Original Article

Evaluation of the applicability of a North American cephalometric standard to Brazilian patients subjected to orthognathic surgery

Fernando Paganeli Machado Giglio*, Eduardo Sant'Ana**

Abstract

Objectives: To study the applicability of a North American cephalometric standard to Brazilian patients subjected to orthognathic surgery by comparing the post-surgical/orthodontic treatment cephalometric tracings of 29 patients who had undergone surgery of the maxilla and mandible with the cephalometric standard used as guidance in planning the cases. **Methods:** The tracings were generated by the Dolphin Imaging 9.0 computer program from scanned lateral cephalograms in which 48 dental, osseous and tegumentary landmarks were defined. Thus, were obtained 26 linear and angular cephalometric measurements to be compared with normative values, considering sexual dimorphism and possible modifications to the treatment plan to meet the individual needs of each case, as well as any possible ethnic and racial differences. The sample data were compared with the standard using Student's t-test means and standard deviations. **Results:** The results showed that for males, the sample means were significantly different from the standard in five of the measurements, while for women, nine were statistically different. However, despite the similarity of the means of most measurements in both genders, the data showed marked individual variations. **Conclusions:** An analysis of the results suggests that the North American cephalometric standard is applicable as a reference for planning orthodontic-surgical cases of Brazilian patients, provided that consideration is given to variations in the individual needs of each patient.

Keywords: Orthognathic surgery. Facial analysis. Cephalometric standard.

* MSc and PhD in Stomatology, FOB, USP.
** MSc in Oral Diagnosis and PhD in Periodontics, FOB, USP. Full Professor of Surgery, FOB, USP.

INTRODUCTION

Recent years have seen an increase in the demand for orthodontic treatment and surgical correction of severe skeletal discrepancies. The main reasons for this phenomenon are a growing aesthetic concern, a large number of adult patients in need of occlusal correction, and improvements in surgical techniques.[7]

The treatment plan for performing facial changes is complex, especially due to the need to integrate them with occlusal correction. It should include clinical judgment, familiarity with the functional relationship between hard and soft tissues, knowledge of tegumentary responses to dentoskeletal movements, experienced professionals and the patients' willingness to undergo treatment. As a result, occlusion and facial aesthetics should become interdependent and be treated as concurrent treatment goals.[18]

Cephalometric analyses based on lateral radiographs play an important part in diagnosis, planning, prognosis and follow-up of cases involving orthodontics and orthognathic surgery.[21] Some of these analyses aim to qualify and/or quantify aesthetic facial profiles. Diagnoses based only on cephalometry, however, may not produce satisfactory cosmetic results as they focus predominantly on dental and skeletal structures, with little or no attention to overlying soft tissue.[4]

Given their paramount importance, normative cephalometric values have been sought to guide diagnoses and decisions pertaining to bone and tooth movements.[2] However, although such values contribute to determining the goals of treatment, it should be noted that the appearance of soft tissues is only partially dependent on the underlying hard tissues. Several authors have therefore suggested the need for a detailed analysis of soft tissues to guide the treatment of malocclusion and facial aesthetic changes, in combination with radiographs, photographs and models.[3]

Authors from many regions of the world have established cephalometric standards for hard and soft tissue normality for their specific populations with the purpose of orienting treatment plans according to the characteristics of each ethnic-racial group.[17] Arnett et al,[5] for example, launched their soft tissue cephalometric analysis based on the clinical examination of lateral and frontal facial features.[2,3] It was designed to serve as a guide as well as a planning and diagnostic tool for orthodontists and surgeons to use in patients with malocclusions associated or not with skeletal discrepancies. The authors used a true vertical line[20] (TVL) as the main parameter for determining anteroposterior relationships. This line is perpendicular to the horizontal plane, as determined by the natural head position, passing through the subnasal point, as illustrated in Figure 1, a radiograph used to determine method error. One of the peculiarities of this analysis is an objective approach to the final positioning of the soft tissues that comprise the profile for subsequent planning of the dental and skeletal changes needed to achieve those aesthetic goals. It is one of the most comprehensive analyses currently employed in orthognathic surgery and it is based on normative cephalometric values proposed by the authors, which were obtained from a population in the State of California, USA.

The purpose of this study is to assess the applicability of this North American cephalometric standard[5] to Brazilian patients subjected to orthognathic surgery, taking into account any adjustments made to the plan owing to possible differences between populations, and finally comparing the postoperative results with the cephalometric standard employed in the treatment plan.

MATERIAL AND METHODS

Sample

The sample was selected among adult Caucasian patients who had undergone surgical-orthodontic treatment with bimaxillary surgery.

FIGURE 1 - Representation of the true vertical line (TVL).

They were analyzed and planned with the aid of Dolphin Imaging 9.0 software (Dolphin Imaging Systems) following the cephalometric standard proposed by Arnett et al.[5] The sample included 29 lateral cephalograms taken after orthodontic treatment had been completed. To be eligible, radiographs had to be of good quality, allowing proper identification of cephalometric landmarks of interest and had to be taken with the head in a natural position, in centric occlusal relation and lips at rest.[2]

The sample consisted of 14 male and 15 female patients aged between 16 and 44 years (mean of 27.2). All patients were of Mediterranean stock and hailed from different cities located in São Paulo and Paraná States, Brazil. They were treated by four experienced orthodontists and operated on by the same surgeon. Thirteen patients underwent maxilla, mandible and chin surgery, while the other 16 patients had no chin intervention. It is worth noting that all patients were treated without premolar extraction and no sample inclusion criteria were adopted with respect to facial pattern. Surgical procedures included: Le Fort I osteotomy for the maxilla, with or without multisegmentation; bilateral sagittal split osteotomy of the mandible, with or without midline osteotomy; and mentoplasty.

Cephalometric tracing preparation

Dolphin Imaging 9.0 is a program used for the analysis and generation of facial cephalometric tracings for diagnosis, planning, prognosis and follow-up of orthodontic and/or surgical patients. It allows the insertion and comparison of intra and extraoral photographs and models, working as a case storage and management tool in a convenient and orderly fashion.[10,16]

For inclusion in the program, the radiographs were scanned on a HP Scanjet 4C/T scanner with 300 dpi of resolution and processed in Adobe Photoshop 7.0 for brightness and contrast adjustments, thereby improving the visualization of the structures of interest. Following the steps outlined by the program, we used the mouse to determine the 48 dental, osseous and tegumentary cephalometric landmarks for preparation of the cephalometric tracing, namely: porion, orbital, pterygomaxillary, saddle, nasion, basion, soft glabella, soft nasion, nose tip, bridge of the nose, subnasal, soft "A", upper lip, upper stomion, lower stomion, lower lip, soft "B", soft pogonion, soft menton, soft gnathion, neck/mandible, "B", pogonion, menton, gnathion, gonion, mandibular ramus, medium third of ramus, sigmoid notch, articular, condyle, anterior nasal spine, "A", posterior nasal spine, upper first molar occlusal (Mx6), lower first molar occlusal (Md6), Mx6 distal, Mx6 mesial, Md6 distal, Md6 mesial, amelocemental junction (ACJ), labial of the lower central incisor (Md1), Md1 incisal, Md1 root apex, lingual ACJ of Md1, labial ACJ of upper central incisor (Mx1), Mx1 incisal, root apex of Mx1 and lingual ACJ of Mx1. All tracings were made by the same professional.

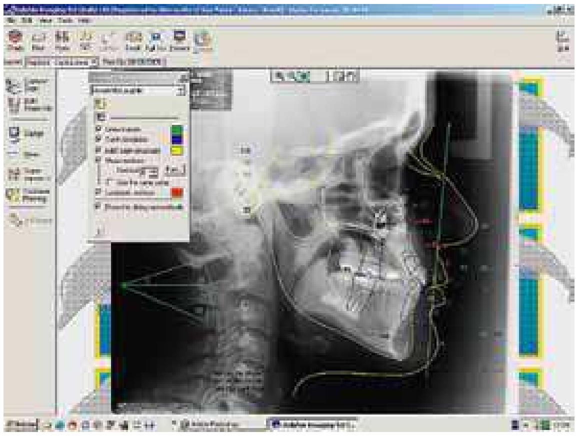

FIGURE 2 - Completed cephalometric tracing.

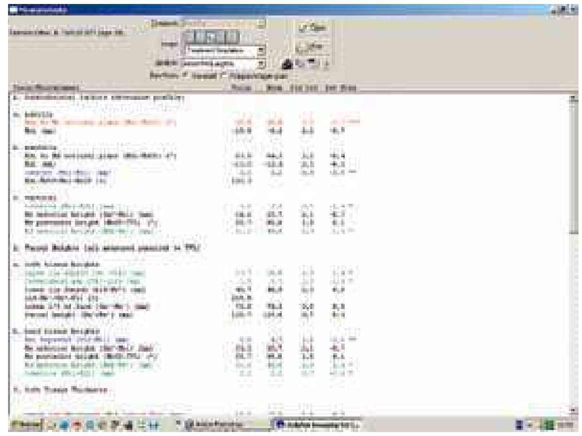

FIGURE 3 - All listed measurements.

After all landmarks had been determined the program brought them together to draw the tracing (Fig 2). The values corresponding to each linear or angular measurement appeared automatically on the radiographic image. The program's measuring tool provides a list of all cephalometric data measured and compared with the standard and its corresponding standard deviation (Fig 3).

Method error

Dolphin Imaging, as described, requires the operator to use the mouse to mark reference points of interest in the radiograph for the tracing. Despite the clear definition of each of the points, the tracing may still be biased by subjectivity. With the purpose of checking for the presence or absence of such variations, it was necessary to evaluate the error or reliability of the method.

To calculate the error of the method, 24 lateral cephalograms were randomly selected from the archives of the discipline of Surgery at the School of Dentistry of Bauru, University of São Paulo, according to one single criterion: adequate image quality. Once again, all radiographs were scanned and processed with the computer program to obtain two cephalometric tracings with an interval of 15 days between the two. Determination of method error consisted in an analysis of differences between values obtained on both occasions, using 25 linear cephalometric measurements. Systematic (paired t-test) and casual (Dahlberg) errors were calculated. Method error calculation results are summarized in Table 1 and show no statistically significant differences between the tracings, suggesting that the error inherent in the method did not influence the results.

Cephalometric measurements

The next step consisted in interpreting the data on hand. To this end, we used the following 26 cephalometric measurements to compare the sample's postoperative results with the standard used in planning:

1. Angle between Mx1 and the maxillary occlusal plane.
2. Projection of Mx1 onto TVL.
3. Angle between Md1 and the mandibular occlusal plane.
4. Projection of Md1 onto TVL.
5. Overjet.
6. Overbite.
7. Anterior maxillary height (Sn-Mx1).
8. Anterior mandibular height (Md1-Me').
9. Upper lip height.
10. Interlabial space.
11. Lower lip height.
12. Height of the lower facial third (Sn-Me').

13. Total facial height (Na'-Me').
14. Mx1 exposure.
15. Upper lip thickness.
16. Lower lip thickness.
17. Mentum thickness (Pog-Pog').
18. Nasal projection onto TVL.
19. Projection of point A' onto TVL.
20. Projection of upper lip onto TVL.
21. Nasolabial angle.
22. Projection of lower lip onto TVL.
23. Projection of point B' onto TVL.
24. Projection of point Pog' onto TVL.
25. Tegumentary maxillomandibular distance (A'-B').
26. Horizontal distance between the upper and lower lips.

Student's t-test was applied to compare the patients' postoperative means with the standard for each cephalometric measurement, taking into account sexual dimorphism.

RESULTS

Tables 2 and 3 show the results for male and female subjects, respectively.

TABLE 1 - Method error (systematic and casual errors - values in mm).

Radiographs	1st tracing		2nd tracing		t	p*	error
	mean	s.d.	mean	s.d.			(Dahlberg)*
X-ray 1	18.96	35.16	18.66	35.29	1.831	0.077	0.54
X-ray 2	16.95	28.30	16.40	28.51	1.856	0.074	0.98
X-ray 3	17.33	33.92	17.82	33.78	1.804	0.082	0.91
X-ray 4	20.48	30.64	20.64	30.63	2.027	0.052	0.27
X-ray 5	17.61	32.73	18.06	32.86	1.586	0.124	0.93
X-ray 6	16.38	29.89	16.44	30.84	0.228	0.821	0.78
X-ray 7	15.45	31.23	15.34	31.54	0.428	0.672	0.83
X-ray 8	19.43	32.79	19.50	33.07	0.414	0.682	0.55
X-ray 9	17.55	33.89	17.53	33.20	0.117	0.907	0.65
X-ray 10	16.92	31.04	17.16	30.94	1.270	0.214	0.62
X-ray 11	20.56	35.70	20.01	35.50	1.967	0.059	0.96
X-ray 12	14.61	30.73	14.65	30.26	0.161	0.873	0.71
X-ray 13	13.10	30.28	13.23	31.01	0.428	0.672	0.95
X-ray 14	17.07	35.04	16.68	35.15	1.339	0.191	0.95
X-ray 15	15.20	30.27	15.58	30.66	1.742	0.092	0.72
X-ray 16	16.24	32.11	16.48	32.66	1.206	0.238	0.67
X-ray 17	16.03	35.11	15.68	35.69	1.519	0.140	0.75
X-ray 18	15.52	36.10	15.77	36.00	0.811	0.424	0.98
X-ray 19	16.75	35.24	17.23	34.90	1.892	0.068	0.85
X-ray 20	17.16	30.15	16.96	30.22	1.850	0.075	0.36
X-ray 21	15.65	29.54	15.56	29.59	0.650	0.521	0.41
X-ray 22	12.02	26.77	12.05	26.79	0.113	0.911	0.67
X-ray 23	17.92	32.66	17.93	33.47	0.027	0.979	0.94
X-ray 24	15.67	30.91	15.62	30.17	0.208	0.837	0.73

* Significance: for $p < 0.05$ and Dahlberg > 1.

TABLE 2 - Results for males.

Measurement	Sample	s.d.	Standard	s.d.	Difference	Classification*	t	p**
1	55.2	6.2	57.8	3	2.6	0	1.630	0.1130
2	-12.3	4.8	-12.1	1.8	0.2	0	-0.171	0.8654
3	70.1	7.5	64	4	6.1	+++	3.078	0.0043
4	-14.9	4.5	-15.4	1.9	0.5	0	0.446	0.6589
5	2.6	1.2	3.2	0.6	0.6	0	-1.927	0.0630
6	1.8	1	3.2	0.7	1.4	---	-4.812	0.0000
7	28.3	4.5	28.4	3.2	0.1	0	-0.076	0.9400
8	54.4	2.1	56	3	1.6	0	-1.719	0.0953
9	25.7	3.6	24.4	2.5	1.3	0	1.245	0.2221
10	2.1	1.7	2.4	1.1	0.3	0	-0.626	0.5359
11	53.3	3.1	54.3	2.4	1	0	-1.060	0.2969
12	81	5.6	81.1	4.7	0.1	0	-0.056	0.9553
13	138.7	7.8	138	6.5	0.7	0	0.285	0.7777
14	2.6	1.8	3.9	1.2	1.3	---	-2.532	0.0165
15	14.9	2.5	14.8	1.4	0.1	0	-0.149	0.8824
16	11.9	1.4	15.1	1.2	3.2	---	7.146	0.0000
17	14.5	2.5	13.5	2.3	1	0	-1.204	0.2374
18	17.2	1.8	17	1.7	0.2	0	-0.330	0.7438
19	0.5	1.9	-0.3	1	0.8	0	-1.599	0.1196
20	3.8	2.6	3.3	1.7	0.5	0	-0.679	0.5019
21	103.2	8.7	106	7.7	2.8	0	0.989	0.3299
22	0.6	5.4	1	2.2	0.4	0	-0.299	0.7667
23	-8.2	7.2	-7.1	1.6	1.3	0	0.785	0.4382
24	-3.7	8.8	-3.5	1.8	0.2	0	0.099	0.9215
25	9	6.1	6.8	1.5	2.2	+++	-1.556	0.1294
26	3.1	3.4	2.3	1.2	0.8	0	-0.974	0.3372

* --- = below standard, 0 = standard, +++ = above standard.
** Statistically significant difference for $p < 0.05$.

DISCUSSION

Diagnosis, treatment plan and treatment implementation are the three steps of malocclusion care.[2] This triad is interdependent, so that failure in one of the steps can lead to case failure. It should be emphasized that the goal should not focus on malocclusion correction alone but also on enhancing or maintaining the components of facial aesthetics, as determined by bone, soft tissue and teeth. Although a normal occlusion is important for facial harmony it does not mean that once it has been achieved the profile will always be balanced. A balanced facial contour can often be found even if a malocclusion is present and vice versa.[15] This has led orthodontists and maxillofacial surgeons to invest in studies and resources to provide their patients with improved diagnosis and treatment. In this context, advanced computer programs have been developed that allow treatment planning

TABLE 3 - Results for females.

Measurement	Sample	s.d.	Standard	s.d.	Difference	Classification*	t	p**
1	54.1	7	56.8	2.5	2.7	---	1.792	0.0809
2	-9.2	3.5	-9.2	2.2	0	0	0.000	1.000
3	67	6.7	64.3	3.2	2.7	0	1.749	0.0882
4	-12.1	3.2	-12.4	2.2	0.3	0	0.355	0.7242
5	2.9	1.1	3.2	0.4	0.3	0	-1.263	0.2142
6	2.2	0.7	3.2	0.7	1	---	-4.406	0.0001
7	26.6	3.9	25.7	2.1	0.9	0	0.964	0.3409
8	50.4	4.2	48.6	2.4	1.8	0	1.753	0.0874
9	23.6	3.1	21	1.9	2.6	+++	3.340	0.0019
10	1.7	1.3	3.3	1.3	1.6	---	-3.796	0.0005
11	49.5	5.1	46.9	2.3	2.6	+++	2.248	0.0303
12	74.8	7.2	71.1	3.5	3.7	+++	2.218	0.0324
13	130.1	8.5	125	4.7	5.1	+++	2.484	0.0174
14	2.9	2.5	4.7	1.6	1.8	---	-2.817	0.0076
15	12.6	2.2	12.6	1.8	0.6	0	0.000	1.000
16	11.2	1.5	13.6	1.4	2.4	---	5.152	0.0000
17	12.9	2.2	11.8	1.5	1.1	0	-1.903	0.0645
18	17.3	1.9	16	1.4	1.3	0	-2.510	0.0163
19	-0.2	1.9	-0.1	1	0.1	0	0.222	0.8258
20	2.9	2.4	3.7	1.2	0.8	0	1.427	0.1616
21	105.6	8.2	104	6.8	1.6	0	-0.673	0.5050
22	1.3	3.8	1.9	1.4	0.6	0	0.729	0.4702
23	-6.1	3.8	-5.3	1.5	0.8	0	0.959	0.3437
24	-2.2	4.5	-2.6	1.9	0.4	0	-0.399	0.6924
25	5.8	3	5.2	1.6	0.6	0	-0.838	0.4069
26	1.6	1.7	1.8	1	0.2	0	0.476	0.6366

* --- = below standard, 0 = standard, +++ = above standard.
** Statistically significant difference for $p < 0.05$.

and visualization. These programs are becoming increasingly useful in the communication between patients and professionals before and during treatment,[14] especially when it comes to predicting results. Among the advantages of computerized methods are the ability to manipulate the images, allowing enhanced viewing of areas with low resolution or too much overlapping, time savings, convenient selection and exchange of cephalometric analyses, speedy superimposition of serial radiographs, streamlined data storage and retrieval as well as the ability to promptly compare data for retrospective studies.[16]

This study compared the post-treatment cephalometric results of patients who had undergone orthognathic surgery in conformity to the normative values used to inform the treatment plans. The goal was to check whether or not the use of such standard would be feasible for this group of patients. This study did not aim to assess the prognostic accuracy of the results, although such results can be extrapolated to the extent that the treatment followed certain normative values. We therefore expected the results to be within the scope of these values, which became our "gold standard" prognosis and—subject to any changes required for each specific case—can be used as a communication tool between patients and professionals.

The Dolphin Imaging computer program, version 9.0 (Dolphin Imaging Systems) was used to generate cephalometric tracings by marking a series of dental, osseous and tegumentary landmarks on previously scanned radiographic images. This program was chosen because it is one of the most comprehensive available in the market today. Despite all the advantages and the fact that nowadays such software plays a key role in the treatment of malocclusion, it does have certain limitations, which are also present in manual methods, such as a potential inaccuracy in identifying reference points (landmarks), leading to distortion in the tracings.[6] By calculating the method error the tracings became more reliable by ensuring that the investigator who marked the reference points was duly calibrated.

In studies of this nature, the uniformity of patient features is extremely important. Ethnic and racial differences, sexual dimorphism, inclusion of young patients with growth potential after treatment, or patients with cleft lip and palate, can compromise the outcome. Our sample for this study comprised Caucasian individuals hailing from the states of São Paulo and Paraná, of Mediterranean stock, separated into groups according to gender. Patients who had undergone any type of corrective or reconstructive plastic surgery were excluded from the sample.

Determining the extent of the discrepancy found between the treatment plan or the cephalometric standard and the final treatment results in patients subjected to orthognathic surgery is a challenging task due to the numerous potential sources of inaccuracy, such as: Landmark identification, radiographic scanning method, accuracy in the transfer of planned movements to the articulator, accuracy in the model surgery and in fabricating the surgical guide, implementation of the surgical technique, the team's skill and experience (orthodontists and surgeons), settlement of the soft tissues on the dental and skeletal movements and relapse.[8] It is also important to bear in mind that most planning methods use two-dimensional representations of three-dimensional structures.[19] The method used in this study aimed to eliminate or at least minimize these shortcomings.

Another noteworthy factor is that as the extent of the surgical movements increases, so does the potential inaccuracy of the results.[1] In this study, all patients underwent maxillary and mandibular surgery, with or without mentoplasty. Therefore, they experienced significant spatial changes in teeth, bones and soft tissues, thereby increasing the likelihood of inaccurate—especially long-term—results. Surgeries involving only the maxilla or only the mandible enable greater predictability and easier achievement of planned results.[9]

The period of patient follow-up also seems to influence interpretation of the results. Studies that use immediate postoperative radiographs tend to display more accurate data and the longer the interval between surgery and final radiographs, the greater the inaccuracies between treatment plan and final profile. For proper evaluation of the results, a follow-up period of at least 18 months is necessary to ensure that the data collected are stable. Short-term data are prone to considerable variability in spatial changes between hard and soft tissues, occurring over time. This is due to tissue adaptations following abrupt changes in bone caused by the surgery.[13] To minimize this variable, in our sample we chose to use radiographs taken at the end of postoperative orthodontics since the average time for completion of orthodontic treatment was 1.4 year.

In orthodontic practice, diagnosis and planning are determined in part by comparing the cephalometric measurements of patients with normative values, although most of these standards were established based on samples of Caucasian European or North American patients.[11] Given a wide variation in the mean values of cephalometric standards expressed by large standard deviation values, cephalometric standards should be used with caution, always taking into account their respective standard deviations in analyses, diagnoses and planning.[12]

In our particular study, concordance was found between the means of the results and the standard used in the treatment plan in 21 cephalometric measurements of men and 17 of women (80.8% and 65.4% respectively). In both genders, we found a statistically significant difference for overbite, exposure of upper central incisor and lower lip thickness. In these cases, the sample data values were smaller than the standard. For men, two other measurements differed from the standard, i.e., the angle formed by the lower central incisor and the mandibular occlusal plane, and the horizontal distance between points A' and B' (anteroposterior maxillomandibular relationship of the soft tissues). In these cases, sample patient values were significantly higher than the standard. Moreover, for women, there were differences in the angle formed by the upper central incisor and maxillary occlusal plane and the interlabial space—which were smaller than the standard—, whereas upper lip height, lower lip height, height of lower facial third and total facial height were higher than the standard.

Despite a high correlation found between result means and the standard, there was great individual variation, which can be explained by the high standard deviation values of the sample. One likely source of variation between our data and the standard stems from the fact that although the treatment plans followed a specific cephalometric standard, they were not standardized among themselves. This may mean that plans were subject to variations geared to meeting the needs of each specific case and achieving the best possible result, i.e., after the treatment plans had been prepared based on the normative values advocated by Arnett et al,[5] these plans could be modified so as to ensure a better outcome in a particular area of the facial profile.

This was precisely the purpose of this study, namely, to evaluate the feasibility of using a North American cephalometric standard to plan the orthognathic surgery of Brazilian patients, taking into consideration possible changes in the plans to suit the specific needs of each case. In short, we sought to assess whether the racial/ethnic differences between these two populations—although already intensely intermingled—are sufficient to contraindicate the use of cephalometric standards adopted by one population in planning the treatment of the other population's patients. It is noteworthy, however, that the standards should be considered as planning guidelines, not treatment guidelines, so as to ensure the fulfillment of individual case needs.

The use of three-dimensional facial reconstruction using CAT scans and facial scanners are currently under study. Hopefully, in the near future the two will combine definitively or even replace the current two-dimensional models so that orthognathic surgery planning and treatment predictability can be further refined, especially with regard to soft tissues.[22,23]

Version 10 of the Dolphin Imaging computer program already features these 3D capabilities.

CONCLUSIONS

After analyzing and discussing the findings of this study, we concluded that, despite significant individual variations, it is feasible to apply the cephalometric standard proposed by Arnett et al[5] in Brazilian patients who have undergone orthognathic surgery, although some planning adjustments are required to offset possible racial/ethnic differences between the two populations.

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Contact Address
Fernando Paganeli Machado Giglio
Rua André Rodrigues Benavides nº 67 aptº 403 - Pq. Campolim
CEP: 18.048-050 - Sorocaba/SP, Brazil
E-mail: fernando.giglio@uol.com.br