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Original research article

The impact of body mass index on craniofacial parameters

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ABSTRACT

The purpose of the study is to analyze BMI and the mean values of craniofacial parameters in the patients measured by directed anthropometry (PDAA) and by 3D scan (P3DAS). The aim of the study is to identify the most frequent localization of facial fat. The study sample was recruited from patients attending dental surgeries in Bratislava. Data were collected from November 2013 to February 2016. In the first subgroup patients were analyzed by directed anthropometry (PDAA) (n = 65). In the second subgroup patients were analyzed from 3D scan (P3DAS) (n = 35). The differences in mean values of craniofacial parameters between the P3DAS and the PDAA groups had no significant effect on the evaluation of nose breadth, mouth and lower-lip height in the BMI category (18.6–24.9 kg/m^2). We found an association between BMI values and craniofacial parameters. In two study groups with >25.0 kg/m^2 higher values were observed in nose breadth, bi-zygomatic breadth, total facial height, mouth breadth and morphologic face height than in the group with 18.6–24.9 kg/m^2. In the P3DAS the facial fat was most often localized in the bi-gonial breadth and in the PDAA in the bi-zygomatic breadth.

Introduction

Morphometric measurements are widely used in the diagnosis, follow-up and treatment of the diseases [1].

Anthropometry provides an objective means of assessing the facial shape and can detect shape changes over time. Although the term anthropometry covers the measurement of any aspect of the human form, the term surface anthropometry is used in this paper to refer to the measurement of the facial surface features [2].

The ideal or attractive face of one generation is different from another and depends in a large measure on racial, ethnic, national, personal, BMI, as well as gender preferences to name a few of the important factors involved in the determination of beauty [3].

Within dentistry and particularly in the provision of conscious sedation, obesity can be a potentially complicating factor. For example, the position of anatomical landmarks may be less obvious if surrounded by fatty tissue [4].

One of the major reasons patients seek orthodontic treatment is to improve their facial appearance [5]. One of

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the most important components of orthodontic diagnosis and treatment planning is the evaluation of the patient's facial soft tissue. Since the shape of the human face depends on both the structure of the hard tissue (bone) and the soft tissue that covers it, soft tissue should be analyzed for the correct evaluation of an underlying skeletal discrepancy because of individual differences in soft tissue thickness [6].

Facial soft tissues fluctuate in accordance with the nutritional condition of the individual, and facial variations resulting from different body types may limit the effectiveness of facial reconstruction. Several studies incorporated three body-type categories (slender, normal, and obese) into their assessments of soft tissue thicknesses, and found that body mass index (BMI) was a major contributing factor in accurately determining differences in facial soft tissue thicknesses between individuals. Consequently, future studies in facial recognition now demand a consideration of the different BMI categories when estimating soft tissues thicknesses [7]. BMI plays a dominant role in the alteration of soft tissue thickness [8].

Currently, two non-invasive methods can be used to collect quantitative soft tissue facial data in the three dimensions: conventional anthropometry [2] and digital, computerized anthropometry. Craniofacial anthropometry is very suitable for identification and quantification of clinical features, treatment planning, monitoring of operative outcomes, and assessment of longitudinal change [2]. Although the role of conventional anthropometry has already been well recognized by clinicians working with the maxillofacial complex, the use of computerized anthropometry is more recent and not widespread [9, 10]. In recent times, non-invasive 3D scanning has become a more popular and reliable method of analysing craniofacial complex [11, 12].

In recent times there is a high variability in the proportion of soft tissues and we do not know the optimal standards of craniofacial parameters for the Caucasian population in central Europe, in our case the Slovak population. The purpose of the study is to analyze BMI and the mean values of craniofacial parameters in the patients measured by directed anthropometry (PDAA) and patients analyzed by 3D scan (P3DAS), also the aim of the study is to identify the most frequent localization of facial fat.

Materials and methods

Ethical issues (including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

The study sample was recruited from patients attending dental surgeries in Bratislava. Data were collected from November 2013 to February 2016. The selection criterion for patients' inclusion in the study was being over 18 years of age (without any ontogenetic changes in the face area) and their diagnosis (malocclusion). The data was collected anonymously and the privacy of patients was respected, participation in the study was voluntary.

The whole sample was divided into two study groups (PDAA and P3DAS) according to BMI. The sample consisted of 100 patients (50.0% men, 50.0% women) aged between 18 and 32 years (mean age 23.09 ± 2.70 years) (Table 1). The following craniofacial parameters were analyzed in this paper: nose breadth (al–al), bi-entocanthion breadth (en–en), bi-zygomatic breadth (zy–zy), bi-gonial breadth (go–go), total facial height (n–gn), mouth breadth (ch–ch), morphologic face height (sn–gn), upper-lip height (Ls–Stm), lower-lip height (Stm–Li) and pupils – mid-face (right).

Table 1 – Basic characteristics of the sample (*n* = 100)

Variables		Study groups	
		P3DAS	PDAA
		n	*n*
Gender	Male	19	31
	Female	16	34
Age [years]	Mean (x ± SD)	24.11 ± 3.45	22.54 ± 2.02
	≤24	18	58
	>25	17	7
BMI [kg m^2]	18.6–24.9	31	57
	>25.0	6	8

Study groups were divided into two subgroups. In the first subgroup were patients analyzed by directed anthropometry (PDAA) (*n* = 65). In the second subgroup were patients analysed with a 3D scan (P3DAS) (*n* = 35).

The study group, which were analyzed by PDAA were measured sitting on a chair, looking forward and with straight face. The face was not covered by hair. The measuring tools were sliding caliper and digital caliper.

The group with 3DCT scans were analyzed in three vertical planes. The defined anthropometric parameters were the base for analyses, according to which we circumscribe the measured lines that cover each part of the face (Chart 1). We used the special system – 3D Dimensional Imaging's Standard DI3D, which was developed to capture the surface of the human face in high quality. It works on the principle of passive stereophotogrammetry (DI3D capture software) with four cameras. We created a set of 3D models of patients under standard conditions by using this apparatus. Patients sat opposite the Shaped 3D scanner. The distance from the patient's scanner was determined by displaying the faces of DI3D capture software and the targets in the frames directed to the corners of the mouth. The patient's hair was arranged so that it does not cover the face. They fix the gaze into the distance and the head was in a natural position.

The data were analyzed by the statistical program SPSS. Descriptive statistics (percentages, averages, standard deviations, median, minimum and maximal value) were used. A two-sample *t*-test was applied to compare the mean value of craniofacial parameters (cm) in subgroups according to gender and age. The statistically significant level was determined at p values < 0.05.

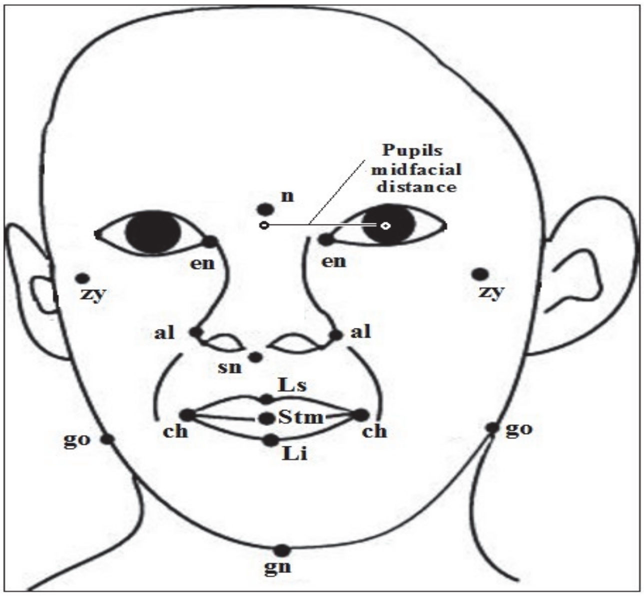

Chart 1 – Measurements used in the study

Results

Mean values of craniofacial parameters in the P3DAS and the PDAA according to BMI 18.6–24.9 kg/m^2 and BMI > 25.0 kg/m^2 are presented in Table 2.

In the category BMI 18.6–24.9 kg/m^2 the differences in mean values of craniofacial parameters between the P3DAS and the PDAA had no significant effect on the evaluation of nose breadth (al–al: 3.47 ± 0.35 cm vs. 3.44 ± 0.38 cm; MPD –0.87), mouth breadth (ch–ch: 5.02 ± 0.57 cm vs. 5.05 ± 0.39 cm; MPD 0.59) and lower-lip height (Stm–Li: 1.01 ± 0.15 cm vs. 1.06 ± 0.18 cm; MPD 4.72). In this same category the highest MPD mean values of craniofacial parameters between the P3DAS and the PDAA was observed in upper-lip height (LS–Stm: MPD 41.98; p = 0.000), bi-entocanthion breadth (en–en: MPD –18.15; p = 0.000) and bi-gonial breadth (go–go: MPD –12.93; p = 0.000). The differences in mean values of craniofacial parameters bi-entocanthion breadth, bi-zygomatic breadth, bi-gonial breadth, total facial height, morphologic face height, upper-lip height and pupils-mid face (right) between the PA3DS and the PDAA had a statistically significant effect in the category BMI 18.6–24.9 kg/m^2.

In the category BMI > 25.0 kg/m^2 the differences in mean values of craniofacial parameters between the P3DAS and the PDAA had a significant effect on the evaluation of pupils-mid face (right) (3.18 ± 0.03 cm vs. 3.60 ± 0.09 cm; MPD 11.67). The PDAA had higher mean values of craniofacial parameters than the P3DAS in upper-lip height (Ls–Stm: MPD 54.22; n.s.) and in pupils-mid face (right) (MPD 11.67; p = 0.005) and lower mean values of craniofacial parameters in bi-gonial breadth (go–go: MPD –26.31; n.s.) and morphologic face height (sn–gn: MPD –13.88; n.s.) according to category BMI > 25.0 kg/m^2.

Table 2 – Mean values of craniofacial parameters in the P3DAS and the PDAA according to BMI 18.6–24.9 kg/m^2 and BMI > 25.0 kg/m^2 (*n* = 100)

Craniofacial parameters	Category		Study groups				MPD[a] (%)	*P*
			P3DAS		PDAA			
			n	x (SD)	*n*	x (SD)		
al–al (cm)	BMI [kg/m^{-2}]	18.6–24.9	31	3.47 (0.35)	57	3.44 (0.38)	–0.87	0.716
nose breadth		>25.0	6	3.60 (0.43)	8	3.78 (0.25)	4.76	0.818
en–en (cm)	BMI [kg/m^{-2}]	18.6–24.9	31	3.32 (0.37)	57	2.81 (0.26)	–18.15	**0.000**
bi-entocanthion breadth		>25.0	6	3.17 (0.42)	8	2.99 (0.27)	–6.02	0.079
zy–zy (cm)	BMI [kg/m^{-2}]	18.6–24.9	31	11.93 (0.89)	57	12.85 (0.90)	7.16	**0.000**
bi-zygomatic breadth		>25.0	6	12.59 (0.89)	8	13.89 (1.10)	9.36	0.738
go–go (cm)	BMI [kg/m^{-2}]	18.6–24.9	31	12.14 (0.92)	57	10.75 (0.53)	–12.93	**0.000**
bi-gonial breadth		>25.0	6	13.06 (0.38)	8	10.34 (0.19)	–26.31	0.099
n–gn (cm)	BMI [kg/m^{-2}]	18.6–24.9	31	12.44 (0.68)	57	11.34 (0.75)	–9.70	**0.000**
total facial height		>25.0	6	13.21 (0.31)	8	12.06 (0.53)	–9.54	0.267
ch–ch (cm)	BMI [kg/m^{-2}]	18.6–24.9	31	5.02 (0.57)	57	5.05 (0.39)	0.59	0.789
mouth breadth		>25.0	6	5.30 (0.39)	8	5.51 (0.20)	3.81	0.125
sn–gn (cm)	BMI [kg/m^{-2}]	18.6–24.9	31	6.85 (0.63)	57	6.05 (0.58)	–13.22	**0.000**
morphologic face height		>25.0	6	7.30 (0.76)	8	6.41 (0.47)	–13.88	0.246
Ls–Stm (cm)	BMI [kg/m^{-2}]	18.6–24.9	31	0.47 (0.15)	57	0.81 (0.16)	41.98	**0.000**
upper-lip height		>25.0	6	0.38 (0.13)	8	0.83 (0.19)	54.22	0.398
Stm–Li (cm)	BMI [kg/m^{-2}]	18.6–24.9	31	1.01 (0.15)	57	1.06 (0.18)	4.72	0.147
lower-lip height		>25.0	6	1.07 (0.08)	8	1.06 (0.13)	–0.94	0.352
Pupils-mid face (right) (cm)	BMI [kg/m^{-2}]	18.6–24.9	31	3.27 (0.27)	57	3.48 (0.29)	6.03	**0.001**
		>25.0	6	3.18 (0.03)	8	3.60 (0.09)	11.67	**0.005**

[a] Mean percentage difference (MPD) of analysed craniofacial parameters between the PDAA and the P3DAS.

Discussion

Currently we have two basic methods for measuring the soft tissues on the face in three-dimensional direction – direct and digital. The importance is given to the proportions of the soft tissue before treatments and the evaluation of the soft tissue after orthodontic treatments; so one of these methods should be used (PDAA, P3DAS). We compared the accuracy of direct/conventional craniometry, which requires less expensive instruments then the digital craniometry, which has higher demands in terms of hardware and software. Digital craniometry could save 3D scans of the face soft tissues so the specialists of maxillofacial surgery, plastic surgery or other orthodontic have the possibility to send these 3D scans.

Many researchers deal with digital and direct craniometry. A study by Weinberg et al. [13] analyzed these two methods by measuring the defined distances of facial points by labeling the points and without. They found that positioning the points before measurements improve the accuracy of both methods (direct and digital craniometry). Respectively, a higher result of measurement accuracy was confirmed by digital craniometry. Both methods are quite accurate but it depends on the labeling of the craniometrical points and thus the precision of the method depends on measurements calibration.

This equivalence theory of direct and digital craniometry was confirmed by the study of Mollow [14]. The author found higher measurements accuracy when measuring individuals than when they measured more examinants. The process of no-calibration of two and more examinants is leading to measurement errors [14].

We selected only young respondents because we do not expect further growth of their bones; moreover, this is the age when orthognathic surgeries take place most frequently. Older segments of the population have often accepted their appearance and do not wish to change it, while in the younger generations, it is otherwise. This is a pilot study and in the future we want to extend the measurements to children's categories and in ages over 35 years.

In youth, facial fat is diffused, plentiful, and balanced. However, as the face fat becomes "unbalanced", areas of apparent fat excess and atrophy show. These changes appear in set patterns and seem to correlate with the changes in overall body fat [15]. This correlation was in part confirmed in our study. Measurements of larger areas such as the face height or width of the face are more reliable than detailed measurements of facial structures that require precise positioning of points at which measurements takes place.

We found an association between BMI rate and craniofacial parameters. In two study groups with > 25.0 kg/m^2 were observed higher values in nose breadth, bizygomatic breadth, total facial height, mouth breadth and morphologic face height than 18.6–24.9 kg/m^2. This can be explained by the fact that these craniofacial parameters are most often placed where the facial fat is located.

Winder et al. [16] compared 20 linear measurements on the live models (examinants) and by using the software. The mean difference between direct and digital measurements was 0.62 mm (maximum 1.43 mm and minimum 0.06 mm), and in our study a higher difference between direct and digital measurements was observed. This can be explained by the fact that in a study by Winder et al. [16] the sample size was different and females were 70%.

The practical impact of the study consists in important benefit for clinical practise because in recent studies there is not accessible data of optimal facial proportions in the Caucasian population in central Europe. This is a pilot study and our data are used in maxillofacial surgical treatment so the surgeon can choose what is best for the patient based on the anthropometric data from the physiological population (in our case the group of 18–32 years old people of both genders). Our results can be also applied by orthognathic surgeries (in cooperation between a jaw orthopaedist and a maxillofacial surgeon) when, for example, the jaw is underdeveloped and it is crucial to know the optimal facial proportions of physiological population. Without optimal facial proportions, the jaw orthopaedist is not able to achieve the correct dental positioning and the correct shape of the dental arch and jaw. Optimal craniofacial parameters can also help the doctor to design the appropriate dental interventions and they are seen as an improvement of the quality of clinical outcomes. We also considered in this study, the impact of BMI of anthropometric facial parameters, because in dental practice it is very important to know the thickness of the soft tissues of the face: Therefore we have implemented this expansion of the study and after these first results continued in deeper analysis, which will be helpful in clinical practice. The added value of this study is in comparing two methods – direct anthropometry and 3D measurement of the scan face. We showed comparable results in both methods in facial parameters and we can conclude that direct anthropometry is time-undemanding.

Possible limitations of this study are the low number of studies that analyze craniofacial parameters for the Caucasian population, and the sample size and its representativeness, which could pose problems in terms of generalizing the results.

Conclusion

The values of craniofacial parameters in the Slovak population can be used for the comparison of subjects with malocclusions, indicating areas of facial disharmony.

We observed the most frequent localization of facial fat. In the P3DAS it was most often localized facial fat in bigonial breadth and in the PDAA in bi-zygomatic breadth.

Based on our study results and other international researches we can confirm that the maximum difference between direct and digital craniometry is <3 mm, which is a clinically insignificant value, and therefore the use of direct craniometry is almost identical to digital craniometry. Due to the different labeling of the craniometrical points in direct and digital craniometry the highest error rates were confirmed.

Conflict of interest

The authors have no conflict of interest to declare.

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