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Influence of skeletal class, occlusal pattern, age and sex on facial soft tissue thickness: a retrospective study using cone beam computed tomography in a Brazilian population

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ABSTRACT. This retrospective study analyzed the influence of skeletal class, occlusal pattern, age, and gender on the thickness of facial soft tissues, utilizing cone-beam computed tomography (CBCT) in a Brazilian population. In a retrospective approach, 239 CBCT scans were examined, including 100 male and 139 female patients, categorized into skeletal and occlusal classes (I, II, and III). The soft tissue thickness was evaluated at 10 strategic points along the midline. Significant differences were detected related to skeletal classes, gender, and age. In the occlusal classes, there were significant variations between genders, particularly evident in classes I and II, and less so in class III. Age was found to be an influential factor, especially in individuals under 40 years of age, with notable differences in class I. This study highlights that skeletal class, occlusal pattern, gender, and age play fundamental roles in determining facial soft tissue thickness. These findings are important for improving the accuracy of facial reconstructions and are particularly relevant for the Brazilian population.

Keywords: Facial reconstruction; soft tissue; computed tomography; retrospective study.

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Introduction

Restoration of facial morphology is accomplished through facial reconstruction, a complex process that aims to recreate soft tissues based on unidentified skulls. This multidisciplinary approach involves knowledge of anatomy, anthropology, aesthetics, and computing (Zhao et al., 2020). The main purpose of facial reconstruction is to reproduce unidentified or lost features of unknown individuals, playing an essential role in facilitating human identification and recognition when no presumed identity is available (Hamid & Abuaffan, 2016). This technique does not seek to be an identification method but rather a tool aimed at recognition as it allows the reconstructed face to be identified by family members, resulting in a shortlist of suspects. Subsequent identification occurs through fingerprint and DNA analysis, and dental records (Fernandes et al., 2012; Park et al., 2023).

Several approaches are used to analyze facial soft tissue thickness. Among these techniques, needle puncture in cadavers and the evaluation of living individuals through radiographic examinations, magnetic resonance imaging, and computed tomography scans stand out (Utsuno et al., 2014). The literature highlights cone beam computed tomography (CBCT) as a reliable method for performing these measurements in the facial region, providing an accurate representation of soft tissues (Park et al., 2023) (Fourie et al., 2010) (Hwang et al., 2012). This, therefore, makes it possible to create a database relating to the thickness of these facial tissues (Fourie et al., 2010).

Measurements to analyze the thickness of facial soft tissues are variable and can change at each landmark and according to sex, facial patterns, age, and ethnicity (Cha, 2013) (Gomes et al., 2020). Currently, due to the increase in ethnic mixtures, the heterogeneity of the Brazilian population has become a model for forensic research, predicting future reconstructions in non-homogeneous populations. To date, in the literature, only two studies have analyzed the thickness of the craniofacial soft tissue of Brazilian individuals, considering facial skeletal classes. One of them was carried out on children aged eight to 12 years (Pithon et al., 2014), while the other on adult individuals (Gomes et al., 2020).

For effective facial reconstruction, it is essential to have a thorough knowledge of skull morphology and access to a database containing information on the thickness of facial soft tissues (Thiemann et al., 2017). Therefore, it is necessary to establish parameters that accurately represent tissue thickness at specific and strategic craniometric points, which will allow for more realistic facial reconstructions (Almeida et al., 2013).

Furthermore, the recent study by Park, Chang, and Park (2023) makes significant contributions to the field of facial reconstruction. This study on the South Korean population used CBCT to analyze differences in facial soft tissue thickness between different skeletal classes and sexes. The study revealed notable variations in tissue thickness, particularly in the lip region, emphasizing the importance of considering these differences in facial reconstructions. These findings are essential for understanding variations in the thickness of facial soft tissues and their application in accurate facial reconstructions, especially in populations with distinct physical characteristics such as South Koreans.

Previous studies have explored the relationship between facial soft tissue thickness and factors such as gender, age, race, and ethnicity. However, there is a lack of studies reporting facial soft tissue thickness in cases of dental and skeletal malocclusion. Malocclusion refers to an occlusal relationship that is aesthetically and functionally problematic because the arrangement of the teeth is not aligned for various reasons, or the state of the upper and lower fit is out of normal position. Cases of malocclusion are divided into dental malocclusion and skeletal malocclusion. Dental malocclusion occurs when abnormalities are manifested in the size, position, and shape of the teeth, while skeletal malocclusion occurs when the jaws and teeth are not in harmony due to skeletal causes, or when the relationship between the maxilla and mandible is disharmonious (Park et al., 2023). This comparative study analyzed facial soft tissue thickness measurements in different skeletal classes based on facial profiles of patients with dental and skeletal malocclusion.

In that regard, the importance of studies like this becomes evident. The study by Park et al. (2023) that investigated facial soft tissue thickness in South Korean adults with normal facial profiles highlighted the relevance of these measurements in clinical and forensic contexts. Therefore, this study sought to fill this gap by providing data to improve facial reconstructions and contribute to accuracy in forensic investigations and clinical practices.

Considering the ethnic diversity in Brazil and the need for accurate facial reconstructions in heterogeneous, the main objective of this study was to analyze the influence of skeletal class, occlusal class, age, and sex on the thickness of facial soft tissues in a sample of the Brazilian population. It is hoped that the results of this study will not only advance our understanding of soft tissue thickness variations but also provide reliable information for more accurate and adapted facial reconstructions, both in a national and global context.

Material and methods

This was an observational, longitudinal, and retrospective study, with approval from the ethics committee for research on human beings (CAAE: 45559521.0.0000.0104). The CBCTs used were obtained from Brazilian patients who had their images archived at the Clinical Research Imaging Laboratory (LIPC) of the Health Technology Center (CTS), linked to the Research Support Center Complex (COMCAP) of the State University of Maringá (UEM), during the period from January 2014 to December 2019.

Regarding the inclusion criteria, research participants needed to be over 18 years old, and the CBCT scans had to completely cover the regions of interest, without the use of chin support at the time of acquisition, to avoid interference with soft tissues of the chin. Images of patients who presented craniofacial syndrome, severe asymmetries, pathological processes in the head and neck, signs of maxillofacial trauma, presence of artifacts that hindered the visualization of the areas to be evaluated, dental implants in the anterior region and severe skeletal deformity or malocclusion, indicating difficulty in lip closure, were excluded. After applying the criteria, 239 patient images were analyzed, 100 male and 139 female. A total of 463 CBCTs were excluded, following the established exclusion criteria.

In the context of tomographic analysis, patients were classified according to facial skeletal class into Class I ($0° < ANB < 4°$), Class II ($ANB \geq 4°$), and Class III ($ANB \leq 0°$), using the ANB cephalometric measurement of Steiner (1953). This measurement was performed with anatomical points A (the most concave point on the anterior maxilla), N for nasion (the most anterior point on the frontonasal suture), and B (the most concave point on the mandibular symphysis), with classification angles according to the degree of severity (Aranitasi et al., 2017). Such measurements were analyzed using the InVesalius 3.0® software (Division for Product Development – CTI, Brazil).

The classification according to Angle's occlusal class (Angle's 1899) divided the patients into class I (neutrocclusion), class II (distocclusion) and class III (mesiocclusion). CBCT was adjusted so that the anterior and posterior nasal spines were observed in the same sagittal and axial reconstructions. Subsequently, the most central sagittal reconstruction was selected, and soft tissue thickness measurements were analyzed at 10 different points in the midline region. The landmarks and their descriptions are in Table 1.

Table 1. Nomenclature for landmarks and their descriptions.

Glabella - glabella' (g-g')	Distance from the most anterior point of the frontal bone to the most anterior point of the midline of the forehead, in the region of the superciliary crests.
Nasion - nasion' (n-n')	Distance from the nasofrontal suture to the point directly anterior to the nasofrontal suture, in the midline, superimposed on n.
Rhinion - rhinion' (rhi-rhi')	Distance from the most rostral point (end) on the internasal suture to the corresponding soft tissue.
Subspinale - subnasale' (ss-sn')	Distance between the deepest point in the anterior concavity of the maxilla (orthodontic point A) and the subnasal point (confluence between the nasal base and the upper lip).
Prosthion - labrale superius' (pr-ls')	Distance between the prosthion (the median point between the central incisors on the most anterior margin of the superior alveolar border) and labrale superius' (confluence between the labial vermilion and the skin of the upper lip, usually the most anterior point).
Incision - stomion' (inc-sto')	Distance between the incision (point on the occlusal surface where the upper central incisors meet) and the stomion (point on the midline of the cleft lip when the lips are closed naturally, with the teeth closed in the natural position).
Infradentale - labrale inferius' (id-li')	Distance between the infradentale (median point on the upper tip of the septum between the lower central incisors) and the labrale inferius' (midpoint of the vermilion border of the lower lip).
Supramentale - supramentale' (sm- sm')	Distance from the orthodontic point B and the supramentale' (deepest midpoint of the mentolabial groove).
Pogonion - pogonion' (pg-pg')	Distance from the most anterior midpoint of the mandibular symphysis to the most anterior midpoint of the chin, located on the surface of the skin anterior to the identical bone point.
Gnathion - gnathion' (gn-gn')	Distance between the lowest median point of the mandibular symphysis and the lowest median point of the chin.

All retrospective CBCT scans for this study were acquired on the i-Cat Next Generation® equipment (Imaging Sciences International, Hatfield, PA, USA), operated at 120 kVp and 3-8 mA, with an isometric voxel of 0.300 mm. All CBCTs were performed by a single specialist in Dental Radiology and Imaging, after prescription by the clinician responsible for each patient. Image analysis was conducted using the CT software (Xoran version 3.1.62; Xoran Technologies, Ann Arbor, MI, USA), in a quiet room with dimmed lighting.

The analyses were carried out by two specialists in Dental Radiology and Imaging, duly calibrated. For inter-examiner calibration, 20 CBCTs were used, coming from the LIPC database. The analyses were carried out in duplicate, with a two-week interval, aiming to establish intra- and inter-examiner reliability. Evaluators were authorized to adjust the brightness and contrast of the images to obtain ideal visual conditions for diagnoses. To avoid eye fatigue, only 10 images were evaluated per day, and in 100% of the sample, measurements were repeated after 15 days.

Statistical analyses were conducted using R software version 4.0.2 (R., Auckland, NZL). In this study, the t-test, ANOVA, Tukey's Test, and Pearson correlation were used. All hypothesis tests considered a significance of 5%, that is, the null hypothesis was rejected when the p-value was less than 0.05. The t-test was applied to evaluate the relationship of the studied measurements between the sexes (male and female). The ANOVA and Tukey tests were applied to check for relationships between the studied measurements and the different malocclusions and facial skeletal patterns. The Pearson correlation test was used to evaluate the intra- and inter-examiner relationship of all analyzed measures. The following parameters were adopted for interpretation: 0.9 positive or negative: very strong correlation; 0.7 to 0.9 positive or negative: strong correlation; 0.5 to 0.7 positive or negative: moderate correlation; 0.3 to 0.5 positive or negative: weak correlation; 0 to 0.3 positive or negative: negligible correlation.

Results and discussion

The sample of this study was divided based on several variables, including sex (male and female), three facial skeletal groups (I, II, and III), three occlusal class groups (I, II, and III), and two age groups (< 40 years and ≥ 40 years), totaling 239 patients, of which 100 were male and 139 females. The average age of the sample was 32.61 ± 12.27, ranging between 18 and 78 years old. The distribution revealed 100 individuals in the type I skeletal class, 77 in type II, and 62 in type III. Regarding occlusal class, they were classified as type I: 152, type II: 72, and type III: 15.

As for the intra- and inter-examiner correlation analysis, the Pearson correlation indicated a robust correlation for both intra-examiners (examiner 1: r (Pearson) = 0.9994 and examiner 2: r (Pearson) = 0.9995) and inter-examiner (r (Pearson) = 0.9996).

The application of multivariate analysis of covariance (MANCOVA) to facial soft tissue thickness data revealed a significant effect ($p < 0.05$) of age (covariate), sex, facial type, and skeletal class on soft tissue thickness measurements. However, none of the interactions was significant ($p > 0.05$). Notably, the specific interactions between sex X facial type and sex X skeletal class X facial type showed significance for facial soft tissue thickness, with p values of 0.024 and 0.030, respectively Table 2.

Table 2. Wilk's Lambda values from multivariate analysis of covariance (MANCOVA).

Variable	Value	F	df1	df2	p
Sex	0.459	25.369	10	215	< .001*
Class	0.766	3.060	20	430	< .001*
Facial	0.844	1.902	20	430	0.011*
Sex X Class	0.890	1.294	20	430	0.178
Sex X Facial	0.855	1.747	20	430	0.024*
Class X Facial	0.974	0.290	20	430	0.999
Sex X Class X Facial	0.858	1.705	20	430	0.030*
Age	0.698	9.296	10	215	< .001*

*p < 0.05 significant difference.

Data in Table 3 show the relationships between the measurements in males and females, considering the facial skeletal class, indicating that the majority, regardless of the facial skeletal class, are statistically significant. This suggests that, in general, males tend to have greater soft tissue thickness.

It is important to highlight that statistically significant differences were found in the inc-sto' and id-li' measurements between males and females in the different facial skeletal classes. In the case of female inc-sto', the differences occurred between classes I and II, while for males, the disparity was between classes II and III, with the greatest thickness observed in class III.

As for the female id-li' measurement, there was a difference between classes I and II, with class II presenting greater thickness. For males, the discrepancy occurred between classes II and III, with the greatest thickness also observed in class II. These results provide information about variations in soft tissue thickness across different facial skeletal classes and between sexes.

Table 3. Relationship of studied measurements between facial skeletal classes with mean values (± standard deviation), using ANOVA and Tukey test, and t-test for sex.

Parameters	Class I (n = 100)		Class II (n = 77)		Class III (n = 62)		
	Mean	SD ±	Mean	SD ±	Mean	SD ±	**p-value
g-g': female	5.522	0.981	5.696	1.000	5.685	0.948	0.612
g-g': male	6.151	1.159	6.335	1.092	6.249	1.184	0.806
***p-value	0.002*		0.006*		0.020*		
n-n': female	6.921	1.126	6.852	1.150	6.958	1.501	0.920
n-n': male	8.518	1.749	8.510	1.363	8.463	1.695	0.989
***p-value	< 0.0001*		< 0.0001*		0.0002*		
rhi-rhi': female	2.440	0.649	2.486	0.519	2.488	0.643	0.904
rhi-rhi': male	3.257	0.734	3.032	0.581	3.118	0.913	0.455
***p-value	< 0.0001*		< 0.0001*		0.001*		
ss-sn': female	14.114	1.923	13.720	2.085	14.296	1.606	0.353
ss-sn': male	16.413	2.334	16.970	2.638	17.166	2.435	0.387
***p-value	< 0.0001*		< 0.0001*		< 0.0001*		
pr-Is': female	12.498	1.951	12.823	1.902	13.381	2.212	0.136
pr-Is': male	15.974	2.583	15.236	1.918	16.436	2.066	0.165
***p-value	< 0.0001*		< 0.0001*		< 0.0001*		
inc-sto': female	5.454^{A}	1.669	5.511^{A}	1.757	7.479^{B}	2.231	< 0.001*
inc-sto' male	8.310^{AB}	2.611	7.134^{A}	2.245	8.908^{B}	2.203	0.028*
***p-value	< 0.0001*		0.0004*		0.007*		
id-li': female	14.380^{A}	2.048	15.699^{B}	2.105	15.454^{B}	1.830	0.002*
id-li': male	16.612^{AB}	2.641	17.705^{A}	2.793	15.906^{B}	1.838	0.034*

***p-value	< 0.0001*		0.0003*		0.169		
sm-sm': female	12.671	2.045	13.135	1.846	13.089	2.469	0.473
sm-sm': male	13.593	2.180	14.480	2.264	13.244	1.829	0.094
***p-value	0.015*		0.003*		0.392		
pg-pg': female	11.934	2.123	11.507	2.758	11.447	3.230	0.624
pg-pg': male	12.209	2.835	12.609	2.207	12.025	2.703	0.716
***p-value	0.290		0.042*		0.227		
gn-gn': female	6.960	2.074	7.075	2.177	7.025	2.454	0.964
gn-gn': male	8.343	2.744	9.170	2.15	9.024	3.338	0.407
***p-value	0.002*		< 0.0001*		0.004*		

*p < 0.05 significant difference. **p-value for t-test between sexes for different skeletal classes. ***p-value for analysis of variance (ANOVA).

Different letters, in the same row, indicate statistically significant differences (Tukey's test).

Table 4 shows data on the relationship of the studied measurements according to age and skeletal class, for which we highlight some significant observations. Significant differences were detected between classes only in the pr-Is' and inc-sto' measurements in individuals under 40 years of age, revealing a greater thickness in class III. Additionally, there were statistical differences between ages in class I for measurements n-n', sm-sm', pg-pg', and gn-gn', with thickness, with higher values in individuals over 40 years of age.

In class II, for the measurements g-g', n-n', rhi-rhi', ss-sn', sm-sm', pg-pg', and gn-gn', all thickness values were greater in individuals over 40 years of age. In class III, the statistical difference was found only for the rhi-rhi' measurement, also being greater in individuals over 40 years of age. These results highlight the influence of both age and skeletal class on variations in facial soft tissue thickness, providing a more in-depth understanding of these specific relationships.

Table 4. Relationship of the studied measurements between facial skeletal classes with mean values (± standard deviation), using ANOVA and Tukey's test, and t-test for age.

Parameters	Class I (n = 100)		Class II (n = 77)		Class III (n = 62)		
	Mean	SD ±	Mean	SD ±	Mean	SD ±	**p-value
g-g': < 40	5.710	1.132	5.549	0.985	5.893	1.101	0.285
g-g': ⩾ 40	6.126	0.993	6.560	0.901	6.134	1.061	0.220
***p-value	0.054		< 0.0001*		0.248		
n-n': < 40	7.489	1.518	6.947	1.277	7.568	1.795	0.084
n-n': ⩾ 40	8.220	1.931	8.211	1.394	7.928	1.581	0.863
***p-value	0.027*		< 0.0001*		0.263		
rhi-rhi': < 40	2.751	0.675	2.509	0.562	2.677	0.778	0.147
rhi-rhi': ⩾ 40	3.044	1.082	2.949	0.554	3.171	0.962	0.758
***p-value	0.056		0.0007*		0.032*		
ss-sn': < 40	15.415	2.286	15.225	2.737	15.592	2.392	0.755
ss-sn': ⩾ 40	14.537	2.687	13.944	2.565	15.591	2.881	0.213
***p-value	0.057		0.024*		0.499		
pr-Is': < 40	14.305^{AB}	2.650	13.516^{A}	2.109	14.819^{B}	2.542	0.031*
pr-Is': ⩾ 40	13.612	3.398	13.774	2.418	14.520	3.054	0.672
***p-value	0.147		0.313		0.363		
inc-sto': < 40	6.814^{A}	2.552	5.936^{A}	1.999	8.216^{B}	2.221	< 0.0001*
inc-sto' ⩾ 40	6.745	2.735	6.227	2.196	7.741	2.740	0.230
***p-value	0.454		0.278		0.264		
id-li': < 40	15.530	2.715	16.498	2.728	15.804	1.785	0.103
id-li': ⩾ 40	15.125	2.183	16.077	2.086	15.049	1.978	0.175
***p-value	0.250		0.243		0.101		
sm-sm': < 40	12.796	2.053	13.190	1.891	13.005	2.221	0.571
sm-sm': ⩾ 40	14.031	2.205	14.278	2.246	13.798	2.002	0.806
***p-value	0.006*		0.013*		0.131		
pg-pg': < 40	11.778	2.348	11.278	2.628	11.594	3.087	0.592
pg-pg': ⩾ 40	12.919	2.550	12.952	2.302	12.183	2.637	0.635
***p-value	0.022*		0.003*		0.272		
gn-gn': < 40	7.291	2.246	7.156	2.123	7.759	3.052	0.432
gn-gn': ⩾ 40	8.564	2.985	8.864	2.489	8.629	2.968	0.923
***p-value	0.013*		0.001*		0.188		

*p < 0.05 significant difference. **p-value for t-test between sexes for different skeletal classes. ***p-value for analysis of variance (ANOVA).

Different letters, in the same row, indicate statistically significant differences (Tukey's test).

Examining Table 5 and analyzing the relationship between the different occlusal classes and sex, there was a statistically significant difference between the sexes in all measurements for occlusal classes I and II, except for the pg-pg' measurement. In class III, a significant difference was detected between the sexes only in ss-sn' and pr-ls' measurements.

Regarding the analysis between occlusal classes, there were significant differences for the g-g' measurements in males, where class I differed from class II, with greater thickness in class II. For the n-n' measurement in females, classes I and II were different from class III, the latter being thicker than the other two. About the pr-ls' measurement in males, class II differed from class III, with higher values in class III. In the inc-sto' measurement, a difference was found between classes I and II, II and III, with the lowest thickness observed in class II.

These results emphasize variations in facial soft tissue thicknesses across different occlusal classes and between sexes, providing a deeper understanding of these specific relationships.

Table 5. Relationship of the studied measurements between occlusal classes with mean values (± standard deviation), using ANOVA and Tukey's test, and t-test for sex.

Parameters	Class I (n =)		Class II (n =)		Class III (n =)		
	Mean	SD ±	Mean	SD ±	Mean	SD ±	**p-value
g-g':female	5.549	1.041	5.690	0.868	6.094	0.880	0.315
g-g':male	6.026^{A}	1.124	6.710^{B}	1.057	6.626^{AB}	1.129	0.027*
***p-value	0.003*		< 0.0001*		0.166		
n-n': female	6.797^{A}	1.290	6.911^{A}	0.943	8.107^{B}	1.753	0.024*
n-n': male	8.514	1.642	8.520	1.730	8.329	1.392	0.953
***p-value	< 0.0001*		< 0.0001*		0.394		
rhi-rhi': female	2.452	0.560	2.481	0.643	2.574	0.772	0.863
rhi-rhi': male	3.214	0.786	3.082	0.709	2.928	0.573	0.512
***p-value	< 0.0001*		0.0003*		0.164		
ss-sn': female	14.078	1.87	13.809	2.162	14.673	1.131	0.478
ss-sn': male	16.9	2.378	15.985	2.533	17.701	2.462	0.162
***p-value	< 0.0001*		< 0.0001*		0.005*		
pr-Is': female	12.933	2.102	12.498	1.763	14.097	2.310	0.113
pr-Is': male	16.110^{AB}	2.334	14.830^{A}	1.979	17.245^{B}	2.034	0.016*
***p-value	< 0.0001*		< 0.0001*		0.007*		
inc-sto': female	6.055	2.130	5.634	1.811	7.391	1.834	0.083
inc-sto' male	8.546^{A}	2.320	6.700^{A}	2.253	9.081	3.078	0.004*
***p-value	< 0.0001*		0.018*		0.114		
id-li': female	14.898	2.099	15.559	2.87	14.904	1.834	0.204
id-li': male	16.583	2.451	17.069	3.054	16.550	2.005	0.732
***p-value	< 0.0001*		0.008*		0.061		
sm-sm': female	12.959	2.157	13.089	1.935	11.786	2.161	0.301
sm-sm': male	13.559	2.074	14.431	2.276	13.131	2.150	0.181
***p-value	0.042*		0.006*		0.124		
pg-pg': female	11.877	2.830	11.237	2.335	12.043	2.691	0.377
pg-pg': male	12.163	2.778	12.596	2.185	11.139	2.215	0.212
***p-value	0.266		0,002*		0.243		
gn-gn': female	6.896	2.303	7.008	1.932	8.533	2.387	0.166
gn-gn': male	8.511	2.714	9.168	2.680	9.575	3.905	0.434
***p-value	< 0.0001*		0.0001*		0.275		

*p < 0.05 significant difference. **p-value for t-test between sexes for different skeletal classes. ***p-value for analysis of variance (ANOVA).

Different letters, in the same row, indicate statistically significant differences (Tukey's test).

In Table 6, no statistically significant difference was found between ages for all occlusal class II measurements. However, there was a significant difference in the g-g' measurement in individuals under 40 years of age, where occlusal class I differed from occlusal class III. This result highlights that, for this specific age group, there is a variation in the thickness of the facial soft tissue between the different occlusal classes.

Additionally, there was a difference between occlusal classes only for individuals under 40 years old concerning the measurements g-g', n-n', rhi-rhi', pr-ls', inc-sto', and gn-gn '. This suggests that, for this age group, the different occlusal classes show significant variations in these specific soft tissue thickness measurements. These observations contribute to a clearer understanding of the relationships between age and occlusal classes for the analyzed characteristics.

Different letters, in the same row, indicate statistically significant differences (Tukey's test).

Table 7 lists the relationship between the measures studied, considering both sex and age. Except for the pg-pg' measurement, there was no statistically significant difference in individuals over or under 40 years of age.

Table 6. Relationship of the studied measurements between occlusal classes with mean values (± standard deviation), using ANOVA and Tukey's test, and t-test for age.

Parameters	Class I (n =)		Class II (n =)		Class III (n =)		
	Mean	SD ±	Mean	SD ±	Mean	SD ±	**p-value
g-g': < 40	5.668 A	1.103	5.647 AB	0.948	6.44 B	1.079	0.042*
g-g': > 40	6.132	1.056	6.431	0.971	5.950	0.494	0.450
***p-value	0.019*		0.0004*		0.272		
n-n': < 40	7.375 AB	1.593	7.015 A	1.283	8.245 B	1.618	0.043*
n-n': > 40	8.388	1.881	7.876	1.461	8.100	0.848	0.480
***p-value	0.0015*		0.004*		0.452		
rhi-rhi': < 40	2.728 A	0.685	2.428 B	0.620	2.701 AB	0.692	0.049*
rhi-rhi': > 40	3.111	1.001	2.936	0.726	3.165	0.473	0.708
***p-value	0.007*		0.0009*		0.191		
ss-sn': < 40	15.425	2.393	14.991	2.498	16.648	2.047	0.102
ss-sn': > 40	15.200	2.968	13.909	2.343	13.950	1.484	0.155
***p-value	0.330		0.031*		0.077		
pr-Is': < 40	14.366 A	2.555	13.277 B	1.908	15.738 A	2.771	0.003*
pr-Is': > 40	14.508	3.312	13.129	2.340	16.020	2.375	0.093
***p-value	0.398		0.383		0.447		
inc-sto': < 40	7.176 A	2.459	5.828 B	1.955	8.376 A	2.629	0.0008*
inc-sto' > 40	7.288	2.849	6.125	2.047	7.750	3.691	0.158
***p-value	0.414		0.264		0.375		
id-li': < 40	15.755	2.488	16.363	2.730	15.825	2.151	0.412
id-li': > 40	15.370	2.137	15.673	2.165	15.500	1.654	0.854
***p-value	0.216		0.121		0.421		
sm-sm': < 40	12.945	2.035	13.287	2.070	12.442	2.356	0.411
sm-sm': > 40	14.389	2.136	13.848	2.209	12.900	0.424	0.455
***p-value	0.0003*		0.133		0.397		
pg-pg': < 40	11.700	2.781	11.209	2.481	11.308	2.294	0.567
pg-pg': > 40	13.297	2.490	12.311	2.297	13.200	3.394	0.268
***p-value	0.002*		0.027*		0.158		
gn-gn': < 40	7.308 AB	2.396	7.055 A	2.219	8.941 B	3.406	0.049*
gn-gn': > 40	8.986	3.042	8.324	2.450	10.050	1.909	0.492
***p-value	0.0007*		0.011*		0.333		

*p < 0.05 significant difference. **p-value for t-test between sexes for different skeletal classes. ***p-value for analysis of variance (ANOVA).

Table 7. Relationship of the studied measurements between gender with mean values (± standard deviation), and age with t-test.

Parameters	Male (n = 100)		Female (n = 139)		
	Mean	SD ±	Mean	SD ±	**p-value
g-g': < 40	6.078	1.144	5.462	0.966	< 0.0001*
g-g': ⩾ 40	6.623	1.052	6.083	0.862	0.013
***p-value	0.016*		0.0003*		
n-n': < 40	8.237	1.516	6.727	1.250	< 0.0001*
n-n': ⩾ 40	9.215	1.736	7.393	1.029	< 0.0001*
***p-value	0.003*		0.002*		
rhi-rhi': < 40	3.034	0.642	2.393	0.575	< 0.0001*
rhi-rhi': ⩾ 40	3.508	0.924	2.678	0.617	< 0.0001*
***p-value	0.002*		0.006*		
ss-sn': < 40	16.910	2.336	14.338	1.896	< 0.0001*
ss-sn': ⩾ 40	16.366	2.705	13.111	1.689	< 0.0001*
***p-value	0.162		0.0003*		
pr-Is': < 40	15.985	2.122	12.968	1.955	< 0.0001*
pr-Is': ⩾ 40	15.742	2.803	12.471	2.155	< 0.0001*
***p-value	0.321		0.100		
inc-sto': < 40	8.175	2.326	6.097	2.178	< 0.0001*
inc-sto' ⩾ 40	8.206	2.901	5.624	1.524	< 0.0001*
***p-value	0.477		0.113		
id-li': < 40	16.876	2.750	15.176	2.050	< 0.0001*
id-li': ⩾ 40	16.176	1.846	15.0227	2.213	0.015*
***p-value	0.112		0.356		
sm-sm': < 40	13.309	2.051	12.725	2.030	0.031*
sm-sm': > 40	14.819	2.015	13.560	2.132	0.010*
***p-value	0.0007*		0.017*		
pg-pg': < 40	11.876	2.618	11.373	2.696	0.109
pg-pg' ⩾ 40	13.289	2.449	12.435	2.106	0.084
***p-value	0.008*		0.013*		

gn-gn': < 40	8.138	2.695	6.848	2.152	0.0002*
gn-gn': ⩾ 40	10.369	2468	7.489	2.269	< 0.0001*
***p-value	0.0001*		0.063		

*p < 0.05 significant difference. ** p-value for t-test between sexes for different skeletal classes. *** p-value for analysis of variance (ANOVA).

Different letters, in the same row, indicate statistically significant differences (Tukey's test).

Discussion

Soft tissue restoration plays a key role in facial reconstruction, reproducing identifiable or lost features of an unknown person, which is essential to facilitate recognition by family members and with an essential role in forensic identification (Hamid & Abuaffan, 2016; Fernandes et al., 2012).

Our results, by revealing the influence of skeletal pattern, type of occlusion, sex, and age on soft tissue thickness, offer information to improve the accuracy of facial reconstructions. This deeper understanding of the variables involved can have significant implications in clinical and forensic contexts, contributing to more accurate reconstructions and more reliable identifications of the Brazilian population.

Regarding the skeletal pattern, the results indicate significant differences between soft tissue measurements for males and females, considering the facial skeletal class, corroborating previous studies (Hamid & Abuaffan, 2016) (Utsuno et al., 2014). A tendency for soft tissue compensation is perceived in regions with lower skeletal development, especially in class III individuals, who have greater mandible development, reflected in significantly higher values in the thickness of soft tissues in the maxillary region.

Previous studies, such as Gomes et al. (2020), reported similar results, highlighting a greater thickness of inc-sto' in the case of skeletal class III and higher values of id-li' for skeletal class II. Hamid & Abuaffan (2016), in a Sudanese sample, also identified differences in soft tissue thickness between skeletal classes.

The analysis of soft tissue thickness according to skeletal classes and sex (Table 3) revealed a difference in almost all measurements, showing greater soft tissue thickness in males at almost all points. These results are in line with previous studies, confirming sexual dimorphism in the midline region of the face in several populations (Gomes et al., 2020; Hamid & Abuaffan, 2016; Utsuno et al., 2014).

The studies conducted by Utsuno et al. (2014) and Thiemann et al. (2017) demonstrated the effect of age on the thickness of facial soft tissues. In this study, corroborated by Gomes et al. (2020), age emerges as a determining element for several measures. The results indicate significant differences in individuals over 40 years of age (Table 4), with greater soft tissue thickness at various points, regardless of facial skeletal class. However, greater thickness is observed in the middle third of the face in younger individuals. Table 7 shows that, regardless of age, males have greater soft tissue thickness in all points studied, except for pg-pg'.

The analysis of the relationship between occlusal types and sex (Table 5) shows significant differences in practically all measurements for classes I and II, while for class III, the difference is only in the ss-sn' and pr-ls' measurements. Perhaps this is an attempt by the upper lip to compensate for occlusal imbalances. (Table 6) reveals that, in class II, there is no significant difference between ages for all measurements, except for g-g' in individuals nder 40 years of age, where class I differs from class III.

The lack of studies addressing the influence of skeletal class and occlusal type on soft tissues, especially through CBCT, in the Brazilian population justifies the importance of this research (Pithon et al., 2014; Gomes et al., 2020; Park et al., 2023). Similar studies are necessary to form a database that allows for more accurate facial reconstructions of the Brazilian population. Furthermore, recent findings by Park et al. (2023), who investigated variations in facial soft tissue thickness in a Korean population, provide a valuable point of comparison with our results. Their analysis identified significant differences in soft tissue thickness between sexes and skeletal classes using CBCT. This study highlights the importance of considering ethnic and demographic variations in facial reconstructions. The comparison between the data from Park et al. (2023) and our results in the Brazilian population reveal important similarities and differences, reinforcing the need for specific databases for each population to improve accuracy in clinical and forensic contexts.

Although this study has significantly contributed to the understanding of the influences of skeletal class, occlusion type, sex, and age on facial soft tissue thickness, it is important to highlight its limitations. The main one lies in the need for larger samples to guarantee a more comprehensive representation of the studied population. Furthermore, the lack of consideration of facial types is another gap that could be explored in future research to deepen the understanding of the variables involved, including the influence of facial harmonization with cosmetic substances.

Additionally, the incorporation of other factors, such as medical history, lifestyle, and ethnicity, which were not addressed in this analysis, can further enrich the understanding of the complex interactions that shape facial characteristics, including the effects of facial harmonization with filler substances. Facial reconstructions using imaging software should be carried out to validate and improve the accuracy of the measurements obtained in this study. These considerations are essential for a more comprehensive interpretation and reliable application of results in clinical and forensic contexts, considering the growing relevance of facial harmonization in aesthetics and the identification of individuals.

Conclusion

This study emphasized the significant influence of skeletal class, occlusal pattern, sex, and age on facial soft tissue thickness. Skeletal class plays an important role, along with implications for occlusal pattern, revealing a marked relationship with age and distinct differences between men and women. Soft tissue compensation was observed in areas of less bone development, especially in class III individuals. Men consistently had greater soft tissue thickness at various points on the face. Regardless of age, sex, and facial skeletal class, older individuals showed reduced soft tissue thickness in specific areas of the upper lip. These conclusions enrich our understanding of the variables that shape the thickness of facial soft tissues, contributing to more accurate facial reconstructions adapted to the diversity of the Brazilian population.

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