Accuracy of mandibular measurements of sexual dimorphism using stabilizer equipment

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Abstract: The objective of this investigation was to compare the accuracy of mandibular measurements using a stabilizer (MS) with gold standard computed tomography (GS) images. Sixty mandibles were studied. Werth TomoScope HV Compact® was used to obtain CT images (GS), and the MS was also used. Analysis of the CT scans was performed using the VG Studio Max software® (Volume Graphics GmbH, Heidelberg, Germany), and MS was used after the proper positioning of the mandible. Descriptive and paired t test measures were used, and a ROC curve was calculated, as well as sensibility and specificity. MedCalc and STATA 13.0® were used (95% level of significance). Bicondylar breadth, bicoronoid breadth and minimum ramus breadth reached the highest concordance correlation coefficients at 0.99 (0.99-1.00), 0.99 (0.99–1.00) and 1.00 (0.99–1.00), respectively. Comparing observers with GS, the lowest accuracy was noted for the maximum mandibular length [0.59 (0.45–0.69), 0.64 (0.51–0.74)], the breadth of the right (0.14 (0.04–0.23), 0.14 (0.004–0.24)) and left mandibular body [0.14 (0.03–0.24), 0.16 (0.05-0.26)], and the right [0.58 (0.45–0.69), 0.63 (0.51–0.73) and left (0.59 (0.45–0.70), 0.59 (0.46–0.69)] mandibular angle. Various measurements exhibited good sensibility for males using MS: maximum mandibular length (78.12), bicondylar breadth (78.12), left mandibular notch breadth (84.37), and the left height of the mandibular body at the mental foramen (75.00). High specificity in discriminating females was observed for the left maximal ramus height (85.19), mandibular length (85.71), bicoronoid breadth (96.43), right height of the mandibular body at the mental foramen (82.19), bimental breadth (78.57), breadth right (92.86) and left (96.43) mandibular body, minimum ramus breadth (89.29), and left mandibular angle (85.71). MS was able to discriminate sexual dimorphism.

Keywords: Mandible; Tomography Scanners, X-Ray Computed; Anthropology; Sex Determination Analysis.

Introduction

The field of anthropology offers important parameters to understand human variability that can be useful for forensic purposes and the study of evolutionary processes.[1] The skeleton offers countless characteristics that indicate sexual dimorphism. In this regard, skulls and mandibles have been described as highly useful both in historical and modern collections.

In this context, various studies[2,3,4,5] have demonstrated that several anatomic landmarks of the skull and mandible can be used and that some of these landmarks typically present increased precision in identifying an individual compared with other.[3] Furthermore, the mandible is one of the most preserved bones in hominid and hominoid fossil records,[6] making it relevant to anthropological studies.

Several techniques have been cited, and most of them describe qualitative parameters to perform the evaluations. As these parameters are subjective, more accurate results are typically achieved by experts. Furthermore, most international investigations use qualitative parameters to perform the measurements; thus, there is a need for methods that are reproducible (quantitative) in measuring mandibular characteristics.

Some authors consider that due to recent migrations, genetic flow and difficulties in determining skeleton ancestry, morphological analysis is limited.[2,3,4,5,7,8] On the other hand, the metric method is gaining increasing importance as technical reports or case discussion on tribunals make it necessary to statistically present data to prove a specific point of view. Additionally, a less subjective argumentation highlights the reliability of the data.[9,10,11,12,13] However, the quantification of the structures used in the metric method is not yet well understood.

Considering the lack of standardization of mandible measurements, we built a piece of equipment (mandibular stabilizer, MS) that standardizes the position of the mandible and allows us to perform quantitative measurements. Therefore, the objective of this investigation was to compare the accuracy of mandibular measurements using the mandibular stabilizer (MS) with gold standard computed tomography (GS) images of Brazilian mandibles.

Methodology

Sixty mandibles from the Institute of Teaching and Research in Forensic Sciences of Guarulhos were studied. After proper training and achieving acceptable concordance levels (kappa test), two calibrated observers obtained 13 measurements of the mandible. Calibration was performed using mandible samples other than those used in the study.

In the first method, the mandibles were analyzed using 3D images. To perform these measurements, we used a Multisensor Coordinate Measurement Machine that has X-ray Tomography as one of its sensors, the Werth TomoScope HV Compact® (Werth Messtechnik GmbH, Gieben, Germany) (Figure 1). This equipment is located at the Laboratory of Micromanufacturing at the Institute for Technological Research (IPT) in São Paulo, Brazil. The TomoScope can reach levels of precision highly superior to those of a typical cone beam CT, and a resolution of 5 µm can be achieved. Analysis of the CT scans was performed using the VG Studio Max software® (Volume Graphics GmbH, Heidelberg, Germany). The mandibular measurements using the TomoScope were considered the gold standard (GS).

In the second method, a mandibular stabilizer was used (Figure 2). The equipment was developed with the aim of making measurements easier with more precision and to create measurement standards. The equipment has a base, a fixation and positioning table, and a measurement table. The patent registration was requested from the National Institute of Industrial Property in Brazil (INPI), BR 10 2013 003270-0. The mandible measurements are described in Table 1 and presented in Figure 3.

The reproducibility and accuracy were presented using descriptive statistics showing the sample size, mean and standard deviation. Additionally, the coefficient of variation, single and average intraclass correlation, concordance correlation coefficient (95%CI), and Pearson and bias correction factors were presented. To verify the sexual dimorphism, descriptive and paired t test measures were used, and a ROC curve was fabricated. The sensibility and specificity were also calculated. MedCalc® (MedCalc Software bvba, Ostend, Belgium) and STATA 13.0® (StataCorp LP, College Station- TX, USA) were used at a 95% of level of significance.

This investigation is in accordance with the international and national parameters of ethics for the investigation of human beings; the investigation protocol was submitted and approved by the Ethics Committee of the University of São Paulo's School of Dentistry (FOUSP), process number 350.960.

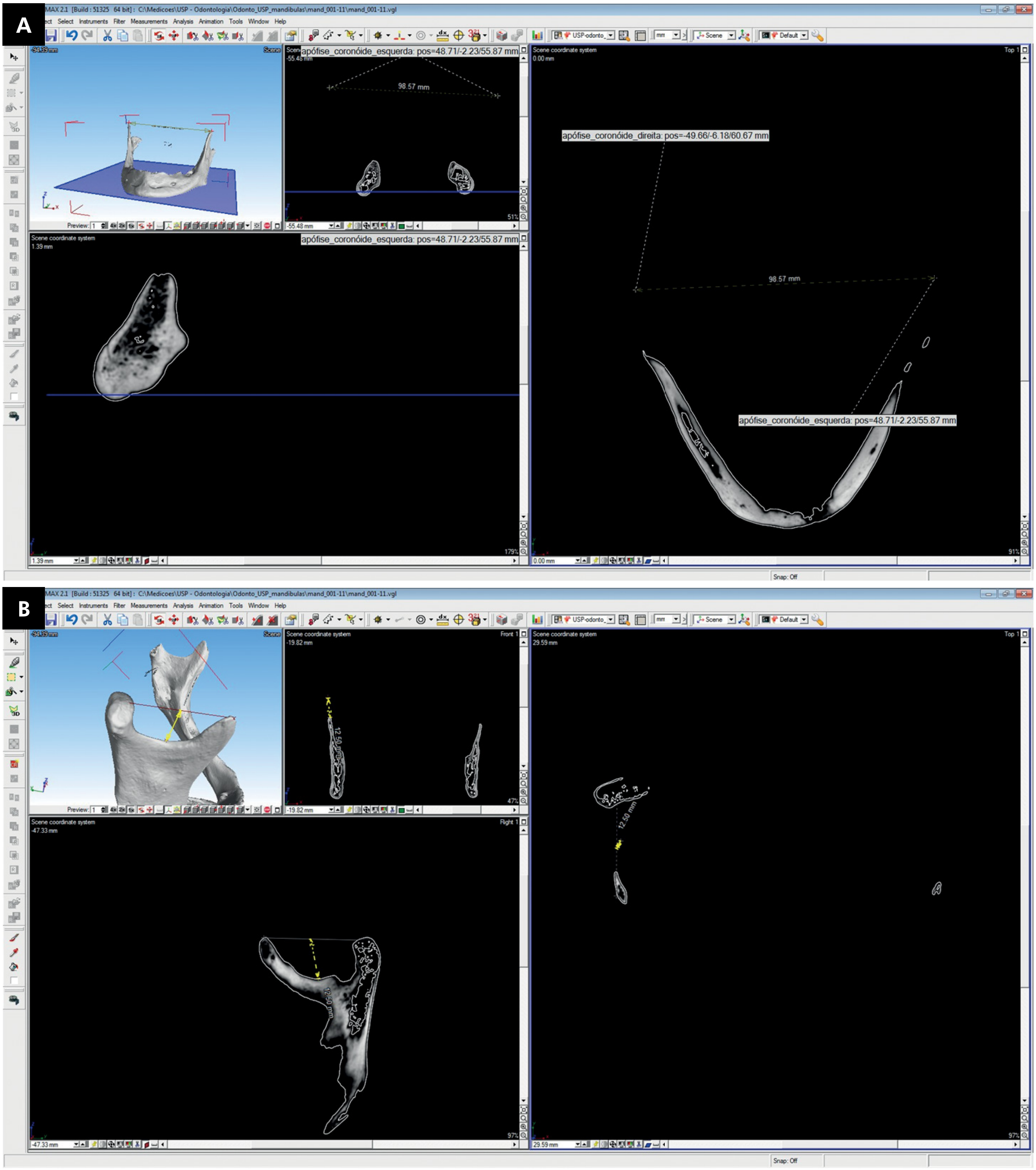

Figure 1. CT mandible images (gold standard). 1a: bicoronoid breadth; 1b: mandibular notch depth.

Results

Table 2 presents the descriptive data of sex and age estimation of the samples. Tables 3 and 4 present the reproducibility and accuracy results of the measurements. Bicondylar breadth, bicoronoid breadth and minimum ramus breadth reached the highest concordance correlation coefficients, with values of 0.99 (0.99– 1.00), 0.99 (0.99–1.00) and 1.00 (0.99–1.00) (Table 3), respectively. On the other hand, mandibular notch breadth and mandibular notch depth presented lower results in this regard (0.85 (0.73–0.92) and 0.80 (0.70–0.87), respectively) (Table 3).

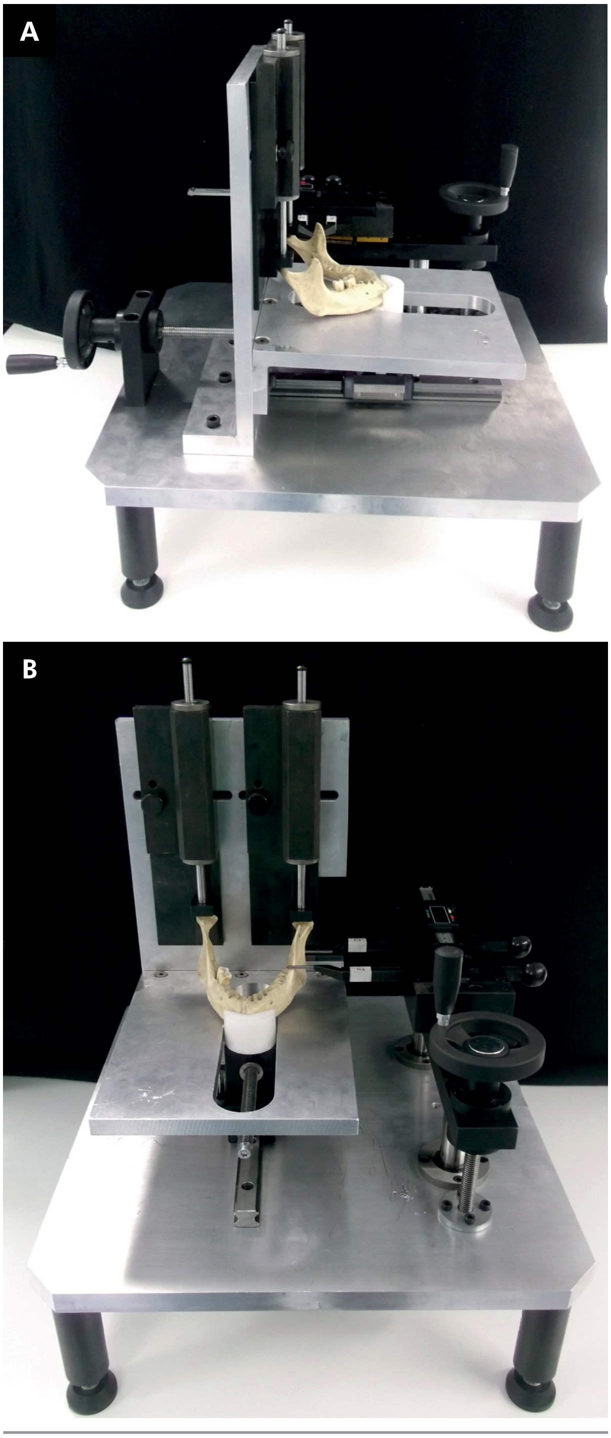

Figure 2. Mandible stabilizer.

Comparing observer 1 and 2's measurements with the gold standard, the lowest accuracy measurements were found for maximum mandibular length [0.59 (0.45–0.69), 0.64 (0.51–0.74)], breadth of the right [0.14 (0.04v0.23), 0.14 (0.004–0.24)] and left [0.14 (0.03-0.24), 0.16 (0.05-0.26)] mandibular body, and right [0.58 (0.45–0.69), 0.63 (0.51–0.73) and left (0.59 (0.45–0.70), 0.59 (0.46–0.69)] mandibular angle (data not shown in tables).

Tables 4 and 5 present the variables and the sexual dimorphism. In Table 4, the results are presented as the means of the values among male and female mandibles. All mean measurements were higher in male mandibles, and most of them correctly showed differences between the sexes using both the gold standard (GS) and the mandible stabilizer (MS). Some values did not differ between males and females when the mandible stabilizer (MS) was used: mandibular length ($p = 0.146$), breadth of the right and left ($p = 0.135$ and $p = 0.432$, respectively) mandibular body, and the right and left ($p = 0.215$ and $p = 0.301$, respectively) mandibular angle. The only measurement using the GS that did not show differences between the sexes was the right and left ($p = 0.128$ and $p = 0.215$, respectively) mandibular angle.

Table 5 shows the ROC curve results. Some measurements exhibited good sensibility for male mandibles using the MS as follows: the maximum mandibular length (78.12), the bicondylar breadth (78.12), the left mandibular notch breadth (84.37), and the left height of the mandibular body at the mental foramen (75.00). The GS performed better for the right maximum ramus height (93.75) in the male sample. High specificity in discriminating female mandibles was observed for the left maximus ramus height (85.19), the mandibular length (85.71), the bicoronoid breadth (96.43), the right height of the mandibular body at the mental foramen (82.19), the bimental breadth (78.57), the breadth of the right (92.86) and left (96.43) mandibular body, the minimum ramus breadth (89.29), the left mandibular angle (85.71), variables using MS and the bigonial width (89.29), the bicoronoid breadth (96.43), the breadth of the right (85.71) and left (85.19) mandibular notch, the right height of the mandibular body at the mental foramen (78.57),

Table 1. Mandible measurements.

Variable number	Measurement	Definition
Var1	Maximum mandibular length	Distance from the anterior midline point on the chin (*pogonion*) to a center point of the *bigonion* line.
Var2	Bigonial width	Direct distance between the right and left *gonion*.
Var3	Maximum ramus height*	Direct distance from the highest point on the mandibular condyle to the *gonion*.
Var4	Mandibular length (projection)	Distance from the anterior midline point on the chin (*pogonion*) to the perpendicular line tangent to the posterior point of the left condyle.
Var5	Bicondylar breadth	Direct distance between the most lateral points on the two condyles (*condylion laterale*).
Var6	Bicoronoid breadth	Direct distance between the points at the tip of the two coronoid processes (*coronion*).
Var7*	Mandibular notch breadth*	Direct distance from the *condylion superior* point to the *coronion*.
Var8*	Height of mandibular body*	Direct distance from the alveolar process to the inferior border of the mandible perpendicular to the base at the level of the mental foramen.
Var9*	Bimental breadth	Direct distance between the most inferior point on the margin of the mandibular mental foramen (*mentale*).
Var10*	Breadth of mandibular body*	Maximum breadth measured in the region of the mental foramen perpendicular to the long axis of the mandibular body.
Var11*	Minimum ramus breadth	Minimum breadth of the mandibular ramus measured perpendicular to the height of the ramus.
Var12*	Mandibular angle*	Angle formed by the inferior border of the corpus and the posterior border of the ramus.
Var13*	Mandibular notch depth*	Distance from the deepest part of the mandibular notch, to a center point of the *condylion superior* – *(coronion)* line.

*Bilateral measurements (left and right).

the bimental breadth (82.14), the right breadth of the mandibular body (78.57), the minimum ramus breadth (85.71), and the right mandibular angle (92.86) using GS (Table 5).

Discussion

The objective of comparing the accuracy of the MS with GS demonstrated that the MS can discriminate sex in mandibles. High observer concordance was noted in some anatomical landmarks, and these landmarks should be preferred to discriminate sex.

The sample had more male than female mandibles, and 40% of the sample had an age estimation in the range of 60 to 79 years. It must be highlighted that age estimation is prone to variability. In addition, less precision is achieved in older samples.[14]

In general, a high level of agreement between the observers was observed, indicating that the MS method is reproducible. One recommendation should be the need to be trained to perform the measurements. Thus, training with theoretical discussions and practical activities are necessary to achieve high levels of reproducibility when performing comparisons with a gold standard. This topic should be considered in the area of forensics given that sex determinations must be performed in numerous settings.

Bicondylar breadth, bicoronoid breadth and minimum ramus breadth reached the highest concordance coefficients; this was an expected result because these measurements are based on easy-to-find anatomical landmarks. On the other hand, mandibular notch breadth and depth reached lower concordance rates because these anatomical landmarks require more expert knowledge and training to be established.

As mentioned in the results section, the lowest accuracy measures were observed for the maximum mandibular length, the breadth of the mandibular body and the mandibular angle. The maximum mandibular length was the distance from the pogonion (the most anterior point of the mentonian prominence) and the tangent perpendicular of the posterior part of the condyle. Therefore, this localization can be exposed to variations among different observers because it corresponds to a projection. When using the VG StudioMax program to perform the GS measurements, the program automatically generated this perpendicular line, so the GS was considerably more precise than the observers using the MS.

As expected, the breadth of the mandibular body also has limitations during measurements due to the presence of teeth and tori. Again, given that the mandibular angle is the angle formed by the lower border of the mandibular body and the posterior border of the ramus, it was expected that the software would achieve more precise measurements than MS.

Differences were observed between GS and MS. MS has demonstrated good accuracy to discriminate the sex of mandibles, allowing a standardization of the measurements performed by experts and in training professionals. This feature may be very useful for forensic anthropology settings.

Some measurements have displayed better results than others in discriminating sex. Williams and Rogers[3] evaluated the accuracy of some morphological traits among skulls and mandibles in a skeletal collection in Tennessee, U.S.A., and they found that the goniac angle exhibited high precision and low accuracy. Another study performed in Brazil found that the bigonial width and mandibular ramus height obtained good results in discriminating sex;[15] our study observed similar results for discriminating sex with the maximum ramus height compared with a Korean study.[16] Furthermore, studies have highlighted that the shape of the mandible can offer a better contribution than the size for sex determination in Gorilla, Pongo and H. s. syndactylus and to a lesser extent in modern humans.[1, 6]

Some mandibular measurements did not accurately discriminate sex with MS: the mandibular length and the breadth of the mandibular body. Some authors also found similar results, especially when comparing different ethnic groups.[17] Additionally, the mandibular angle measured using both methods did not show values sufficient to discriminate male and female mandibles probably due to the difficulties in establishing anatomical reference marks. A Korean study[16] revealed sex differences ($p < 0.032$). The literature indicates

Table 2. Descriptive data of the sample (mandibles).

Variable	n	%
Sex		
Male	32	53.34
Female	28	46.66
Age (in years)		
17–39	10	16.67
40–59	16	26.66
60–79	24	40.00
80+	10	16.67

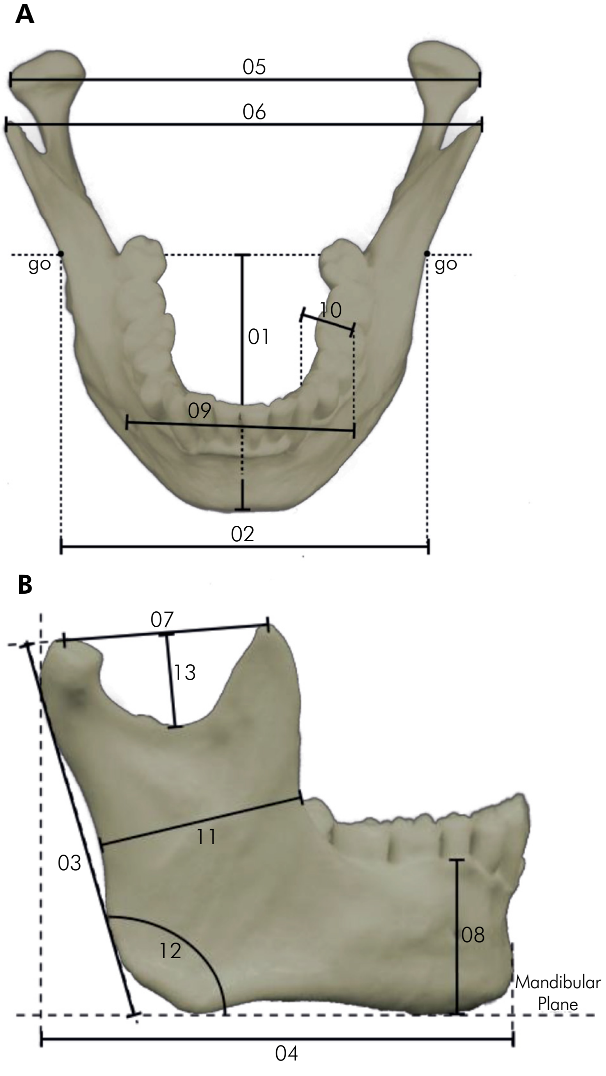

Figure 3. Mandible measurements. 1. maximum mandibular length; 2. bigonial width; 3. maximum ramus height, right and left; 4. mandibular length (projection); 5. bicondylar breadth; 6. bicoronoid breadth; 7. mandibular notch breadth, right and left; 8. height of the mandibular body at the mental foramen, right and left; 9. bimental breadth; 10. breadth of the mandibular body, right and left; 11. minimum ramus breadth; 12. mandibular angle, right and left; 13. mandibular notch depth, right and left.

Table 3. Reproducibility of the measurements per variable.

Variable	Reproducibility of the measurements	
Maximum mandibular length	Diff[a], CV[b], (IC Single[c] and average[d])	0.70, 1,55, (0.93 and 0.97)
	CCC[e] (95%CI), Pearson ρ[f], BCF[g]	0.92(0.89-0.96), 0.93, 0.99
Bigonial width	Diff[a], CV[b], (IC Single[d] and average[e])	1.42, 1.94, (0.95 and 0.98)
	CCC(95%CI), Pearson ρ, BCF	0.93(0.89-0.96), 0.95-0,96
Maximum ramus height, right**	Diff[a], CV[b], (IC Single[d] and average[e])	0.80,1.79, (0.98-0.99)
	CCC(95%CI), Pearson ρ, BCF	0.98(0.96-0.99), 0.98, 0.99
Maximum ramus height, left (n= 59)	Diff[a], CV[b], (IC Single[d] and average[e])	0.58, 2.14, (0.97 and 0.98)
	CCC(95%CI), Pearson ρ, BCF	0.96(0.94–0.98), 0.97,0.99
Mandibular length (projection) (n = 59)	Diff[a], CV[b], (IC Single[d] and average[e])	0.28,1.44, (0.96–0.98)
	CCC(95%CI), Pearson ρ, BCF	0.96(0.94–0.98). 0.96, 0.99
Bicondylar breadth	Diff[a], CV[b], (IC Single[d] and average[e])	0.21, 0.41, (0.99–1.00)
	CCC(95%CI), Pearson ρ, BCF	0.99 (0.99–1.00), 1.00, 1.00
Bicoronoid breadth	Diff[a], CV[b], (IC Single[d] and average[e])	0.28, 0.57, (0.9–1.00)
	CCC(95%CI), Pearson ρ, BCF	0.99(0.99–1.00), 0.99, 1.00
Mandibular notch breadth, right (n = 59)	Diff[a], CV[b], (IC Single[d] and average[e])	0.29, 2.81, (0.93–0.96)
	CCC(95%CI), Pearson ρ, BCF	0.93(0.88–0.95), 0.93, 0.99
Mandibular notch breadth, left (n = 59)	Diff[a], CV[b], (IC Single[c] and average[d])	0.95, 4.54, (0.88–0.93)
	CCC[e] (95%CI), Pearson ρ[f], BCF[g]	0.85(0.73–0.92), 0.89, 0.95
Height of the mandibular body at the mental foramen, right	Diff[a], CV[b], (IC Single[d] and average[e])	0.18, 3.58, (0.98–0.99)
	CCC(95%CI), Pearson ρ, BCF	0.98(0.96–0.99), 0.98, 1.00
Height of the mandibular body at the mental foramen, left	Diff[a], CV[b], (IC Single[d] and average[e])	0.10, 3.22, (0.98–0.99)
	CCC(95%CI), Pearson ρ, BCF	0.98(0.97–0.99), 0.99, 1.00
Bimental breadth	Diff[a], CV[b], (IC Single[d] and average[e])	0.20, 1.30, (0.96–0.98)
	CCC(95%CI), Pearson ρ, BCF	0.96(0.94–0.98), 0.96, 1.00
Breadth of the mandibular body, right	Diff[a], CV[b], (IC Single[d] and average[e])	0.12, 4.16, (0.95–0.98)
	CCC(95%CI), Pearson ρ, BCF	0.96(0.93–0.97), 0.95, 0.99
Breadth of the mandibular body, left	Diff[a], CV[b], (IC Single[d] and average[e])	0.09, 4.58, (0.96–0.98)
	CCC(95%CI), Pearson ρ, BCF	0.96(0.92–0.97), 0.96, 1.00
Minimum ramus breadth (n = 59)	Diff[a], CV[b], (IC Single[d] and average[e])	0.07, 0.78, (1.00–1.00)
	CCC(95%CI), Pearson ρ, BCF	1.00 (0.99–1.00), 1.00, 1.00
Mandibular angle, right	Diff[a], CV[b], (IC Single[d] and average[e])	0.70, 1.56, (0.93–0.97)
	CCC(95%CI), Pearson ρ, BCF	0.93(0.89–0.95), 0.93, 0.97
Mandibular angle, left	Diff[a], CV[b], (IC Single[c] and average[d])	0.73, 1.64, (0.93–0.97)
	CCC[e] (95%CI), Pearson ρ[f], BCF[g]	0.92(0.88–0.95), 0.93, 0.99
Mandibular notch depth, right (n = 59)	Diff[a], CV[b], (IC Single[c] and average[d])	0.70, 7.14, (0.85–0.91)
	CCC[e] (95%CI), Pearson ρ[f], BCF[g]	0.80(0.70–0.87), 0.86, 0.94
Mandibular notch depth, left (n = 56)	Diff[a], CV[b], (IC Single[c] and average[d])	0.47, 3.84, (0.96–0.98)
	CCC[e] (95%CI), Pearson ρ[f], BCF[g]	0.94(0.90–0.96), 0.97, 0.98

[a]difference; [b]coefficient of variation (%); Intraclass correlation: [c]single and [d]average; concordance correlation coefficient (95%CI); [f]Pearson's ρ (precision); [g]Bias correction factor C_b.

Table 4. Descriptive statistics of the measurements using the mandible statibilizer (MS) and the tomographic measurements (GS, golden standard) for each sex.

Variable	Descriptive measurements												
	Male						Female						
	Cat	Obs	Mean	SD	Min	Max	Obs	Mean	SD	Min	Max	Diff	p
Maximum mandibular length	MS	32	104.06	6.20	89.79	116.76	28	97.96	6.81	82.70	109.47	6.10	0.001
	GS	32	107.86	6.62	92.96	122.83	28	103.40	6.12	89.70	115.77	4.46	0.001
Bigonial width	MS	32	92.76	6.65	81.21	107.87	28	86.20	5.24	76.17	99.05	6.57	0.001
	GS	32	91.81	5.89	82.31	104.34	28	84.51	4.99	75.77	96.19	7.30	0.001
Maximum ramus height, right**	MS	32	59.19	6.06	44.62	70.15	28	52.71	5.15	38.97	62.08	6.48	0.001
	GS	32	59.28	5.97	36.38	70.55	28	53.73	5.51	41.87	68.00	5.56	0.001
Maximum ramus height, left (n= 59)	MS	32	58.39	5.33	47.38	67.77	27	51.59	4.66	44.18	61.37	6.79	0.001
	GS	32	59.64	5.52	47.12	71.60	27	52.61	5.17	42.95	63.59	7.03	0.001
Mandibular length (projection) (n = 59)	MS	32	71.09	5.71	61.23	81.74	28	69.18	4.06	59.99	77.48	1.91	0.146
	GS	32	73.07	4.87	64.79	86.31	28	70.60	3.86	62.28	79.57	2.46	0.036
Bicondylar breadth	MS	32	116.73	6.35	102.49	131.20	27	111.13	4.98	99.65	119.50	5.60	0.001
	GS	32	116.42	6.97	98.29	131.39	27	110.49	6.23	89.36	119.28	5.93	0.001
Bicoronoid breadth	MS	32	95.63	6.53	78.85	113.02	28	91.34	4.92	80.45	99.41	4.28	0.006
	GS	32	95.94	6.58	78.58	113.23	28	90.79	5.71	73.89	99.33	5.15	0.002
Mandibular notch breadth, right (n = 59)	MS	32	32.62	3.50	25.22	39.81	28	30.85	2.86	23.61	38.03	1.77	0.003
	GS	32	32.97	3.29	24.93	38.42	28	31.31	3.17	23.05	38.58	1.66	0.050
Mandibular notch breadth, left (n = 59)	MS	32	33.47	3.46	25.89	39.33	27	30.98	2.64	26.36	37.64	2.49	0.003
	GS	32	33.91	2.97	27.33	38.65	27	31.29	2.62	25.64	38.41	2.63	0.001
Height of the mandibular body at the mental foramen, right	MS	32	25.39	5.18	12.76	35.60	28	21.25	5.21	9.26	30.41	4.14	0.001
	GS	32	25.85	5.35	13.55	35.55	28	20.91	5.84	9.34	32.67	4.95	0.001
Height of the mandibular body at the mental foramen, left	MS	32	25.73	5.76	8.59	35.83	28	21.36	5.12	9.66	30.65	4.37	0.001
	GS	32	26.39	6.17	9.09	35.99	28	21.24	5.98	8.58	31.41	5.14	0.001
Bimental breadth	MS	32	45.34	3.21	39.19	50.91	28	43.63	2.43	38.85	49.80	1.71	0.024
	GS	32	46.47	3.72	34.83	51.72	28	44.58	2.46	39.33	50.28	1.89	0.001
Breadth of the mandibular body, right	MS	32	10.65	2.31	6.11	16.58	28	9.88	1.44	6.90	13.47	0.77	0.135
	GS	32	15.97	5.05	7.06	25.43	28	14.14	4.26	9.11	25.27	1.83	0.001
Breadth of the mandibular body, left	MS	32	10.30	2.57	4.94	17.47	28	9.84	1.70	6.41	14.29	0.45	0.432
	GS	32	15.96	4.81	8.49	24.74	28	13.81	4.03	9.27	24.00	2.15	0.067
Minimum ramus breadth (n = 59)	MS	31	29.97	4.06	22.06	38.59	28	28.35	2.70	23.54	34.24	1.62	0.079
	GS	31	30.85	4.13	23.80	40.13	28	29.23	2.72	24.10	35.04	1.62	0.083
Mandibular angle, right	MS	32	121.20	7.31	110.00	137.00	28	123.50	7.15	111.00	138.00	-2.30	0.215
	GS	32	127.55	8.26	113.45	145.60	28	130.61	6.92	116.86	142.29	-3.06	0.128
Mandibular angle, left	MS	32	122.22	7.73	111.00	137.00	28	124.27	7.43	112.00	138.00	-2.05	0.301
	GS	32	128.54	8.64	111.58	146.76	28	131.12	7.09	116.25	141.43	-2.58	0.215
Mandibular notch depth, right (n = 59)	MS	32	13.82	1.80	9.80	17.19	27	12.41	1.93	8.56	16.02	1.41	0.005
	GS	32	13.69	1.78	9.99	16.90	27	12.33	1.98	8.95	16.61	1.36	0.006
Mandibular notch depth, left (n = 56)	MS	31	13.77	1.91	9.74	16.59	25	12.50	2.24	8.26	16.00	1.28	0.025
	GS	31	13.78	1.96	9.61	16.73	25	12.52	2.18	8.48	16.32	1.25	0.027

MS: mandible stabilizer; GS: gold standard.

Table 5. ROC curve of the measurements using the mandible stabilizer (MS) and the tomographic measurements (GS, golden standard) for each sex.

Variable	ROC curve for each sex (n = 60)			
	Cat.	Area under the ROC curve (p)	Associated criterion	Sensibility-specificity
Maximum mandibular length	MS	0.739 (0.001)	> 101.68	78.12–64.29
	GS	0.686 (0,008)	> 105.19	71.97–64.29
Bigonial width	MS	0.778 (0.001)	> 89.95	65.62–82.14
	GS	0.823 (0.001)	> 90.43	62.50–89.29
Maximum ramus height, right**	MS	0.794 (0.001)	> 55.70	75.00–78.57
	GS	0.797 (0.001)	> 54.79	93.75–60.71
Maximum ramus height, left (n= 59)	MS	0.882 (0.001)	> 56.54	75.00–85.19
	GS	0.819 (0.001)	> 57.84	75.00–85.19
Mandibular length (projection) (n = 59)	MS	0.593 (0.210)	> 72.89	40.63–85.71
	GS	0.643 (0.048)	> 72.33	56.25–75.00
Bicondylar breadth	MS	0.758 (0.001)	> 113.58	78.12–66.67
	GS	0.760 (0.001)	> 114.81	65.62–81.48
Bicoronoid breadth	MS	0.708 (0.001)	> 96.98	43.75–96.43
	GS	0.747 (0.001	> 97.21	46.88–96.43
Mandibular notch breadth, right (n = 59)	MS	0.650 (0.037	> 31.47	68.75–60.71
	GS	0.646 (0.043)	> 33.37	46.88–85.71
Mandibular notch breadth, left (n = 59)	MS	0.729 (0.001)	> 30.41	84.37–59.26
	GS	0.738 (0.001)	> 32.62	62.50–85.19
Height of the mandibular body at the mental foramen, right	MS	0.710 (0.002)	> 25.09	56.25–82.19
	GS	0.732 (0,001)	> 25.06	62.50–78.57
Height of the mandibular body at the mental foramen, left	MS	0.730 (0.001)	> 22.52	75.00–64.29
	GS	0.732 (0.001)	> 24.20	71.87–67.86
Bimental breadth	MS	0.670 (0.001)	> 44.74	62.50–78.57
	GS	0.689 (0.001)	> 46.04	62.50–82.14
Breadth of the mandibular body, right	MS	0.592 (0.209)	> 11.41	31.25–92.86
	GS	0.608 (0.147)	> 16.25	50.00–78.57
Breadth of the mandibular body, left	MS	0.531 (0.680)	> 12.23	21.87–96.43
	GS	0.638 (0.063)	> 14.65	56.25–78.57
Minimum ramus breadth (n = 59)	MS	0.618 (0.117)	> 31.04	41.94–89.29
	GS	0.615 (0.126)	> 31.69	48.39–85.71
Mandibular angle, right	MS	0.599 (0.178)	> 122.00	65.62–53.57
	GS	0.599 (0.182)	> 122.90	28.12–92.86
Mandibular angle, left	MS	0.573 (0.331)	> 117.00	31.25–85.71
	GS	0.587 (0.243)	> 126.42	43.75–75.00
Mandibular notch depth, right (n = 59)	MS	0.707 (0.002)	> 13.11	71.87–66.67
	GS	0.0.707 (0.023)	> 13.11	71.87–66.67
Mandibular notch depth, left (n = 56)	MS	0.665 (0.024)	> 13.75	61.29–68.00
	GS	0.667 (0.023)	> 13.37	64.52–68.00

that the mandibular angle measurement has been mainly used for age estimation.[18]

Multivariate analysis considering several skull and mandible characteristics at the same time achieves better results than individual measurements.[5] With more cranial and mandibular traits analyzed, better results are achieved. Walker[5] found that five cranial traits evaluated together classified 90% of the individuals correctly.

It is necessary to perform studies in several populations to discriminate sex because temporal and spatial variations can contribute to differences among different population groups.[5] The MS should be used in several populations, including ancient and modern, so that more precise sexual dimorphism parameters can be established. There are variations within and among populations because hormonal and environmental factors can affect bone growth.[19]

An investigation performed using skulls and mandibles in South Africa showed that several mandibular characteristics were useful in studying the sexual dimorphism, and the measure that was most dimorphic was bigonial breadth.[4]

The limitations of the study include focusing on a specific sample of the metropolitan area of São Paulo, Brazil from the Institute of Teaching and Research in Forensic Sciences of Guarulhos. It is important to take into consideration that a documented sample does not mean that it is representative of an entire population group,[20] as most worldwide collections are used for convenience. Therefore, more studies are necessary in other population groups using the same methods to establish parameters for adequate measurements to elucidate sexual dimorphism in modern and archaeological collections.[20]

Another aspect that should be discussed is that the Brazilian population is mixed, so there is a low probability of selecting mandibles from exclusively white, brown or black persons. In addition, when the genomic ancestry of Brazilian individuals was evaluated, low differences were observed among the regions of the country. [21]

Conclusion

The mandible stabilizer achieved the aim of discriminating sexual dimorphism using mandible measurements. Some measures exhibit an increased potential to differentiate sex compared with other measures.

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