Applicability of forensic facial approximation in the recognition process of unclaimed victims

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ABSTRACT

Background: Identifying bodies in a state of putrefaction, skeletonization or mutilation is often difficult. In these cases, it is possible to use auxiliary methods such as forensic facial approximation, considering the possibility of recognition by a relative or acquaintance, helping to obtain ante-mortem data for the identification process. The aims of the present study were to evaluate the capacity of recognition of individuals from digital facial approximation and to verify the association between the level of understanding of the issue by evaluators and the recognition success index. **Methods:** 16 skulls with previous photographic records were selected and then utilized for three-dimensional approximation using the digital technique, scanned by photogrammetry, and reconstructed by computerized method using open-source software. Twenty evaluators tried to recognize the facial approximation performed from images present in the photospreads. **Results:** The mean overall score was 23.75%, and it was observed that in only five approximations (31.24%) the option of correct recognition of the victim was the one that obtained the highest number of selections. False positives and negatives corresponded, respectively, to 11.56% and 12.5%. **Conclusions:** It can be concluded that the methodology can provide recognition albeit in low numbers, and permitting the acquisition of ante-mortem data for the proper process of human identification through primary methods.

INTRODUCTION

The performing of identification tests is very frequent[1,2] in forensic practice. However, it is sometimes difficult to identify deceased bodies, due to advanced stages of decomposition, as well as mutilation and carbonization. In these cases, to reduce the possibilities of who this person could be, and increase the chances of a positive identification, an auxiliary method can be applied, such as the forensic facial approximation (FFA)[3,4]. This method recreates the appearance of an unknown skull and then this image is publicized, in the attempt to recognize the person by friends and family, making *ante mortem* data possible to obtain. [5–8]

The chances for identification can be increased when the recognition brings information that enable primary methods of identification to be applied, such as DNA profiling or dental methods. [2,5-9] Despite some limitations on obtaining a positive identification,[10] FFA is very useful in reinforcing the identificatory process, especially when the bodies can be categorized as mentioned above.[4,10]

It is easier to recognize familiar faces, therefore the recognition of people without prior contact is different to that with prior contact.[11-13] For that reason, the unfamiliar face matching has been the target of many previous studies.[11,12,14-16] Some studies show that even people familiarized with the subject are not infallible, sometimes even giving values below average,[14,17–19] therefore Herrera et al.[20] emphasized the need to investigate the evaluator's experience in identifying faces, as it may influence the facial recognition.

The aims of this study were to evaluate a capacity of unfamiliar face matching by facial approximation in skulls whose faces are known, and to verify the existence of an association between level of understanding of the subject by the evaluators and the recognitions matches.

MATERIAL AND METHODS

This project was approved by the Research Ethics Committee (CAAE: 69052017.8.0000.5440) and it was conducted in Ribeirão Preto, São Paulo – Brazil using skulls from southeast region. Sixteen skulls of unclaimed individuals with prior photographic registration from a Forensic Anthropology Laboratory were selected. The laboratory is a section of the legal/forensic medical institute (CEMEL), from Ribeirão Preto Medicine School of University of São Paulo (FMRP/USP). The coroner provided the anthropological profile, including age, sex and ancestry and these aspects were confirmed by their real identification. In addition, the skulls should have an *ante mortem* photo or image before necropsy procedure at morgue. Since the skull should have this photograph, the number of skulls included in the research were limited. Furthermore, skulls with trauma in the facial portion of the head, and photographs of the face in advanced decomposition were excluded.

To perform the digital facial approximation, the skulls were digitalized using the photogrammetry technique, which consists of several photographs around the skull in different angles following a standardized process.[21,22] The photographs were taking using a camera Canon, PowerShot SX1IS (Canon U.S.A Inc, United State of America), focal length of 60mm and images size of 3648 x 2736 pixels. A photographic scale was used to maintain accurate the skull and structures size. A total of 120 photographs of each skull was taken to realize the reconstruction of the images in a 3D model, using the software Autodesk Recap Studio (Autodesk Inc™, United States). This methodology shown accuracy in measures and surface appearance without distortion [21,22]. The digital replica of the skull was imported into the Blender digital program (Blender Foundation™, Netherland), and an open-source 3D digital facial approximation protocol[5] was applied, performing steps used in the manual method, adapted for the virtual environment. The person who performed the facial approximation was graduated in Forensic Odontology for 3 years, having knowledge and ability to perform this methodology.

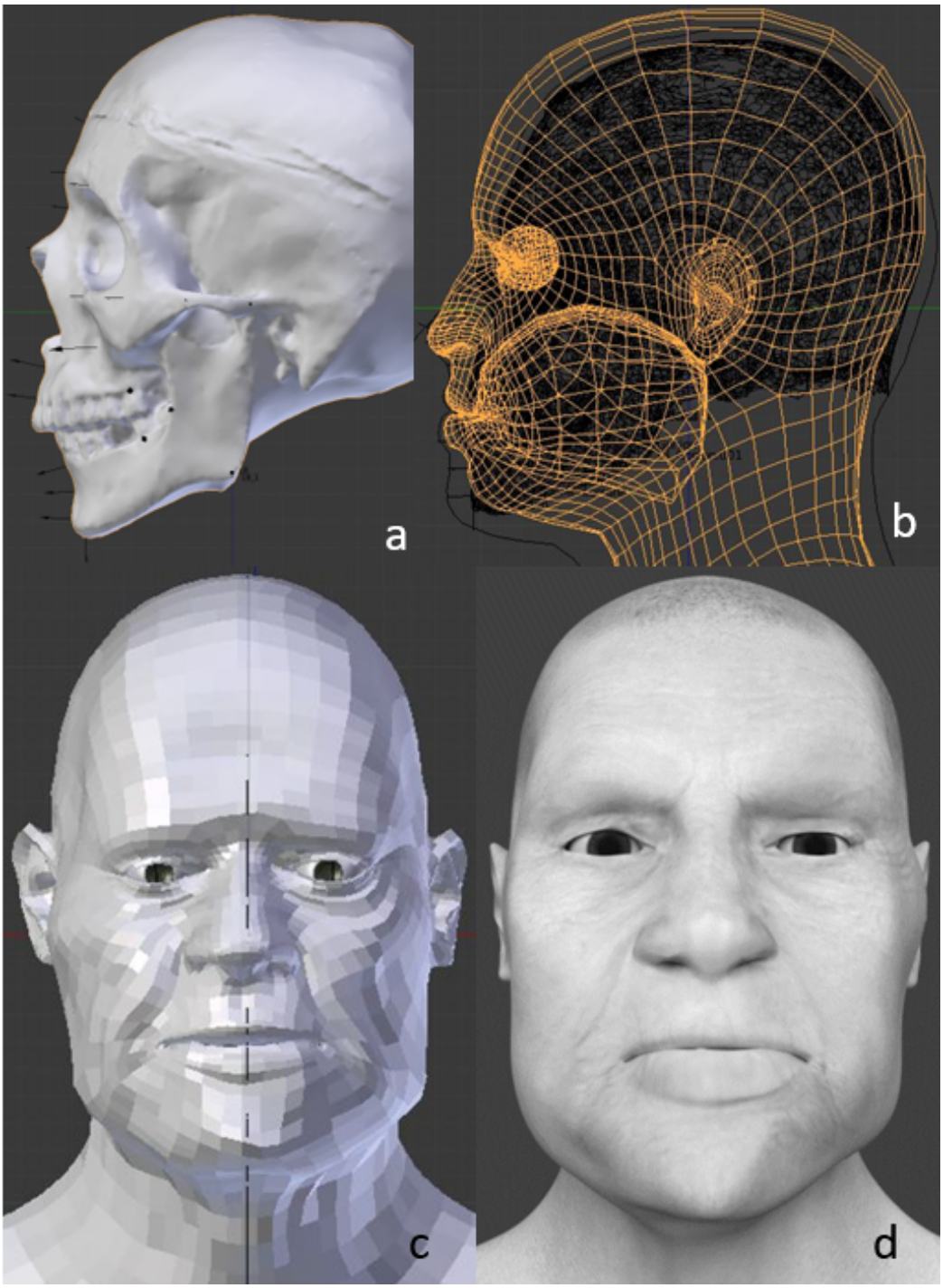
This protocol[5] determines the steps and the sequence to recreate a face. First, the anthropological profile of the skull needed to be provided. These results, such as age, sex and ancestry, will guide all of the reconstruction process. Then, the virtual soft tissue pegs (arrows) are positioned in 21 different landmarks in the skull (Table 1) with the size of the peg according to the anthropological profile. The soft tissue table used was developed by Beaini[23] in a Brazilian sample, using a sample from southeast region, the same region of the skulls from this paper.

Table 1. Name of the twenty-one locations/ landmarks in the skull used to position the virtual soft tissue pegs in the forensic facial reconstruction.

Locations - landmarks	
Midline	**Lateral (right, left)**
Supraglabella	Frontal eminence
Glabella	Supraorbital
Nasion	Suborbital
End of nasal	Inferior malar
Mid-philtrum	Lateral orbits
Upper lip margin	Zygomatic arch
Lower lip margin	Supraglenoid
Chin-lip fold	Occlusal line
Mental eminence	Gonion
Beneath chin	Upper second molar
	Lower second molar

After this step lines are placed to guide the location/shape of the eyes, nose and mouth, then a generic face is developed (automatically with the anthropological profile) and adapted through these markers, creating a unique face to that skull (Figure 1). The finalized version of the face was automatic rendered with the same program using a specific tool, in basic shades without hair, and for the creation of the photospreads both reconstructions and photographs of each individual were placed in shades of gray.

Figure 1. a – Digital skull with facial tissue markers (black arrows) with specific thickness for this given bioanthropological profile (male, older than 41 years, miscegenation – white and black); b – the general face (orange) that will be adapted in the outline created with the connection of the markers (black line); c – face after modifications required and ready to be rendered; d – face rendered and in shades of gray to compose the photospread.

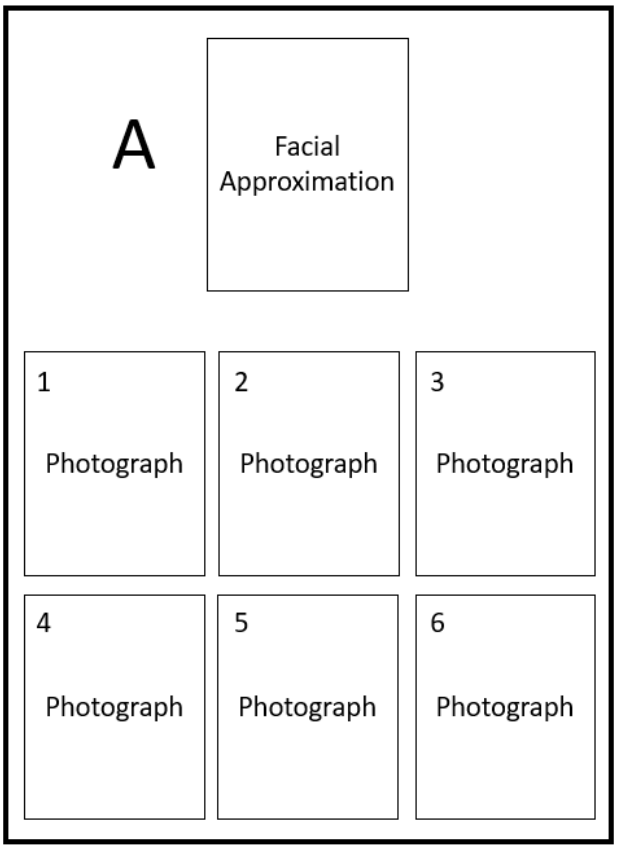


The facial approximations were analyzed by 20 evaluators, separated in equal numbers, into four different groups (according to their level of knowledge on the subject): Forensic Odontologists (group 1), Criminal Experts (group 2), last year undergraduate students (group 3), and people without previous knowledge on the subject (laymen) (group 4). The objective of the evaluators was to try to match faces to the facial approximations in a photospread with photographs of possible individuals. The photospread consisted of six photos, along with each digital facial approximation performed (A to P), randomly ordered on each sheet, totaling 16 sets of photos (one for each facial approximation). In order to standardize the photospreads, all images were placed in shades of gray and photographs of people in similar age groups, population affinity and head shape, both among the individuals themselves and in relation to the facial approximation, were selected as recommended [24].

In total 18 photographs were used, separated in groups of six in the 16 different facial approximations. Of these, only 14 had photographs that could be recognized and thus two approximations should not have matched faces by the evaluators, since the real photography of the FFA was not available. Four more photographs were placed that did not have their facial approximations done, so they should not be chosen, as they do not have a corresponding FFA. The correct photographs were randomly placed at each position.

The evaluators observed each facial approximation separately and indicated which of the six photographs the given approximation belonged (Figure 2). The evaluators should say if the photograph for the specific facial approximation was present or not. For that, they give a number in each set of photograph/approximation, from 0 to 6. Being 0 for non-correspondence (not present), and, once the evaluators recognize the approximation in one of the photographs, they should choose the number (position) 1 to 6, correspondent of the photograph. The evaluators were oriented explicitly, as recommended[24], that the specific person might not be in the photospread, so they could choose the non-correspondence in those cases.

Figure 2. Draft of the photospread analyzed by the evaluators. One image from the corresponding facial approximation (A-P) was placed above than six photographs that could be the person to be or not recognized (1-6). If the evaluators did not recognize any person for the respectively facial approximation, they should mark the number 0.



Descriptive statistics performed from the absolute and relative frequency, as well as the average of correct recognitions for each digital approximation and the chosen options, and false positive and false negative analysis. To verify the association between the approximation and the level of knowledge, categorized according to the different groups of evaluators, the Chi-square test was applied.

RESULTS

It can be verified that there was no relationship between the level of knowledge measured according to the group of evaluators, and the correct answer index, once the values were close

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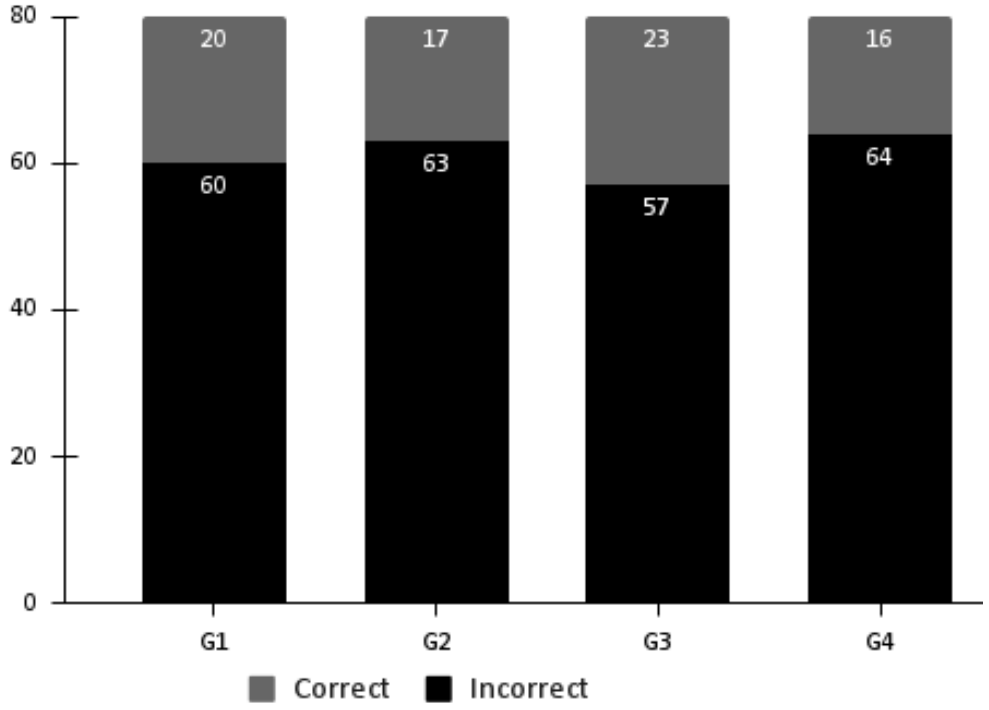
close (Figure 3). The chi-square test was applied between the number of correct and incorrect answers for the facial approximation and all groups of evaluators. The Chi-square (x^2) value was 2.070750 with 3 degrees of freedom, being the value $p=0.5578$, that is, there was no association between the groups and the recognitions. Still regarding correct answers, the average of each group ranged from 20% to 28.75%, being the lowest value observed in group 4 - composed of laymen; and group 3 with the highest average value, composed of undergraduate dentistry students.

After pondering on each evaluator, it was decided to verify the frequency of positive approximation, according to the number of evaluators. In other words, the frequency of how many approximations the five evaluators got right, and the frequency of how many approximations none of the evaluators got correct answers to, going from zero (no evaluator) to five (all evaluators), and this is described in Table 2. Figure 4 shows the number of negative and positive recognitions of each approximation.

Figure 3. Number of correct (gray) and incorrect (black) answers obtained by the evaluators in each group: Group 1 – forensic dentists; group 2 – criminal experts; group 3 – undergraduate students; group 4 - laymen



Number of evaluators	G1		G2		G3		G4		Total
	AF	RF(%)	AF	RF(%)	AF	RF(%)	AF	RF(%)	
0	6	37.50%	8	50.00%	6	37.50%	8	50.00%	28
1	4	25.00%	4	25.00%	2	12.50%	3	18.75%	13
2	4	25.00%	1	6.25%	5	31.25%	3	18.75%	13
3	0	0.00%	2	12.50%	2	12.50%	1	6.25%	5
4	2	12.50%	0	0.00%	0	0.00%	1	6.25%	3
5	0	0.00%	1	6.25%	1	6.25%	0	0.00%	2
Total	16	100%	16	100%	16	100%	16	100%	64

Table 2. Frequency of correct facial recognition according with the number of evaluators in each group.
AF – Absolute frequency; RF – Relative frequency.
G1 – forensic dentists; G2 – criminal experts; G3 – undergraduate students; G4 – laymen

Figure 4. Frequency of positive (grey) and negative (black) recognition of each facial approximation.

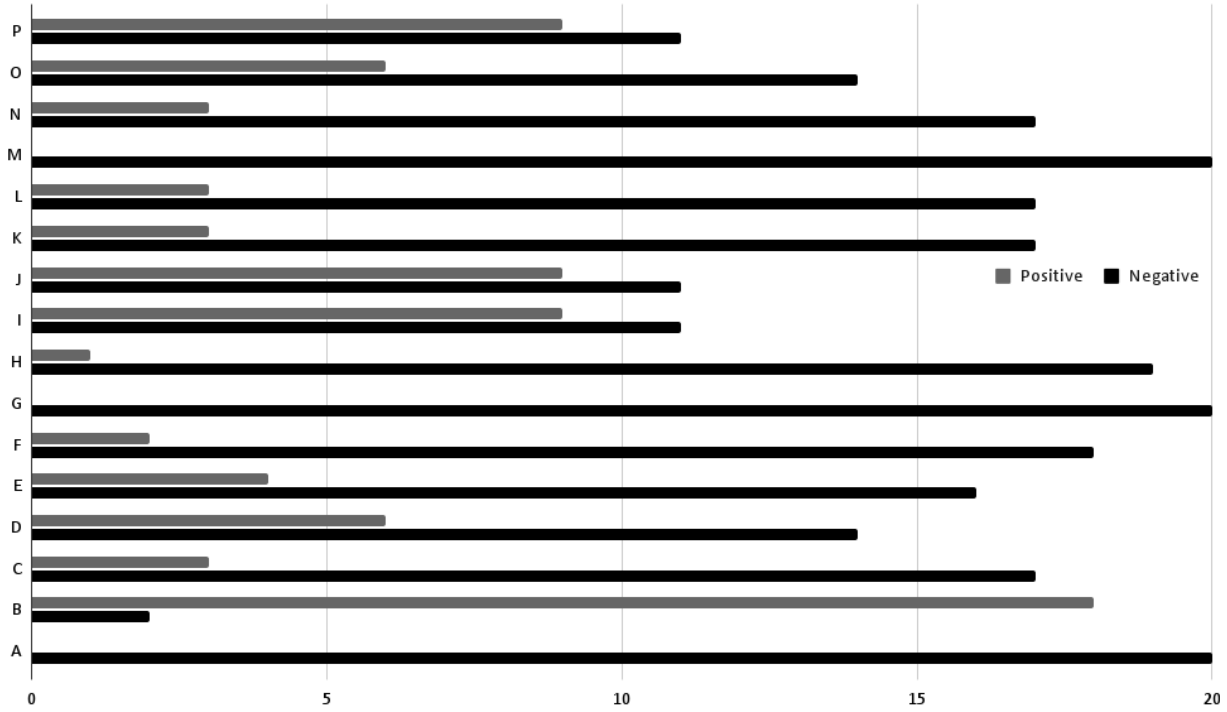


Table 3. Number of times that each photograph was chosen by evaluators in each approximation

	Position of the photographs						
Approximation	**1**	**2**	**3**	**4**	**5**	**6**	**0**
A	0	1	4	10*	0[a]	5	0
B	0	1	18*[a]	0	0	0	1
C	0	0	3	14*	0	0	3[a]
D	6a	1	1	0	0	7*	5
E	2	5*	4a	3	1	4	1
F	8*	1	3	0	3	2a	3
G	4	0	5	10*	0	1	0a
H	0	0	2	1a	12*	4	1
I	5	3	2	9*a	0	1	0
J	3	1	2	1	9a	2	2
K	2	0	2	8*	0	3a	5
L	3	3a	1	3	3	1	6*
M	14*	0a	0	1	1	3	1
N	2	3	3a	0	2	0	10*
O	2	0	5	1	4	6*a	2
P	9a	1	1	1	5	0	3

*Number of photograph chosen the most times for corresponding approximation.
[a] Number of photograph that corresponds correct to the approximation in question

Table 3 shows the data regarding the evaluators' choices concerning the position of the approximations and the photographs. Moreover, it is noted that in only five approximations (31.24%) the option of correct recognition of the individual was the one that obtained the largest number of selections. Another fact noted is that in six approximations, half or more of the evaluators mistakenly opted for the same photograph.

Of the 320 possibilities of correct answers, only 76 were correctly chosen. Of these, 51 (67.10%) were most often chosen by the highest number of evaluators, and concentrated on five approximations. In these approximations, 15.00% of the evaluators chose the correct photograph every single time.

In every single photospread, there was at least one photograph that the approximation had not been performed. From the 18 photographs used, four of them (identified with the number 5, 11, 15, 16) had no facial approximation performed, with a total amount of 22.22% of the photographs used. These images appeared 21 times in the photospreads (Table 4), representing 21.87% of possible choices by evaluators. They were chosen as the correct option 41 times, thus corresponding to 12.81% of the evaluators' choices.

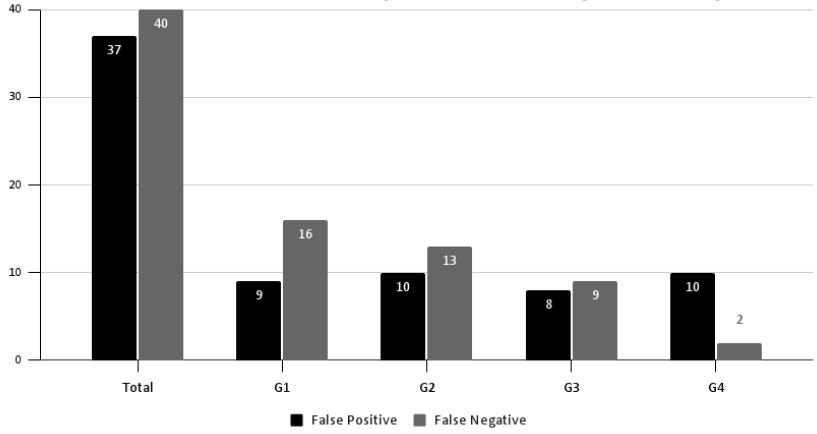
Table 4. Number of times that the four images which did not have a matching approximation appeared, along with the number of approximations in which these were chosen, and the number of evaluators who chose them as the correct option.

	Photographs without approximation *				**TOTAL**
	5	**11**	**15**	**16**	
Number of approximations they appeared in	9	3	3	6	21
Number of approximations in which they were chosen	7	2	2	2	13
How many times they were chosen as the correct option	15	5	15	6	41

The two facial approximations (C and G) that did not have images in the photospreads obtained just three correct answers out of 40, representing only 7.5% of the right answers. Thus, 37 evaluators identified those facial approximations, even when those did not have a photograph in the photospreads. It is worth mentioning that only the approximation C had correct answers.

Figure 5 brings the relationship between the false positives, when the evaluator chose some photograph when he should not have, meaning when the approximation did not have any correct alternative; and the false negatives, when the evaluator did not recognize the approximation in any photograph when it should have been recognized. It is possible to observe that the false positive and negative matched respectively 11.56% and 12.50% of the evaluators' choices, with nearly a quarter of their choices being the correct answers. It can be observed that the groups had very close amounts of false positive and negative, except for group 4 which only had two false negatives, that is, in only two answers out of 20, the evaluators chose to say that there would be no image related to the approximation when it existed.

Figure 5. Number of false positives and negatives according with the groups and the total of answers



DISCUSSION

Facial approximations can be presented to the public in a variety of ways, with the aim of encouraging recognition of the deceased individual by friends and family, and generate information about who the victim might be thus making it possible to apply the primary identification methods.[3,4,19] Posters with photos of missing children can be found on the streets and in different media, and the family of these children, along with the police, expect strangers to recognize the missing child through the poster. However, as previously mentioned, the recognition of people who have had prior contact is different to those who have not had, the former case subsequently making recognition easier than the later.[11]

Regarding the evaluators of the present study, the average of correct answers was 23.75%. However, it is important to emphasize that this study is not about familiar face recognition. The way people processed familiar faces is very different than they do unfamiliar ones,[12,25] and this could be a possible justification the low success rate in the recognition. However, Richard and Monson[19] found poor and similar performance recognition with people familiar and unfamiliar with the subject target.

Facts that can interfere in the facial recognition are lighting, positioning, quality of the image and the age difference between the suspect and the image to be recognized.[17,26,27] It was used in the present study photographs of real cases, and there were several of the factors mentioned above. However, it was decided not to change these aspects (except for the configuration in grayscale), as recommended in other studies [3,14] This characteristic is positive, once in real cases, people will provide any photograph of their parents such as selfies from smartphones, or photographs from old documents.[27] Therefore, this fact brought the study closer to day-to-day forensic practice, and not just a perfect laboratory pattern.

Henderson, Bruce and Burton[28] performed experiments using unknown people through surveillance camera images, and observed a high error of recognition (24%), even if the position and expression of the face were the same in both the surveillance image and the photograph used to perform the recognition. With this, it is observed that even having the so-called "gold standard", the recognition is not something simple and easy to be accomplished. Three facial approximation had no correct answers, in two of them is possible to suggest the cause of these results. In one of them, the photograph was about a man wearing beard, and in the other one, the person in the photograph was smiling. The facial approximation was performed without any characteristics, so they do not have smile or hair. Other studies[3,11,29,30] recommended that hair and clothes should be avoid, because they could complicate the recognition. However, one hypothesis for these two facial approximation were not recognized by anyone is that the evaluators could be expecting these characteristics in the facial approximation and in the photograph.

The defined groups in an attempt to cover various levels of knowledge, and the evaluators, whom had previous knowledge about the method, due to their professional or personal experiences. Caplova et al.[14] evaluated facial recognition of students and qualified professionals (forensic experts that deal with identification and facial recognition). The student average score was 78.1% of the correct answers and for the professionals 80%, with no statistical difference between the groups., concluding that facial recognition is an innate human ability. Countering the cited study[14] and the present study, Wilkinson and Evans[17] evaluated face recognition through photospreads, using groups composed of people from the general public and experts. Data showed that the general public recognized 46% correctly and experts 83%. For the authors, the results suggest that training and experience in facial analysis caused more reliable and accurate recognition. The present study found no significant differences between groups and no association between the level of knowledge and the groups themselves, however, the recognition rate was beneath 25%, well below the cited studies.[14,17]

Another study[31] conducted with passport officers' comparing photos with ID photos found a high frequency of mistakes even with people trained and with experience in this area. Burton et al.[32] concluded that even police officers with experience in forensic identification had a poor recognition rate just as people who did not know the subject targets. One of the possible reasons for the low right answer index is that the evaluators may be expecting to find facial

approximations that would be practically photographs of the subjects, which is not possible, since the facial approximation only estimates and approximates a possible face.

In a criminal or identification context, it is necessary to be careful with false positives (when a different individual is mistakenly matched to the face reconstructed) and false negatives (when the identity of a person whose face appears in the image is dismissed as being correct). In the present study, false positives and negatives corresponded, respectively, to 11.56% and 12.50% of the evaluators' choices, being almost a quarter of their options for the correct answers.

Wilkinson and Evans[17] evaluated the recognition of people with two different experiments. In the first case, out of the ten photospreads, only six had the face to be recognized. The public had 10% false positives and 39% false negatives, and experts had 3% false positives and 8% false negatives. In the second case, the photospreads were composed of six sets containing the subject target and two without the face to be recognized. The public obtained 10% of false positives and 59% of false negatives. The experts, on the other hand, obtained 2% of false positives and 25% of false negatives. Likewise, in the present study there was a higher rate of false negatives than false positives, however, these values were very close to each other. Nevertheless, a discrepancy with the above study is that all groups analyzed in the present study (either with greater or lower knowledge) had similar false positive and negative rates, and the highest rate did not exceed 20% of the possibilities.

As presented, the methodology is limited and needs new studies to be more accurate. It is recommended additional investments in software, technology, high quality of vigilant images to improve this results. Moreover, this important technique is very viable in several aspects, and could be used in more cases than it already has. Finally, an increase in number of workshops will be helpful in training more forensic experts to put it in practice.

CONCLUSIONS

The methodology used increased in almost one quarter (23.75%) the chances of correct recognition, and with this, the possibility to find *ante mortem* data to compare the missing person with the body. In other words, this method helps to increase the identification of a missing person. It is important to highlight that this method is an auxiliary tool and cannot be used alone and exclusively to perform identifications.

The recognition process has no association between the level of understanding of the evaluator and the correct answer provided ($p = 0.5578$). It is noteworthy that in view of the important consequences in the lives of relatives of unidentified victims, in social and psychological spheres, as well as in relation to succession, economic and legal issues, the possibility of getting it right in almost ¼ of the possibilities makes the tool useful as an auxiliary method for investigation, allowing *ante mortem* data to be collected for the proper human identification process through primary methods.

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