on pre and post-operative computed tomography scans of six patients who had undergone midface advancement. The mean, minimal and maximal difference, as well as standard deviation (SD) and intra-class correlation coefficient (ICC) for the inter- and intra-observer landmark selection reliability were calculated.

Additionally, the mean, minimal, maximal difference and standard deviation between pre- and post-operative angular and linear measurements were calculated to examine a connection between the established measurements and any morphological change.

Results The inter and intra-examiner accuracy of all landmarks for three axes was >0.9 ICC. Despite excellent inter and intra-examiner agreement (<2.49 mm $\pm$ 2.05 mm SD) for the landmark selection, linear and angular measurements showed a mismatch, the mean SD for angular measurements was found to be 8.2° and the linear 3.04 mm.

Discussion The possible causes of linear and angular measurement discrepancies are discussed and the future direction for the development of three-dimensional cephalometric analysis of orbits proposed.

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Introduction

Midface hypoplasia is a morphological anomaly characterized by a withdrawn upper lip and seemingly forward protruding chin rather than when compared to a retruded midface. Shorter maxillary bones result in a reduction of orbital depth, which can cause exophthalmos. In addition, morphology of the sphenoid bone is deranged, sphenoid angle of divergence measured between the greater wings is more obtuse and pterygoid plates are posteriorly rotated. The sagittal dimension of anterior cranial fossa are also shorter, though despite these morphological changes, there is no volumetric deficiency [1].

Table 1 Definitions of the landmarks

Landmark	Definition	Type
Anterior nasal spine	Tip of anterior nasal spine	Unilateral
Posterior choanae	Lower lateral corner of the posterior choanae, at the junction between the palatine bone and the pterygoid process	Bilateral
Clival anterior	Inferior and-lateral aspect of the anterior clinoid process, on the lesser wing of the sphenoid bone, lateral to the optic canal (approach to the landmark should be performed from the orbit)	Bilateral
Inferior orbital fissure	Most anterior point of the inferior orbital fissure at the level of the orbital floor	Bilateral
Superior orbital fissure (posterior and inferior)	Lower medial tip of the superior orbital fissure, at the top of foramen rotundum	Bilateral
Superior orbital fissure (anterior and superior)	Upper tip of the superior orbital fissure, at the junction between the lesser and the greater wings of the sphenoid bone	Bilateral
Frontomaxillary suture	Midpoint on the frontomaxillary suture which is build up from frontal process of maxillary bone and frontal bone	Bilateral
Frontozygomatic suture	Anterior midpoint at the frontozygomatic suture (between frontal process of zygomatic bone and frontal bone, on lateral wall of the orbit)	Bilateral
Lacrimal canal	Antero-lateral border of the orbital opening of the naso-lacrimal duct, at the junction between the lacrimal bone and the maxillary bone	Bilateral
Paraforamen caecum (right and left)	Lateral wall of foramen caecum which is situated in midline in front of the crista galli process	Bilateral
Planum sphenoidale	Upper surface of the lesser wing of the sphenoid bone, on the highest concavity of upper border of the optic canal	Bilateral
Small wing of the sphenoid	Lateral border of the small wing of the sphenoid bone, at the junction with the orbital plate of the frontal bone	Bilateral

Midface hypoplasia can occur self-reliant or as a component of complex syndromic defects such as: Apert, Cruzon or Pfeiffer syndrome. A severe form of midface hypoplasia is associated with ocular and respiratory complications [2, 3]. It is caused by reduced nasopharyngeal, velopharyngeal and orbital volume [4].

The current gold standard is surgical treatment in the form of LeFort III monoblock advancement or distraction osteogenesis after a LeFort III osteotomy [2, 3, 5]. Forward displacement of the bony block after the LeFort III osteotomy results in an enlargement of orbital and airway volume [4, 6]. However, there is no specified minimum range of midface advancement which can prevent the occurrence of further complications. This may arise from difficulties in the collection of a sufficiently large study group or the fact that the calculation of orbital or pharyngeal volume change is rarely performed due to the time consuming nature of procedures. In this study we wish to propose a more practical approach based on three-dimensional cephalometry. Our aim was to create an evidence-based three-dimensional cephalometric analysis of the orbits in order to perform no time-consuming orbital morphology change measurements.

Materials and Methods

The study was based on 6 male patients (mean age 10.8 ± 4) suffering from severe midface hypoplasia associated with one of the syndromes: Cruzon, Apert, Binder, Tyabi-Rubinstein, Pfeiffer and Marshall-Stickler. All patients underwent midface advancement following a Le Fort III osteotomy by the same surgeon using rigid external distractors (RED, KLS Martin, Tuttlingen, Germany). After consent from the local ethics committee (no 27/2013/V) was obtained, pre and post-operative computed tomography (CT) scans were collected. All CT scans were carried out using a BrightSpeed Elite scanner (GE Healthcare, Little Chalfont, United Kingdom) with the following scan parameters: slice thickness, 0.625 mm; tube voltage, 120 kVp; tube current, 100–140 mA; 25×25 cm field of view; 512×512 matrix. Acquired DICOM files were loaded into Maxilim software (Medicim, Leuven, Belgium) and reconstructed in three-dimensional (3D) space using a threshold filter with a value of >700 HU. On 3D reconstruction 23 anatomical landmarks (11 bilateral and one unilateral) (Table 1; Fig. 1), were selected twice by two observers (TS, MJ—residents). These landmarks were adopted and modified from a study measuring the influence of

Fig. 1 Landmark positions: (1) Anterior nasal spine; (2) Posterior choanae left and right; (3) Lacrimal canal right; (4) Inferior orbital fissure, Superior orbital fissure (posterior and inferior), Superior orbital fissure (anterior and superior); (5) Clival anterior left and right;

(6) Frontozygomatic suture right; (7) Frontomaxillary suture left; (8) Paraforamen caecum left and right; (9) Planum sphenoidale right; (10) Small wing of the sphenoid right

intentional cranial deformations on orbital morphology [7]. Based on the selected landmarks, 6 planes, 12 angular and 16 linear measurements were determined (Tables 2, 3). The mean, minimal and maximal difference, as well as standard deviation (SD) and intraclass correlation coefficient (ICC) for inter- and intra-observer landmark reliability were calculated. In addition, the mean, minimal, maximal difference and standard deviation between linear and angular measurements for pre- and post-operative scans were calculated to assess a

possible connection between established measurements and morphological change.

Results

The inter and intra-examiner accuracy of all landmarks for three axes was >0.9 ICC (Tables 4, 5). Despite excellent inter and intra examiner agreement ($<2.49 \pm 2.05$ mm

Table 2 Planes definitions

Landmark	Definition	Type
Horizontal maxillary plane	Anterior nasal spine, right posterior choanae, left posterior choanae	Plane defined by 3 points
Orbital floor	Lacrimal canal, superior orbital fissure (posterior–inferior end), medial inferior orbital fissure	Plane defined by 3 points
Lateral orbital wall	Superior orbital fissure (anterior–superior end), superior orbital fissure (posterior–inferior end), medial inferior orbital fissure	Plane defined by 3 points
Orbital roof	Foramen caecum, planum sphenoidale, small wing of the sphenoid	Plane defined by 3 points
Medial orbital wall	Superior orbital fissure (anterior–superior end), anterior clinoid process, fronto–maxillary suture	Plane defined by 3 points
Anterior orbital wall	Fronto–maxillary suture, fronto–zygomatic suture, perpendicular to the horizontal maxillary plane	Plane defined by 2 points and perpendicular to another plane

Table 3 Angles and distances definitions

Landmark	Definition	Type
Medio-lateral orbital angle (left and right)	Median orbital wall, lateral orbital wall	Angle between 2 planes
Anterior orbital angle	Left anterior orbital plane, right anterior orbital plane	Angle between 2 planes
Median orbital angle	Left medial orbital wall, right medial orbital wall	Angle between 2 planes
Vertical orbital angle (left and right)	Orbital roof, orbital floor	Angle between 2 planes
Relative lateral orbital angle (left and right)	Lateral orbital wall, orbital floor	Angle between 2 planes
Relative medial orbital angle (left and right)	Medial orbital wall, orbital floor	Angle between 2 planes
Lateral orbital angle (left and right)	Lateral orbital wall, maxillary horizontal plane	Angle between 2 planes
Anterior orbital width	Fronto–zygomatic suture, fronto–nasal suture	Distance between 2 points
Lateral orbital depth	Fronto–zygomatic suture, superior orbital fissure (posterior–inferior end)	Distance between 2 points
Median orbital depth	Fronto–maxillary suture, superior orbital fissure (posterior–inferior end)	Distance between 2 points
Deep orbital height	Superior orbital fissure (posterior–inferior end), orbital roof	Distance between a point and a plane
Sphenoidal orbital height	Medial inferior orbital fissure, orbital roof	Distance between a point and a plane
Anterior orbital height	Lacrimal canal, orbital roof	Distance between a point and a plane
Posterior orbital width	Superior orbital fissure (anterior–superior end), lateral orbital wall	Distance between a point and a plane
Central orbital depth	Superior orbital fissure (posterior–inferior end), anterior orbital wall	Distance between a point and a plane

SD), linear and angular measurements displayed an inaccuracy: the mean SD for angular measurements was 8.20 and for linear 3.04 mm (Table 6).

Based on these results, it is difficult to establish any correlation between the proposed measurements and any orbital volume change.

Discussion

Since the introduction of three-dimensional imaging techniques, the measurement of orbital morphology has been widely used for patients suffering hypertelorism [8], midface hypoplasia [9], orbital fractures [10] as well as, post

oncological defects [11]. These measurements were calculated either as a distance between points (landmarks) or as a volumetric value. The first method offers quick results, though frequently, they cannot be compared between different samples or between different clinicians due to the lack of standardized reproducible landmarks. Moreover, the procedure of volumetric measurement requires a manual delineation of a whole series of CT slices, a time consuming task, which results in data simply relating to volume change without any information in the direction [6, 10].

To overcome these drawbacks, the technique of three-dimensional (3D) cephalometric analysis seems a clear solution. The introduction of each 3D cephalometric analysis into everyday workflow will consist of several

Table 4 Intraobserver reproducibility

Landmarks	X axis				Y axis				Z axis						
	Mean (mm)	SD (mm)	Min (mm)	Max (mm)	ICC	Mean (mm)	SD (mm)	Min (mm)	Max (mm)	ICC	Mean (mm)	SD (mm)	Min (mm)	Max (mm)	ICC
Anterior nasal spine	0.18	1.15	0.03	0.44	0.979	0.22	0.11	0.07	0.42	0.997	0.34	0.29	0.02	0.89	0.992
Posterior choanae left	1.11	0.82	0.04	2.38	0.9987	0.78	1.09	0.03	2.99	0.971	0.54	0.54	0.01	1.49	0.967
Posterior choanae right	0.41	0.52	0.02	1.34	0.988	0.32	0.34	0.00	1.12	0.979	0.85	0.70	0.02	2.28	0.920
Clival anterior left	0.37	1.19	0.12	1.10	0.967	0.21	0.11	0.01	0.39	0.996	0.32	0.25	0.03	0.85	0.992
Clival anterior right	0.58	1.12	0.04	1.33	0.955	0.29	0.19	0.04	0.59	0.991	0.37	0.26	0.06	0.90	0.991
Inferior orbital fissure left	0.76	0.74	0.01	1.90	0.992	0.91	0.89	0.10	3.29	0.912	0.53	0.70	0.03	2.56	0.952
Inferior orbital fissure right	0.52	0.65	0.10	1.91	0.988	0.45	0.47	0.01	1.38	0.974	0.31	0.33	0.00	1.03	0.990
Superior orbital fissure (anterior–superior) left	0.23	0.47	0.01	0.69	0.994	0.82	1.59	0.04	5.77	0.942	0.33	0.21	0.04	0.67	0.991
Superior orbital fissure (anterior–superior) right	0.24	0.57	0.00	0.96	0.989	0.26	0.25	0.02	0.78	0.985	0.26	0.09	0.15	0.46	0.996
Superior orbital fissure (posterior–inferior) left	0.52	0.96	0.00	1.01	0.970	0.55	0.73	0.01	2.61	0.953	0.49	0.27	0.05	0.96	0.980
Superior orbital fissure (posterior–inferior) right	0.63	1.15	0.09	1.57	0.947	0.56	0.48	0.08	1.36	0.963	0.46	0.45	0.05	1.56	0.987
Frontomaxillary suture left	0.51	0.90	0.03	1.71	0.985	1.10	0.69	0.20	2.46	0.947	0.94	1.22	0.08	4.49	0.948
Frontomaxillary suture right	0.64	0.95	0.13	1.62	0.957	1.06	0.72	0.03	2.26	0.945	0.81	0.60	0.13	1.75	0.979
Frontozygomatic suture left	0.76	1.04	0.08	1.88	0.972	0.66	0.73	0.01	2.11	0.969	0.47	0.52	0.03	1.79	0.973
Frontozygomatic suture right	0.40	0.58	0.02	1.18	0.975	0.78	0.86	0.05	2.53	0.964	1.11	1.51	0.05	5.32	0.984
Lacrimal canal left	0.67	2.05	0.04	2.06	0.923	0.63	0.74	0.02	2.35	0.960	0.38	0.33	0.00	1.11	0.989
Lacrimal canal right	0.30	1.34	0.05	0.71	0.959	0.43	0.57	0.01	2.08	0.981	0.22	0.23	0.03	0.72	0.997
Paraforamen caecum left	0.29	0.52	0.01	0.97	0.994	0.32	0.33	0.05	1.22	0.990	0.44	0.32	0.02	0.84	0.993
Paraforamen caecum right	0.26	0.54	0.02	0.84	0.991	0.47	0.61	0.01	2.21	0.980	1.17	1.83	0.01	6.21	0.981
Planum sphenoidale left	0.39	1.07	0.00	1.07	0.972	0.78	1.11	0.02	3.91	0.943	0.44	0.40	0.04	1.19	0.983
Planum sphenoidale right	0.47	0.80	0.02	1.30	0.976	0.52	0.68	0.03	2.34	0.976	0.36	0.33	0.02	1.24	0.990
Small wing left	0.82	1.42	0.03	2.66	0.971	0.42	0.42	0.09	1.46	0.988	0.48	0.61	0.05	2.25	0.973
Small wing right	1.18	0.94	0.08	5.71	0.933	0.39	0.33	0.10	1.21	0.987	0.82	1.20	0.01	3.21	0.947

Table 5 Interobserver reproducibility

Landmarks	X axis			Y axis			Z axis			ICC	Mean (mm)	SD (mm)	Min (mm)	Max (mm)	ICC	Mean (mm)	SD (mm)	Min (mm)	Max (mm)	ICC	Mean (mm)	SD (mm)	Min (mm)	Max (mm)	ICC
	Mean (mm)	SD (mm)	Min (mm)	Max (mm)	ICC	Mean (mm)	SD (mm)	Min (mm)	Max (mm)																
Anterior nasal spine	1.43	1.15	0.12	4.12	0.928	0.71	0.90	0.02	2.53	0.976	1.20	1.30	0.05	4.70	0.937	1.20	1.30	0.05	4.70	0.937	1.20	1.30	0.05	4.70	0.937
Posterior choanae left	0.78	0.82	0.19	2.65	0.987	1.09	0.77	0.16	2.80	0.939	1.36	1.04	0.11	3.27	0.947	1.36	1.04	0.11	3.27	0.947	1.36	1.04	0.11	3.27	0.947
Posterior choanae right	0.66	0.52	0.12	1.99	0.978	1.13	0.82	0.06	2.26	0.968	1.32	0.74	0.18	2.25	0.937	1.32	0.74	0.18	2.25	0.937	1.32	0.74	0.18	2.25	0.937
Clival anterior left	1.18	1.19	0.06	3.87	0.967	2.48	3.10	0.12	3.47	0.961	2.01	1.60	0.20	4.87	0.943	2.01	1.60	0.20	4.87	0.943	2.01	1.60	0.20	4.87	0.943
Clival anterior right	1.64	1.12	0.06	3.48	0.955	1.97	2.47	0.21	3.21	0.952	2.18	1.48	0.09	4.57	0.941	2.18	1.48	0.09	4.57	0.941	2.18	1.48	0.09	4.57	0.941
Inferior orbital fissure left	1.07	0.74	0.24	2.68	0.942	1.52	1.40	0.12	4.19	0.951	1.14	0.72	0.11	2.46	0.926	1.14	0.72	0.11	2.46	0.926	1.14	0.72	0.11	2.46	0.926
Inferior orbital fissure right	0.94	0.65	0.07	2.23	0.988	1.16	1.22	0.04	3.91	0.944	0.80	0.78	0.02	2.58	0.963	0.80	0.78	0.02	2.58	0.963	0.80	0.78	0.02	2.58	0.963
Superior orbital fissure (anterior–superior) left	0.47	0.47	0.02	1.56	0.994	0.83	0.73	0.20	3.00	0.947	0.77	0.82	0.17	2.71	0.952	0.77	0.82	0.17	2.71	0.952	0.77	0.82	0.17	2.71	0.952
Superior orbital fissure (anterior–superior) right	0.48	0.57	0.00	2.20	0.989	0.54	0.44	0.03	1.27	0.977	0.51	0.69	0.03	2.49	0.974	0.51	0.69	0.03	2.49	0.974	0.51	0.69	0.03	2.49	0.974
Superior orbital fissure (posterior–inferior) left	1.07	0.96	0.08	2.54	0.970	1.97	2.92	0.33	11.00	0.962	1.00	0.65	0.24	2.59	0.925	1.00	0.65	0.24	2.59	0.925	1.00	0.65	0.24	2.59	0.925
Superior orbital fissure (posterior–inferior) right	1.39	1.15	0.03	3.39	0.947	1.07	1.14	0.02	3.13	0.933	0.70	0.66	0.05	1.85	0.959	0.70	0.66	0.05	1.85	0.959	0.70	0.66	0.05	1.85	0.959
Frontomaxillary suture left	1.42	0.90	0.11	3.31	0.985	1.21	0.93	0.29	3.04	0.996	1.98	1.33	0.03	4.74	0.946	1.98	1.33	0.03	4.74	0.946	1.98	1.33	0.03	4.74	0.946
Frontomaxillary suture right	1.72	0.95	0.24	3.48	0.957	1.47	1.13	0.28	4.04	0.925	1.68	1.06	0.07	2.98	0.965	1.68	1.06	0.07	2.98	0.965	1.68	1.06	0.07	2.98	0.965
Frontozygomatic suture left	1.63	1.04	0.51	3.44	0.972	1.52	1.04	0.14	3.11	0.960	1.89	0.96	0.32	3.27	0.950	1.89	0.96	0.32	3.27	0.950	1.89	0.96	0.32	3.27	0.950
Frontozygomatic suture right	2.08	0.58	1.02	2.99	0.975	1.79	1.06	0.24	3.75	0.973	1.59	0.70	0.58	2.88	0.961	1.59	0.70	0.58	2.88	0.961	1.59	0.70	0.58	2.88	0.961
Lacrimal canal left	2.49	2.05	0.26	6.29	0.923	2.58	2.23	0.32	8.42	0.969	1.77	1.06	0.43	3.99	0.954	1.77	1.06	0.43	3.99	0.954	1.77	1.06	0.43	3.99	0.954
Lacrimal canal right	2.19	1.34	0.20	4.46	0.959	2.40	1.64	0.15	5.64	0.934	2.07	0.89	0.43	3.48	0.938	2.07	0.89	0.43	3.48	0.938	2.07	0.89	0.43	3.48	0.938
Paraforamen caecum left	0.66	0.52	0.18	1.92	0.994	0.40	0.45	0.04	1.73	0.984	0.71	0.53	0.13	2.00	0.989	0.71	0.53	0.13	2.00	0.989	0.71	0.53	0.13	2.00	0.989
Paraforamen caecum right	0.61	0.54	0.05	1.80	0.991	0.50	0.43	0.01	1.43	0.979	1.26	1.06	0.21	3.60	0.957	1.26	1.06	0.21	3.60	0.957	1.26	1.06	0.21	3.60	0.957
Planum sphenoidale left	1.22	1.07	0.07	4.00	0.972	0.81	0.82	0.01	2.69	0.950	0.90	1.04	0.06	3.14	0.941	0.90	1.04	0.06	3.14	0.941	0.90	1.04	0.06	3.14	0.941
Planum sphenoidale right	1.01	0.80	0.06	2.48	0.976	0.61	0.55	0.00	1.85	0.957	0.48	0.54	0.02	1.68	0.973	0.48	0.54	0.02	1.68	0.973	0.48	0.54	0.02	1.68	0.973
Small wing left	1.37	1.42	0.02	3.97	0.971	0.56	0.49	0.02	1.54	0.986	1.17	1.16	0.01	3.66	0.941	1.17	1.16	0.01	3.66	0.941	1.17	1.16	0.01	3.66	0.941
Small wing right	1.70	0.94	0.32	3.37	0.933	0.56	0.48	0.01	1.69	0.974	1.35	1.15	0.13	3.67	0.988	1.35	1.15	0.13	3.67	0.988	1.35	1.15	0.13	3.67	0.988

Table 6 Angular and linear measurements change

Angular measurements (°)	Mean change (mm)	SD (mm)	Min (mm)	Max (mm)
Medio-lateral orbital angle (left)	6.20	8.97	−4.6	20.8
Medio-lateral orbital angle (right)	2.53	5.29	−4.6	8.9
Anterior orbital angle	−13.53	16.79	−32.3	13.3
Median orbital angle	0.62	4.79	−5.3	8.3
Vertical orbital angle (left)	1.40	5.48	−3.6	11.5
Vertical orbital angle (right)	−2.25	6.79	−13.6	4.7
Relative lateral orbital angle (left)	0.83	1.68	−2.3	2.2
Relative lateral orbital angle (right)	−3.67	6.53	−12.4	4.4
Relative medial orbital angle (left)	2.23	13.69	−7.3	29.5
Relative medial orbital angle (right)	3.12	11.76	−3.7	26.5
Lateral orbital angle (left)	−3.33	3.31	−8.7	1.4
Lateral orbital angle (right)	−3.33	13.37	−25.2	7.5
<i>Linear measurements (mm)</i>				
Anterior orbital width (left)	−2.20	4.89	−11.1	3.5
Anterior orbital width (right)	−1.28	2.73	−5.3	2.3
Lateral orbital depth (left)	−1.43	1.48	−3.2	0.5
Lateral orbital depth (right)	−1.28	2.50	−5.5	0.9
Median orbital depth (left)	−7.82	6.58	−17.4	1.7
Median orbital depth (right)	−7.07	6.15	−13.9	2
Deep orbital height (left)	−0.13	0.84	−1.1	1.2
Deep orbital height (right)	−0.38	0.42	−1	0.2
Sphenoidal orbital height (left)	−4.85	2.95	−8.6	0
Sphenoidal orbital height (right)	−4.25	3.33	−8.1	1
Anterior orbital height (left)	−6.68	1.95	−8.9	−3.3
Anterior orbital height (right)	−3.72	4.09	−7.9	3.2
Posterior orbital width (left)	−0.30	0.89	−2	0.6
Posterior orbital width (right)	−1.03	2.20	−4.7	0.8
Central orbital depth (left)	−4.63	3.90	−12.2	−1
Central orbital depth (right)	−6.02	3.81	−11.5	−0.9

Fig. 2 Porous structure of lacrimal bone after threshold segmentation

steps [12]. Guided by protocol, in the first step we have established 11 bilateral and 1 unilateral landmarks and a subsequent reliability assessment, showed them to be sufficiently precise ($<2.49 \pm 2.05$ mm SD). It is important that the landmarks presented were selected on a three-dimensional skull reconstruction which reduces selection time and enables measurements between landmarks which have three different coordinates values, an impossible task in flat/two-dimensional tomographic slices.

For the next step, linear and angular measurements were established (based on previously examined landmarks), these serve for any further analysis on pre and postoperative CT scans. Unfortunately the measurement results show large discrepancies (8.2° ; 3.04 mm) with an additional unclear pattern of change (increase and reduction of the same measurements in different patients who underwent the same surgery and distraction protocol). This could be the result of our study limitations.

The first limitation was the fact that our patients have different syndromic defects with diverse severity of midface hypoplasia and additional craniofacial anomalies which could influence landmark localization. One example is the abnormal position of the nasal bones found in Binder syndrome [2]; this could affect the localization of the frontomaxillary suture landmark. Also the Le Fort III osteotomy line crosses three of the proposed landmarks: the frontozygomatic suture where the osteotomy begins; the inferior orbital fissure which could be affected during intraorbital cuts and the lacrimal canal, which lies on the most fragile part of the orbital walls. It should be noted that the lacrimal bone (where lacrimal canal landmark lies) is sensitive to the threshold segmentation process. We used >700 HU values during segmentation which in some cases resulted in porous reconstruction (Fig. 2). A modification of HU values might help to obtain a more detailed reconstruction, however it might also result in more numerous artifacts from metal objects such as orthodontic brackets or distractor devices. Finally the human factor cannot be discounted.

To overcome the difficulties mentioned above, further research should be performed and consider remarks.

The presented landmarks are reproducible and could constitute a base for other linear and angular measurements, however to demonstrate a possible connection between the measurements and a postoperative morphological change, these measurements should be performed on more homogenous and larger group.

If new landmarks are necessary, the location of the osteotomy line and other surgical interventions should be taken into consideration as potentially misleading areas during the selection process.

To shorten the time required for taking these measures, the introduction of automatic landmark selection might be a solution [13, 14]. This could significantly accelerate the analysis process and increase measurement reliability. The extent of accuracy could also be increased through the implementation of pre-measuring calibration [15].

Finally, in most of diagnostic techniques an examined value is compared to a specific pattern- norm value. However our purpose was to create a method for the comparison of pre and post-surgical results, so that the norm was not required, but a study performed on a large group of healthy subjects would enable the establishment of standard value of orbital morphology. This could expand the application of this technique from comparative measurements to differential diagnostics between pathology and acceptable morphology.

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Compliance with Ethical Standards

Conflict of interest None.

Ethical Approval This article does not contain any studies with animals performed by any of the authors. All procedures performed in study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Local ethics committee number 27/2013/V.

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