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ANALYSIS OF THE ANTHROPOMETRIC MEASUREMENTS OF THE SMILE USING 3D STEREOPHOTOGRAMMETRY.

Análise das medidas antropométricas do sorriso utilizando a estereofotogrametria 3D.

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ABSTRACT

3D stereophotogrammetry makes the analysis of facial soft tissues possible, and has the potential to contribute to human identification processes. Nowadays, the images available through social networks are composed of a significant amount of smile photos, making techniques such as 3D stereophotogrammetry relevant. The objective of the present study was to quantitatively analyze the anthropometric measurements of the smile through 3D stereophotogrammetry, including area, angular, and linear measurements. Anatomical landmarks were used to make possible the area, angular, and linear measurements. The sample consisted of 25 volunteers, 13 female and 12 male, both in the 19-25 age group, resulting in a mean age of 22.3±1.9 and 23.3±1.5, respectively. The anatomical landmarks were marked on the face of the volunteers using a black eyeliner, and the photographs were taken using the 3D stereophotogrammetry technique (Vectra H1, Canfield, NY, USA), being 3 photographs with a spontaneous smile and 3 at rest, right lateral, left lateral and frontal of each. Among the results of the comparison between genders and the photo/smile relation of the statistical analysis, variables such as the mentolabial angle and the vermilion height of the upper lip showed significant p-values of 0.046 and 0.014, respectively. It can be concluded that anthropometric measurements of three-dimensional smile images can be performed with the use of 3D stereophotogrammetry, with the purpose of contributing to facial identification methods.

KEYWORDS

Forensic odontology; Stereophotogrammetry; Human identification; Smile.

INTRODUCTION

The human face has its own characteristics in relation to dental occlusion, harmony, musculature, shape, and configuration of structures[1]. There is also the possibility of differentiating soft and hard tissues between races and nations since these have their individualities.

Identification could be defined as a set of procedures and techniques to individualize a person or object. In addition to the use of techniques, the identification process also requires appropriate means to achieve identity and can be performed by trained technicians (judicial or police) or by professionals in the biological area (medico-legal and odontolegal)[2].

Identification by face is of great importance in the field of forensic odontology, as it relates to legal and humanitarian reasons, being widely used in the individualization of the living and the dead. Therefore, the development of techniques that allow the identification of the face using computer programs has been increasingly studied in the scientific literature[3].

Currently, society lives in an era in which there is a large availability of images on social networks, among which photos of the face are often found. Images of radiographs or CT scans, intended for the visualization of hard tissues, do not allow comparison with these photos available on social networks, which can be useful, for example, in antemortem or postmortem identification. Within this perspective, some techniques, such as 3D stereophotogrammetry, which analyze the soft tissue of the face, can be better applied and assist in these facial identification processes.

Facial analysis through soft tissues in three dimensions is being studied more intensively, and among the various techniques used, the most promising method for soft tissue evaluation is stereophotogrammetry. This method generally consists of a group of cameras with a fast capture time. The cameras capture images from multiple angles simultaneously, and the software produces a 3D digital image. The rapid image acquisition reduces the effect of movements and, in addition, there is no need for contact with the facial surface, thus avoiding soft tissue modification[4-8].

The introduction of a new method to analyze the shape and size of facial soft tissue morphology in 3 dimensions (3D), as well as the development of a standard 3D facial soft tissue model provides easy understanding for patients and is useful for clinical diagnosis and pre-treatment of soft tissue morphology[9].

Regardless of the technique used for 3D facial soft tissue measurements, the accuracy and validity of the method are critical for confidence in the analysis of craniofacial deformities[4,8]. The reproducibility of the 3D stereophotogrammetry imaging system (Vectra; Canfield Scientific, Fairfield, NJ) was tested by Menezes *et al.* (2010)[9] on 10 adult subjects, obtaining three-dimensional points and linear measurements. No systematic errors were found in the tests performed in the study described above. The development and validation of the correspondence between dental and facial 3D reconstructions in healthy subjects, as well as the analysis between the distances between the occlusal plane and the facial arches, demonstrated that the method could be used to longitudinally monitor the evolution of orthodontic/orthopedic treatments through the non-invasive acquisition of facial and dental morphology.

In this way, this monitoring can guide dental surgeons in real-time treatment management. Reduced x-ray exposure and the use of a 3D global analysis are probably among its main benefits[10].

Easy image analysis has been used in the forensic area as a means of identification since photography first appeared[11]. The images of the face are a very important piece in the process of confirmation or elimination of a subject, through comparisons of particular anatomical characters, and can be used as evidence for the Judiciary[12]. Human recognition via photographs is performed with comparison techniques that can cover 3 forms of approach, namely: superimposition, analysis of the incisal edge of anterior teeth and direct morphological comparison of dental elements[13]. Some pre-death photographs used for comparison, such as the selfie, usually coming from social networks on the internet, whose face and smile constantly appear in evidence in the image, are of great help in elucidating forensic cases[14]. The main features for recognition that are noticeable in photographs of a smiling individual include morphological features, the shape of the crown, width, size, dental anomalies, alignment and distances between the dental elements, and facial profile[15]. If an individual's anterior teeth are clearly defined in an antemortem photograph, individual tooth attributes can be compared and matched with postmortem photographs. With this, the anterior dentition can provide sufficient evidence of individuality[16].

Photoanthropometry is a modern science, and emerged from the need to establish methodologies for anthropometric analysis on images. It is defined as the analysis of anthropometric points, dimensions and angles to quantify facial features and proportions in a photograph[17]. It aims to collect information from two-dimensional images of the face and metrically compare the relationships and proportions between one photograph and another, identifying similarities and differences[18,19]. Therefore, the aim of this study was to evaluate the anthropometric measurements of the smile using a 3D stereophotogrammetry.

METHODOLOGY

This a cross-sectional descriptive observational study**.** This project was submitted to the Research Ethics Committee of the School of Dentistry of Ribeirão Preto – University of São Paulo (FORP/USP), under approval number CAAE n. 09281919.2.0000.5419. Data were collected after Ethical approval. All the research volunteers were informed about the objectives, risks and benefits, and signed an informed consent form. The Vectra H1 equipment used in this study was purchased with a FAPESP grant (project 2011/50424-6).

This research involves a preliminary study linked to a scientific initiation, so a non-probabilistic sampling technique by convenience was used. As this is an exploratory research, based on age range and gender variables, the sample size calculation was based on previous studies developed in the Laboratory for Research in

Electromyography of the Stomatognathic System (LAPESE) of the Department of Restorative Dentistry of the School of Dentistry of Ribeirão Preto, University of São Paulo (FORP/USP) to determine a minimum representative sample[20-22]. The total sample was composed of 25 healthy Brazilian subjects, 13 male and 12 female, between the age ranges: 18 to 25 years. These volunteers were invited to participate in the research through verbal communication, e-mail, or telephone contact. The inclusion criteria were Brazilian, aged between 18 and 25, and without facial deformities. While the exclusion criteria consisted of volunteers who had a history of tumors and/or surgeries in the head and neck region, patients with cognitive disorders and/or the presence of congenital syndromes, and patients with a history of facial paralysis or neuralgia.

Acquisition of three-dimensional images.

The 3D photographs were obtained in the Laboratory for Research in Electromyography of the Stomatognathic System (LAPESE) of the Department of Restorative Dentistry, Ribeirão Preto School of Dentistry, University of São Paulo (FORP/USP), according to the laboratory's specific and standardized protocol. Two images were taken of each volunteer: one at rest (teeth unclenched, facial muscles relaxed and lips sealed) and another with a spontaneous smile – Figures A and B.

The device used for capturing the images was the Vectra® H1, which follows a different technique from the fixed system (M3). Since the device has no bulkhead and only a set of two lenses, three captures were necessary at different times. The first image was taken focusing on the right side of the participant's face. The portable system was positioned at 45 degrees to the right of the participant, about 30 cm below the subnasal region (the area that coincides with the height of the bust). The distance the camera should remain from the participant's face was defined by the convergence of two bright points, created from the camera lens itself. This convergence of points defined the focal length needed for the correct acquisition of the image, as well as its perfect framing. The points should converge and be directed to the intersection of two lines: one horizontal, drawn at the Subnasale point; and the other vertical, passing through the Exocantion point [r] – Figures C and D.

The second image was taken frontally to the participant, but the vertical positioning of the camera should be just slightly below the Subnasale point. This reference point becomes, at this point, the region where the camera's light points should converge – Figures E and F.

Finally, the third image was obtained similarly to the first, but on the left side of the participant: an average height of 30 cm below the Subnasale point, with the bright points converging at the intersection of the horizontal line passing through the Subnasale point and the vertical line passing through the Exocantion point [l] – Figures G and H.

Once the image-capturing stage is over, the digital files are passed to the computer. It is possible to take images with the camera already connected to the computer, which makes importing the files immediately. However, transfer via memory card is also possible, provided there is an appropriate direct connection from the computer to the camera's memory card or an indirect connection with the help of a specific adapter for this purpose. The indirect import via memory card was the one used in this study because it does not require a wired connection from the camera to the computer, which makes the camera easier to handle. Furthermore, this method of file transfer seems to us much more interesting, since it is this way that makes the system truly portable and useful in places far from the computer. With the files sent to the computer, the software automatically converted each captured image into a three-dimensional image of the photographed region. By selecting the necessary images, the command "stitch images" was performed, thus forming the three-dimensional model of the participant's face.

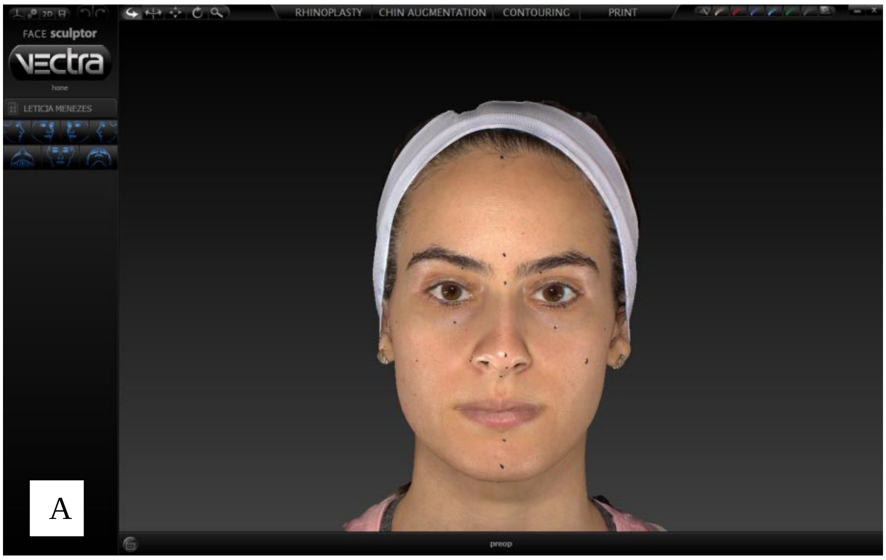

Figure A – Three-dimensional image at rest.

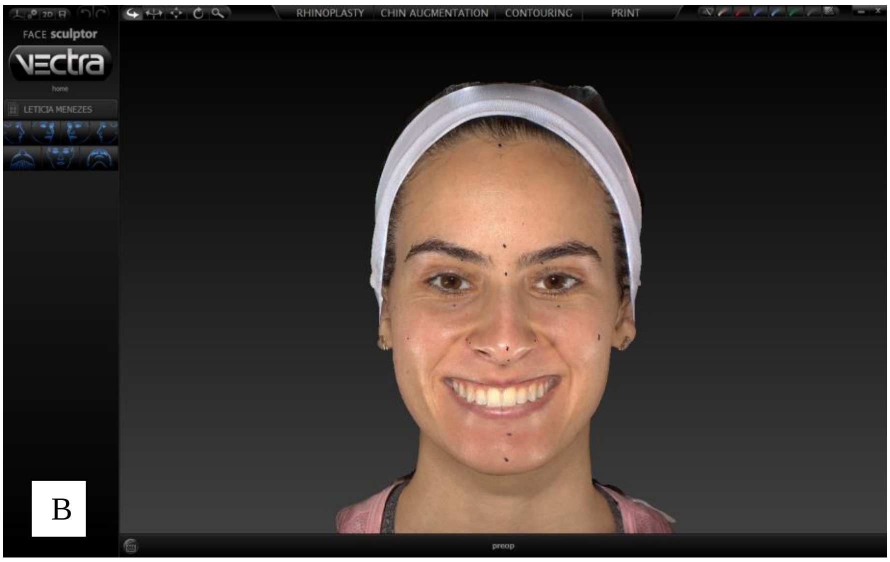

Figure B – Three-dimensional image with spontaneous smile.

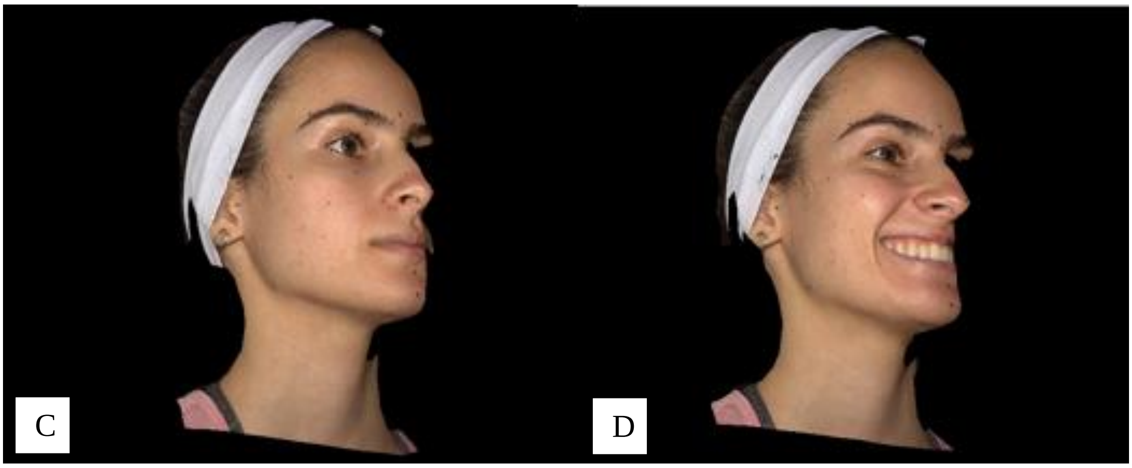

Figure C – Right side at rest. Figure D – Right side with spontaneous smile.

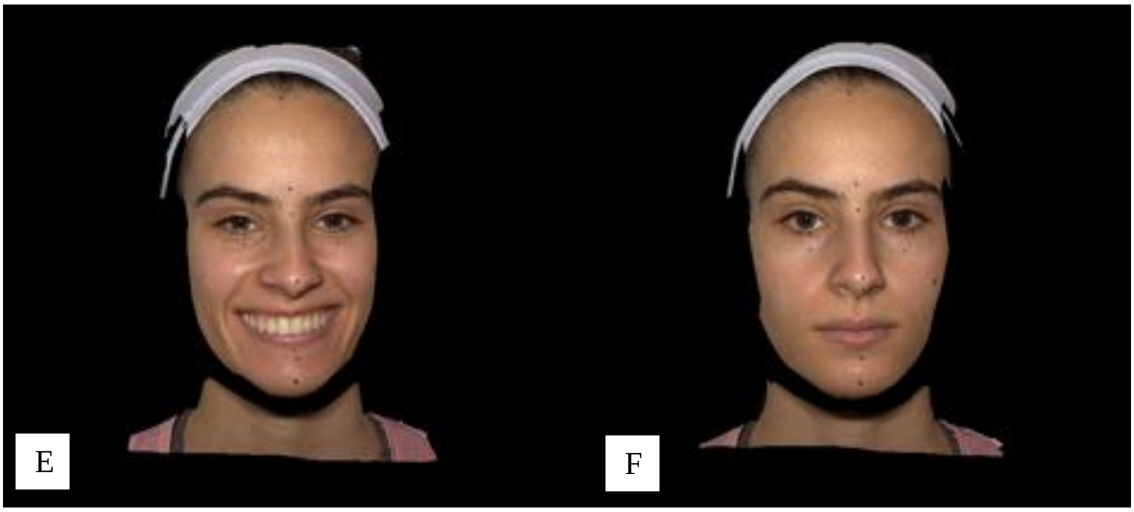

Figure E – Frontal image of the face with spontaneous smile. Figure F – Frontal image of the face at rest.

Figure G – Left side at rest. Figure H – Left side with spontaneous smile.

Protocol for marking reference points on the face (landmarks).

It is of fundamental importance that the operator responsible for marking the landmarks and capturing the images has received previous training. In this study, to test the reliability and accuracy of landmarks prior to image acquisition, a calibration test was performed. The sample consisted of 10 female adults. One experienced and two inexperienced operators were calibrated, taking two pictures of each adult: one picture at rest and one smiling, and 28 linear measurements were calculated for each image. The establishment of facial landmarks for marking and recording the measurements was based on previous studies[23]. In total 32 points were marked on the face, which are considered protocol by the LAPESE team, but in this study, only 11 of these points were used for analysis. These are described in Table 1.

Table 1 - Landmarks used in the present work with their abbreviations and definitions, according to Farkas (1987).

Abbreviation	Reference Point	Definition
C	Columela	Anterior-most point of the columela
Sn	Subnasale	Midpoint at the junction of the inferior border of the nasal septum and upper lip
Ls	Labiale Superius	Midpoint at the beginning of the vermilion of the upper lip
Cph [r] Cph [l]	Crista Philtri	On each high edge of the filter above the upper vermilion line
Ch [r] Ch [l]	Cheilion	Lip commissure
Sto	Stomion	Intersection of the facial midline and the horizontal cleft lip
Li	Labiale Inferius	Midpoint at the beginning of the vermilion of the lower lip
Sl	Sublabiale	In the midline nasolabial fold
Pg	Pogonion	Anterior most point of the chin

The reference points Columela, Subnasale, Labiale Superius, Labiale Inferius, Sublabiale, and Pogonion were used to form the Nasolabial and Mentolabial angles, the Nasolabial being formed by the Columela, Subnasale and Labiale Superius, and the Mentolabial by Labiale Inferius, Sublabiale and Pogonion. The linear measurements were defined by the landmarks Cheilion Left, Cheilion Right, Stomion, Labiale Superius, Labiale inferius, to enable the measurement of lip width and height, and finally, the points Cheilion Left, Cheilion Right, Stomion, Labiale Superius, Labiale inferius, Crista Philtri left and Crista Philtri Right to determine the area, being the vermilion area of the upper and lower lips. In addition to the soft tissue referential, the following points were marked using the software on the teeth: mesial, distal, incisal, and cervical, in order to evaluate the height and width of the teeth of the volunteers.

Statistical analysis.

The results obtained from the anthropometric measurements were submitted to the Shapiro-Wilk Normality Test; the data showed normal distribution (parametric, $p>0.05$). Next, a One-Way ANOVA statistical test was performed to check the variance of the following variables: men, women, rest photo, and smile photo for each measure evaluated, adopting p <0.05 as statistical significance.

RESULTS

Area measurements, such as the vermilion area of the upper and lower lips between the groups, had a p value of 0.18 and 0.41, respectively, while linear measurements, such as the height of the vermilion area of the lower lips and lip width showed a *p* value of 0.37 and 0.26, respectively. In contrast, the most significant p value was observed in the measurement of the Mentolabial Angle and in the linear measurement Upper Lip vermilion height, which showed a p value of 0.04 and 0.01, respectively. Information described in Figures 1 and 2 and Table 2.

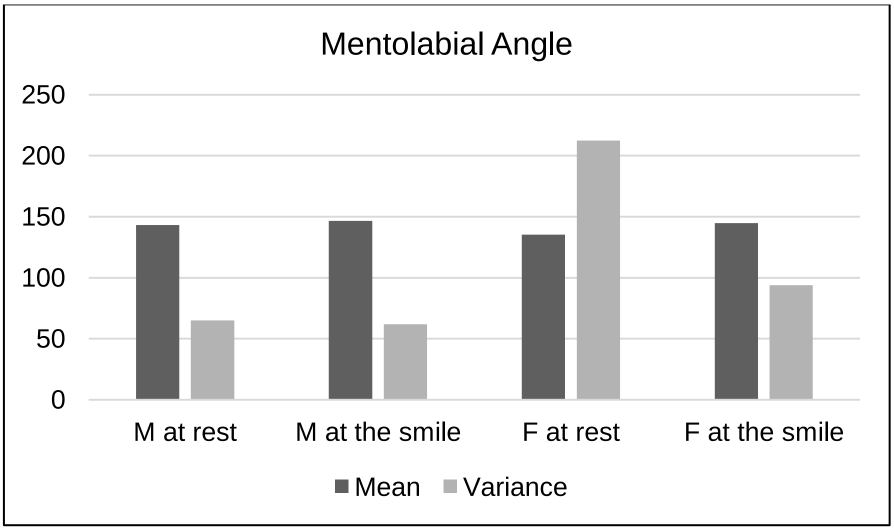

Figure 1 – Variables (significant p value). Variables that presented statiscal significance in the comparison between the analyzed groups- Mentolabial angle. Note: M - male volunteer and F - female volunteer.

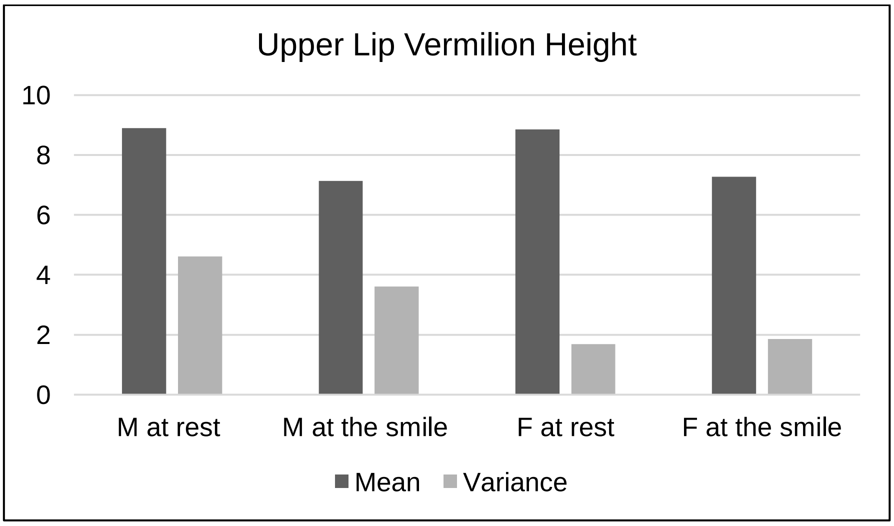

Figure 2 - Variables (significant *P* value). Variables that presented statistical significance in the comparison between the analyzed groups- Upper lip vermilion height. Note: M - male volunteer and F - female volunteer.

Table 2 shows the mean, variance, standard deviation, minimum, maximum, and p-value values between the groups of volunteers (female and male) for the measurements performed through the 11 anatomical points referenced according to the technique's recommendation.

The data from the measurements of the teeth did not show a significant numerical value of variability, so the statistical test was not used, only the data relating to the measurements.

Table 2 - Mean, Variance, Standard Deviation, Maximum, Minimum, and p-value of the investigated area, linear and angular measurements.

	M at rest	M at the smile	F at rest	F at the smile	V. *p*
V.A.U.L. Mean	3,8 ± 0,93 (1,7- 5,6)	4,5 ± 1,44 (2,5-7,6)	3,7 ± 0,5 (3,0-4,6)	4,2 ± 1,0 (2,2-5,6)	0,18
Variance	0,85	2,07	0,35	1,00	0,188
	M at rest	M at the smile	F at rest	F at the smile	V. *p*
V.A.L.L. Mean	4,4 ± 1,3 (2,2-7,1)	6,7 ± 1,9 (2,6-9,7)	4,4 ± 0,8 (3,2-5,7)	6,2 ± 1,4 (4,3-8,5)	0,41
Variance	1,56	3,60	0,63	2,11	0,41
	M at rest	M at the smile	F at rest	F at the smile	V. *p*
H.V.L. Mean	17,2 ± 4,7 (6,7-25,6)	4,5 ± 4,8 (16,6-31,2)	18,1 ± 2,3 (14,7-21,1)	25,5 ± 3,5 (20,9-32,8)	0,37
Variance	22,41	2,071	5,39	12,77	0,37
	M at rest	M at the smile	F at rest	F at the smile	V. *p*
Â. nasolabial Mean	107,0±16,2 (74,0-130,2)	117,7±22,3 (95,0-177,2)	110,8±8,8 (97,5-130,0)	115,6±11,4 (97,6-136,0)	0,31
Variance	263,30	500,74	78,83	131,84	0,31
	M at rest	M at the smile	F at rest	F at the smile	V. *p*
Â. mentolabial Mean	143,2±8,0 (122-152,5)	146,5±7,8 (133,5-161,7)	135,1±14,5 (111,9-166,9)	144,6±9,6 (128,9-159)	**0,04***
Variance	65,06	61,98	212,32	93,87	0,046
	M at rest	M at the smile	F at rest	F at the smile	V. *p*
Lips width Mean	49,7±2,8 (43,5-53,6)	63,8±7,3 (50,0-77,9)	48,0±4,6 (42,3-56,2)	62,4±6,5 (54,3-76,7)	0,26
Variance	7,95	53,78	19,60	42,56	0,26
	M at rest	M at the smile	F at rest	F at the smile	V. *p*
H.U.L.V. Mean	8,8±2,1 (4,0-12,2)	7,1± 1,9 (3,9-10,4)	8,8±1,3 (6,6-10,9)	7,2± 1,3 (5,0-10,8)	**0,01***
Variance	4,60	3,60	1,68	1,85	0,01
	M at rest	M at the smile	F at rest	F at the smile	V. *p*
H.V.L.I. Mean	9,26±2,3 (3,9-12,2)	9,16±2,1 (4,0-11,5)	10,53±1,0 (8,2-11,8)	9,6±1,4 (6,5-11,5)	0,26
Variance	5,69	4,61	1,20	2,06	0,26

Note: M - male volunteer and F - female volunteer
V.A.U.L. - vermilion area of the upper lip; V.A.L.L. - vermilion area of the lower lip; H.V. L - height of the vermilion of the lips; Â. Nasolabial - nasolabial angle; Â. Mentolabial - mentolabial angle; Lips width - width of the lips; H. U. L. V - height of upper lip vermilion; H. V. L. I - height of the vermilion of the lower lip; V. p - p value.

DISCUSSION

The process of human identification may be necessary both in contexts where there are hundreds or even thousands of people, which is the case of natural disasters or plane crashes, and in an isolated case involving a victim or even a suspect of a particular crime[24]. Thus, to scientifically search for human identification processes that are aligned with the current reality, such as the advancement of social media, is fundamental. Therefore, techniques that can analyze photographs, smile and even soft tissues are extremely important, since they are based on anthropometry, which is the science that investigates body size measurements and is considered a low-cost method that does not pose risks to the person being analyzed[25].

In this study, 3D stereophotogrammetry was used in order to obtain three-dimensional images of photographs of the face of individuals at rest and with a spontaneous smile, so that anthropometric and dental measurements could be taken, such as areas, angles, and lines, as previously mentioned. After the measurement, part of the results presented was relevant to the process of using characters of individuals to determine gender and a possible contribution to the process of individualization[26, 27].

It is possible to note that the value of the mentolabial angle and the height of the vermilion of the upper lip had discrepancy, p-value in the statistical analysis significant between the groups studied, contrasted between sexes and the rest/smile photographs, possessing value of 0.046 and 0.014, respectively (Figures 1 and 2).

The values that showed considerable discrepancy are capable of having the potential in assisting techniques that already use anthropometric measurements or photographs for the process of determining racial group, age, and sex, such as craniofacial anthropometry, whether direct or indirect[28]. Thus, the mean mentolabial angle in this study was higher in the female group compared to the male group (Graph 1), which specifically makes some references more relevant for analysis than the others, namely Labiale Inferius, Sublabiale, and Pogonion, and also generates a positive result for the study, because angular measurements are considered more assertive and constant, and with few variations[29].

However, the values achieved in the measurements of the teeth, for example, did not reach significant values regarding the numerical variability, which does not diminish its importance, since the teeth may serve to collaborate in determining gender or even in techniques that use antemortem photographs to identify a particular person[26, 27].

The device used to obtain the image captures, Vectra H1, presented limitations, not strictly related to the device, but to external variables, such as the change in the positioning of the volunteers in relation to the camera and the sequence of photographs, since, to compose the 3D image through stereophotogrammetry, using the Vectra H1, it is necessary to capture six images, three at rest (right lateral-frontal-left lateral) and three with a spontaneous smile following the same order. In some sample collections, it was necessary to repeat the sequence with the volunteer, in order to eliminate the intervention of the individual's position variable and make the analysis possible.

In the process of Odontolegal identification, the use of antemortem and postmortem radiographs is recurrent for human identification, and it is effective most of the time when their records have good quality and enable comparison, especially with regard to antemortem records. However, previous records with low quality, or even the absence of such data, make the expert's work difficult. Making the study of other techniques fundamental to the success in human identification, such as the use of photographs[3, 11]. With the data of the anthropometric measurements through the use of stereophotogrammetry, displayed, it was possible to make the analysis and measurements referring to the previously marked references on the face of the volunteers and perform the addition of references through the software, as it was precise in the process of measuring the teeth in order to make the anthropometric method possible. The values obtained from the measurements of the teeth, despite not reaching a significant value, contributed to corroborate studies already conducted, where they show minimal differences in shape and size and even the intercanine distance in bite analysis of teeth between groups but that collaborate to determine gender[30, 31].

The results achieved can contribute to new studies using this technique in order to collaborate with regard to its relevance in the process of human identification, given that the method can be an answer to the digital age, in which the world lives and the difficulties that not only experts but society as a whole, has. It is possible to signal more significant points and more important referential when there is or not a movement of the soft tissue of the face with the smile or at rest, such as the referential that form the mentolabial angle, and to ratify measurements, variations of certain referential in the case of teeth.

The use of stereophotogrammetry, if it passes in the future the criteria that are necessary for a medium to be called a human identification technique, which is uniqueness, immutability, perenniality, practicability, and classifiability, will bring the possibility of a change in human and facial identification processes. However, it may be the resolution to society's various challenges, and a means of facilitating the routine forensic work if the difficulties presented above are overcome, and, as with all identification techniques, it will serve as a consolation to certain people.

CONCLUSION

Based on the results, it can be concluded that anthropometric measurements of 3D smile images can be analyzed using 3D stereophotogrammetry to contribute to facing identification techniques. The mentolabial angle and the vermilion height of the upper lip can be important variables for the smile-based face identification process.

RESUMO

A estereofotogrametria 3D possibilita a análise dos tecidos moles faciais e tem o potencial de contribuir para os processos de identificação humana. Atualmente, as imagens disponíveis nas redes sociais são compostas por uma quantidade significativa de fotos de sorrisos, tornando relevante técnicas como a estereofotogrametria 3D. O objetivo do presente estudo foi analisar quantitativamente as medidas antropométricas do sorriso por meio da estereofotogrametria 3D, incluindo medidas de área, angulares e lineares. Referenciais anatômicos foram utilizados para possibilitar as medidas de área, angulares e lineares. A amostra foi composta por 25 voluntários, sendo 13 do sexo feminino e 12 do sexo masculino, ambos na faixa etária de 19 a 25 anos, resultando em média de idade de 22,3±1,9 e 23,3±1,5, respectivamente. Os referenciais anatômicos foram marcados na face dos voluntários com delineador preto e as fotografias foram realizadas pela técnica de estereofotogrametria 3D (Vectra H1, Canfield, NY, EUA), sendo 3 fotografias com sorriso espontâneo e 3 em repouso, direita lateral, esquerda lateral e frontal de cada um. Dentre os resultados da comparação entre gêneros e relação foto/sorriso da análise estatística, variáveis como o ângulo mentolabial e a altura do vermelhão do lábio superior apresentaram valores de p significativos de 0,046 e 0,014, respectivamente. Pode-se concluir que medidas antropométricas de imagens tridimensionais do sorriso podem ser realizadas com o uso da estereofotogrametria 3D, com a finalidade de contribuir com os métodos de identificação facial..

PALAVRAS-CHAVE
Odontologia legal; Estereofotogrametria; Identificação humana; Sorriso.

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