Contributions of facial imaging to human identification in forensic cases: a retrospective study (1996-2019) at the Operative Unit of Anthropology of the 'G. d'Annunzio' University of Chieti-Pescara (Italy)

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SUMMARY

Personal identification in legal proceedings and social matters consists of the description, comparison and correct attribution of some relevant biological individualising characteristics. Determination of an identity is generally achieved through construction of the biological profile (i.e. ancestry, sex, age, stature) and comparison of the individualising characteristics, to obtain a positive match. Although present techniques are mainly focused on identification of unknown decedents, due to more recent proliferation of personal, public and commercial installation of video surveillance systems and to image capture on mobile phones, the identification of living persons through video and images has become a major source of evidence in criminal investigations and at trials. This paper retrospectively evaluates the contributions of anthropological reports to the resolution of personal identification cases at the Operative Unit of Anthropology of the 'G. d'Annunzio' University of Chieti–Pescara, Italy, between 1996 and 2019. Of the 476 forensic facial comparisons carried out, for 151 of them (31.7%) it was not possible to carry out any facial imaging analysis due to diverse factors that affected the images and facial features of the subjects being analysed and compared. Of the remaining comparisons (325; 68.3%), the facial imaging techniques used for identification from video recordings and images were: morphological analysis (174; 53.5%); metric analysis (1; 0.3%); combination of morphological and metric analysis (143; 44.0%); photographic superimposition in combination with morphological and metric analysis (4; 1.2%); and facial approximation (3; 0.9%). The aim of this retrospective analysis was a critical evaluation of the advantages and limitations of the different methods used for personal identification in casework. Despite the challenges of facial imaging for human identification, these techniques represent a very important tool in forensic investigations.

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INTRODUCTION

Personal identification represents an essential step in legal proceedings and social matters, and it consists of the description, comparison and correct attribution of relevant biological characteristics that can be used to define any specific individual (Gibelli et al., 2016). In the search for a positive match, determination of an identity can generally be divided into two steps: (i) construction of the biological profile, which will include ancestry, sex, age and stature; and (ii) comparison of the individualising characteristics. Present-day techniques mainly focus on the identification of unknown decedents (Ubelaker et al., 2019). However, due to the proliferation of personal, public and commercial installation of video surveillance systems and to image capture technology that comes as an accessory to mobile phones, the use of video recordings and images for the identification of living persons now provides investigative opportunities that can be used as sources of evidence in criminal investigations and at trials (Evans, 2014; Valentine and Davis, 2015). Thus, forensic facial image comparison is defined as the identification or exclusion of a subject depicted within the imagery via analysis of their facial features.

The Facial Identification Scientific Working Group (FISWG; https://fiswg.org) and the European Network of Forensic Science Institutes (ENFSI; http://enfsi.eu/) are active working groups in which the aim is to develop standards, guidelines and best practices for facial image comparison. However, the details for the standardisation of the processes involved in forensic image comparison of these working groups are vague, and the need for specific guidelines that are agreed upon by the forensic community remains an unsolved problem. Currently, the three main techniques used for forensic facial image comparison are morphological analysis, photo-anthropometry and superimposition (Oxlee, 2007; Ritz-Timme et al., 2011; Evans, 2014; Gibelli, et al., 2016; ENFSI, 2018; FISWG, 2018).

Morphological analysis is a subjective process that is based on the observation and comparison of the shape, appearance, presence and/or location of facial features, to define apparent differences and similarities between subjects depicted in the different images used for the comparison. These features include global (i.e. overall face), local (e.g. anatomical structures, such as eyes, nose, mouth, and their components, such as eyeball prominence, nasal root, nostrils, philtrum) and discriminating characteristic facial marks (e.g. scars, moles, wrinkles) (Fig. 1). Morphological analysis is undertaken in a systematic manner and includes a pre-determined list of the features to be compared for every examination, thereby facilitating the structuration and documentation of comparisons, as well the replication of the identification process. Although a variety of facial feature lists are available (e.g. Vanezis et al., 1996; Ohlrogge et al., 2008, 2009), FISWG and ENFSI do not currently endorse any specific list. Morphological comparison is usually sensitive to loss of image quality (e.g. blurring, reduction in spatial resolution), reducing the visibility of gross details (e.g. specific shape of the eyes, mouth and nose), and reducing or eliminating the visibility of fine details (e.g. freckles, creases on the face). Photo-anthropometry is an approach that is based on the measurement of a range of dimensions (e.g. spatial distances, angles) of anthropological landmarks and other facial features, to quantify their characteristics and proportions (Fig. 2). The measurements collected are then compared between two facial images to determine the level of similarity or dissimilarity. Absolute measurements by themselves are a very inaccurate means of comparison, while normalized proportionality indices calculated as a proportion between two absolute measurements are more suitable, but also have limitations. The use of indices does not overcome problems arising from extrinsic factors such as subject distance to camera, focal length of lens, camera angle or orientation of the head. Thus, indices and angles must be used when exact camera positions and subject-to-camera distances are known (Fig. 3). Moreover, photo-anthropometry is extremely sensitive to loss of image quality (e.g. blurring, reduction in spatial resolution, lens or perspective distortion), which

reduces the ability to determine the specific location of facial landmarks, and consequently reduces the accuracy of all measurements. Superimposition is the process of combining two facial images to highlight potential similarities or dissimilarities. Using video techniques and digital image processing, images can be combined using either reduced opacity overlays, to merge certain parts of the face within another facial image, or by rapidly alternating between two images (Fig. 4). In addition, various fading mechanisms can be used to combine images, such as visual flicker and vertical, horizontal or diagonal wiping, so that a line erasing part of one image reveals part of the second. Superimposition is also sensitive to loss of image quality, reducing the ability to determine the specific location of individual features, which subsequently reduces the ability to generate an accurate superimposition (Oxlee, 2007; Ritz-Timme et al., 2011; Evans, 2014; Gibelli, et al., 2016; ENFSI, 2018; FISWG, 2018). Choice of the specific technique to be used is directly related to the quality of the images to be compared, and generally a fusion of these different techniques is applied in real-life analysis in forensic settings.

This retrospective study presents data from a variety of anthropological reports that were evaluated with a focus on their investigative findings, to better understand the advantages and limitations of the different techniques used in personal identification in forensic cases.

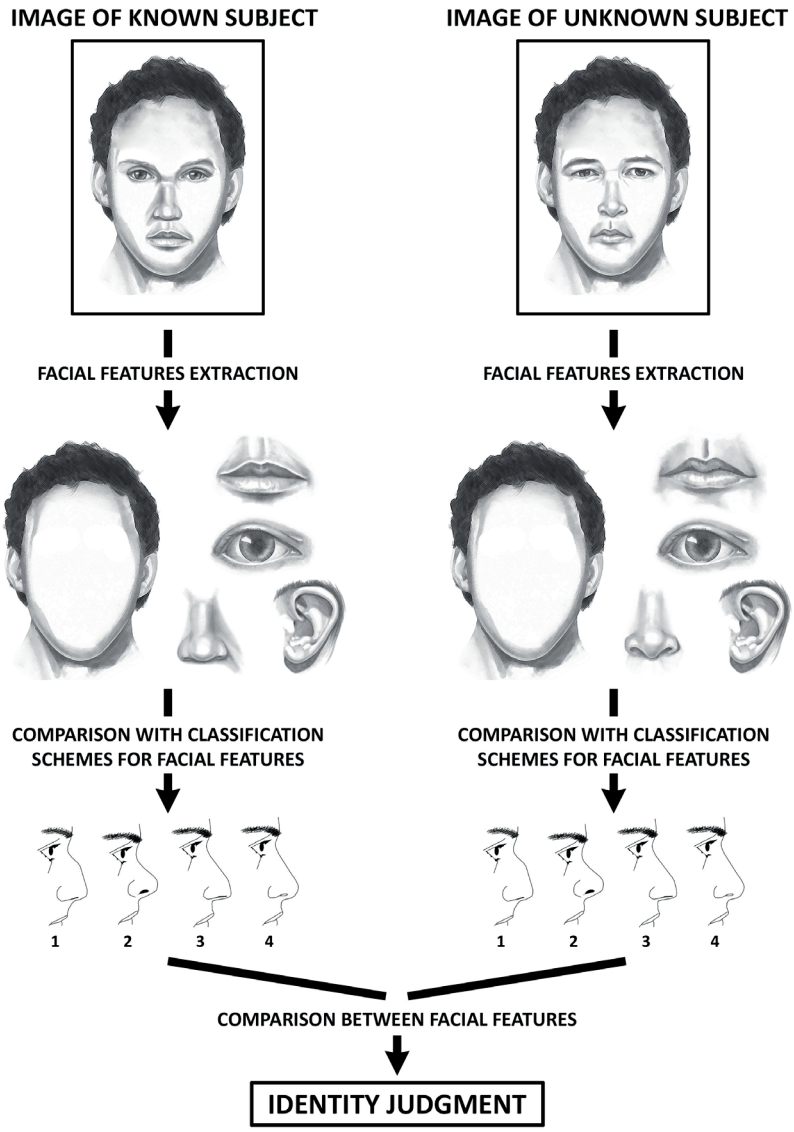


Fig. 1.- Flow diagram illustrating the identification procedure through the characterization of global and local facial features and their components. Morphological analysis is a facial comparison technique in which the features of the face of known and unknown subjects are described and compared.

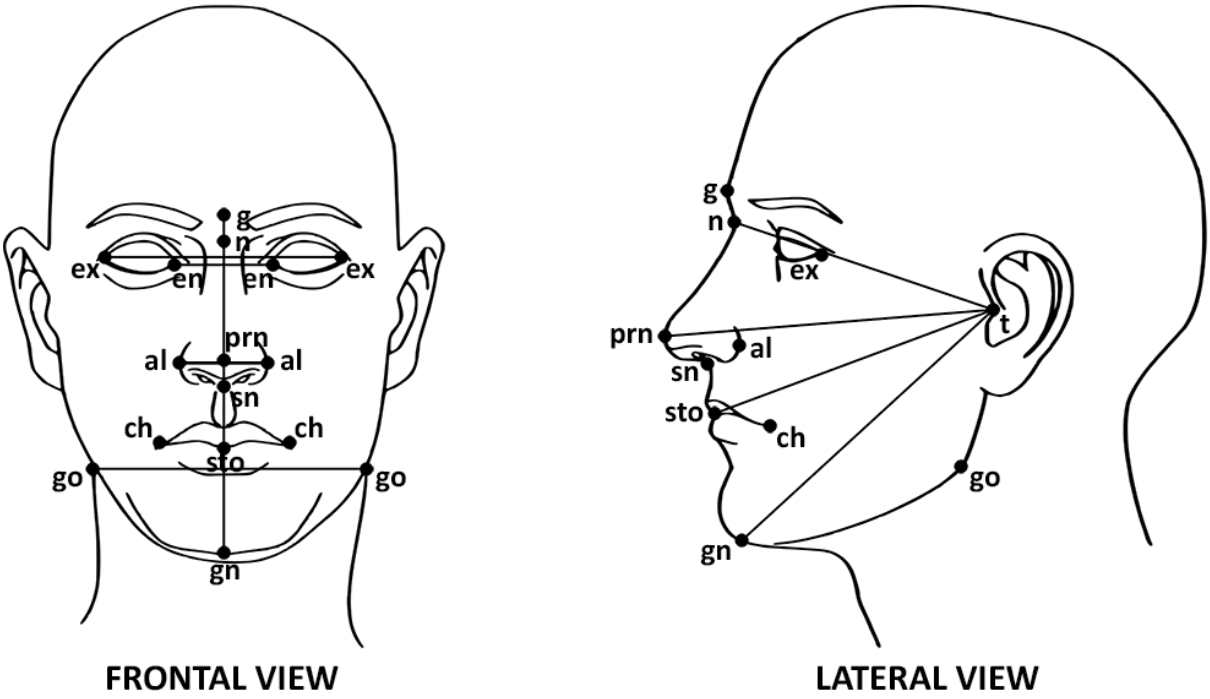


Fig. 2.- Location of some facial landmarks. Frontal and lateral views also show the location of some linear distances and angles. Abbreviations: al, alare; ch, cheilion; en, endocanthion; ex, ectocanthion; g, glabella; gn, gnathion; prn, pronasale; n, nasion; sn, subnasale; sto, stomion; t, tragion.

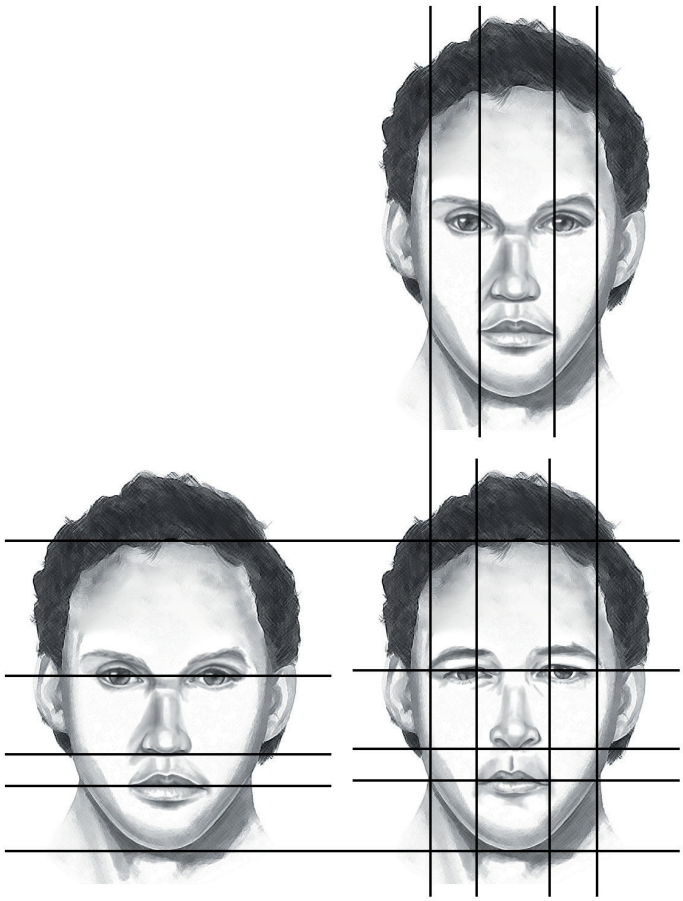


Fig. 3.- Facial landmark alignment. Various facial landmarks are identified on the face and lines are overlaid onto the images at the location of the determined landmarks. The distances between the various landmarks are then compared between the two facial images to determine the level of similarity or dissimilarity, through comparison of the proportions of the distances between landmarks. This Figure illustrates how the results of photo-anthropometrical analysis could be presented by a forensic anthropologist in Court. Accompanying the figure would be a table detailing the measurements in terms of (i) horizontal distances —e.g. expressed as proportions of the distance between the bigonial width (mandibular width)—, and (ii) vertical distances —e.g. expressed as proportions of the distance from the gnathion (chin) to the line crossing the centre of the two pupils (eyes).

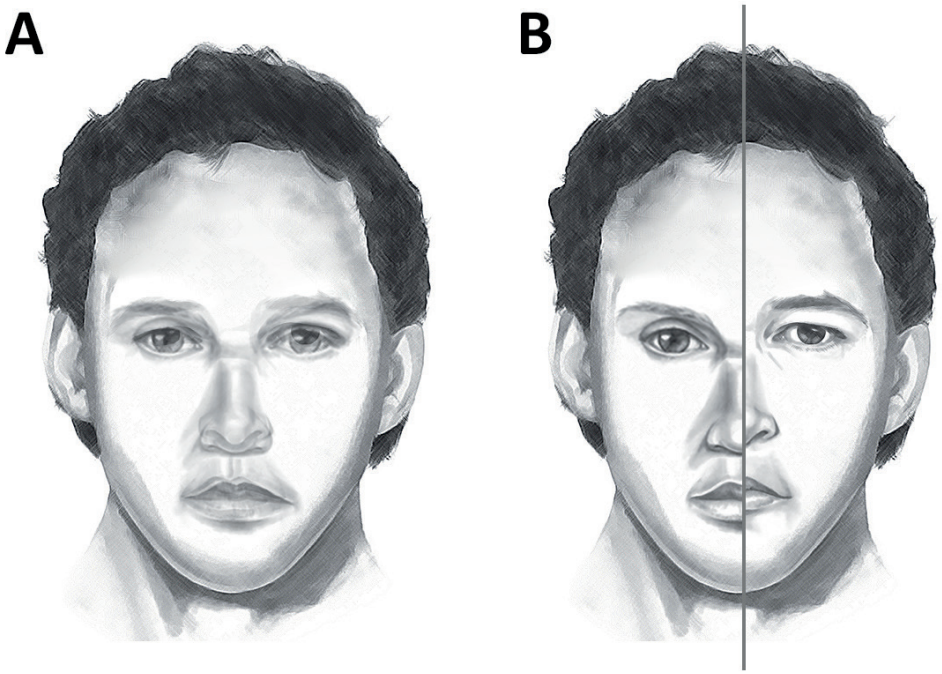


Fig. 4.- Photo-photo superimposition. (A) In this comparison, the face of the unknown subject has been superimposed on the face of the known subject using a reduced opacity overlay. As can be seen there is no difference in the overall face shape and the hairline between the two subjects. However, there are differences in the overall shape, size and position of the eyebrows, eyes, nose and mouth. These differences provide potential indications for exclusion of identity. (B) In this comparison, the right half of the face of the known subject is placed against the left half of the face of the unknown subject (resulting in a chimeric image) to determine if they match. In this case, the differences between the two subjects is more evident.

METHODS

Forensic anthropological reports performed at the Operative Unit of Anthropology of the Department of Medicine and Ageing Sciences of the 'G. d'Annunzio' University of Chieti–Pescara (Italy) were retrospectively evaluated, from 1996 to 2019. These forensic anthropological reports had been performed either at the behest of the *Procura della Repubblica* (Public Prosecutor's Office) or the *Giudice per le Indagini Preliminari* (Preliminary Investigations Judge), or at the request of a lawyer of a victim, the Institute of Legal Medicine, or the law enforcement agencies from national regions or from abroad, all assigned under the responsibility of one of us (L.C.).

For the purpose of the data analysis, the following parameters were considered: geographic location from which a forensic anthropological report was requested; year where the forensic anthropological report was made; requesting Institution for the forensic anthropological report; type of crime/felony committed; number and type of personal identification techniques performed; source of reference images; limiting factors that affected the personal identification process; qualitative scale of level of confidence in the determination of the identification process.

RESULTS

The initial evaluation of the forensic anthropological reports revealed that of the 103 reports included, 84 (81.6%) were reports related to the resolution of personal identification cases. The rest (19; 18.4%) referred to medico-legal death investigations on decomposed cadavers and human remains that were not specifically related to personal identification (e.g. for determination of cause and manner of death, date of death). Thus, only the data for the 84 forensic anthropological reports related to personal identification cases were included in the following analysis.

Geographic location

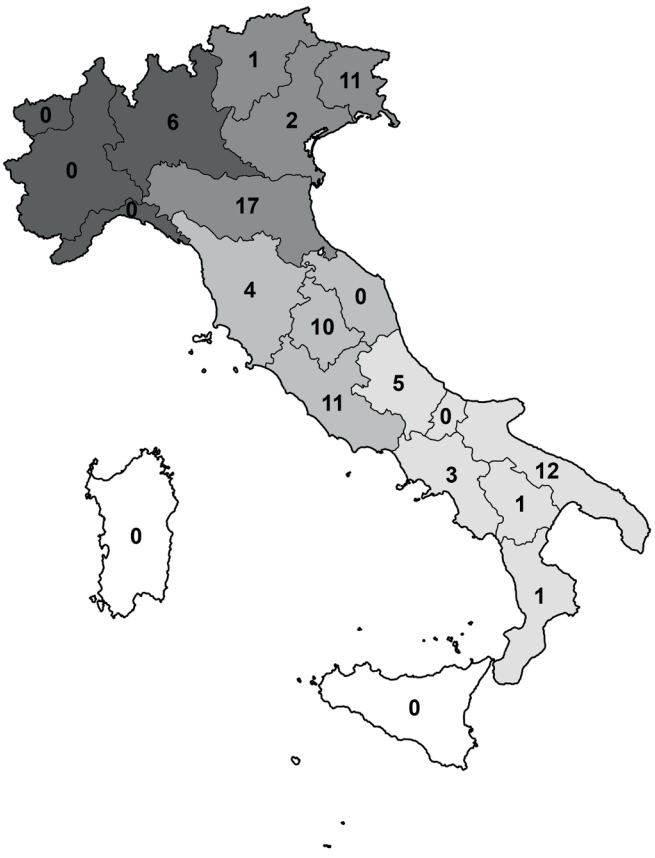
The geographic location is the geographic region from which a forensic anthropological report was requested. For data evaluation, the Nomenclature

of Territorial Units for Statistics (NUTS) standard was adopted. The NUTS standard was developed and is regulated by the European Statistical Office (Eurostat), to provide a single uniform breakdown of territorial units for the production of regional statistics for the European Union (for more information on NUTS, see Eurostat webpage: https://ec.europa.eu/eurostat/web/nuts/background).

Figure 5 summarises the geographic locations for all of the 84 forensic anthropological reports related to personal identification cases performed by the Operative Unit of Anthropology at the request of different Institutions or Agencies. According to the second-level NUTS, of the 20 regions into which the Italian territory is divided, the Operative Unit of Anthropology performed personal identification reports requested by different Institutions in 13 regions (65.0% of all regions). According to the first-level NUTS, of the five macroregions evaluated, the macroregion with the highest number of personal identification reports corresponded to north-eastern Italy (31; 36.9%), followed by central Italy (25; 29.8%), southern Italy (22; 26.2%) and north-western Italy (6; 7.1%). No reports were requested from the island territories around Italy.

Time period

Figure 6 shows that the total number of personal identification reports investigated fluctuated throughout these recent decades, with no cases in 2010 and 2011, and a maximum of nine cases in both 1998 and 2004. Between 1996 and 2006, the number of reports requested followed a fluctuating trend, successively decreasing and increasing, in alternating periods (with a mean of six personal identification reports per year over this period). The number of reports decreased a little between 2007 and 2009 (mean of three reports per year over this period). Finally, the number of reports decreased strongly between 2010 and 2019, with a mean of one report per year related to personal identification.



North-West	
Aosta Valley	0
Liguria	0
Lombardy	6
Piedmont	0
North-East	
Emilia-Romagna	17
Friuli-Venezia Giulia	11
Trentino-South Tyrol	1
Veneto	2
Centre	
Lazio	11
Marche	0
Tuscany	4
Umbria	10
South	
Abruzzo	5
Apulia	12
Basilicata	1
Calabria	1
Campania	3
Molise	0
Islands	
Sardinia	0
Sicily	0

Fig. 5.- Geographical location for all 84 forensic anthropological reports related to the resolution of personal identification cases performed by the Operative Unit of Anthropology of Chieti.

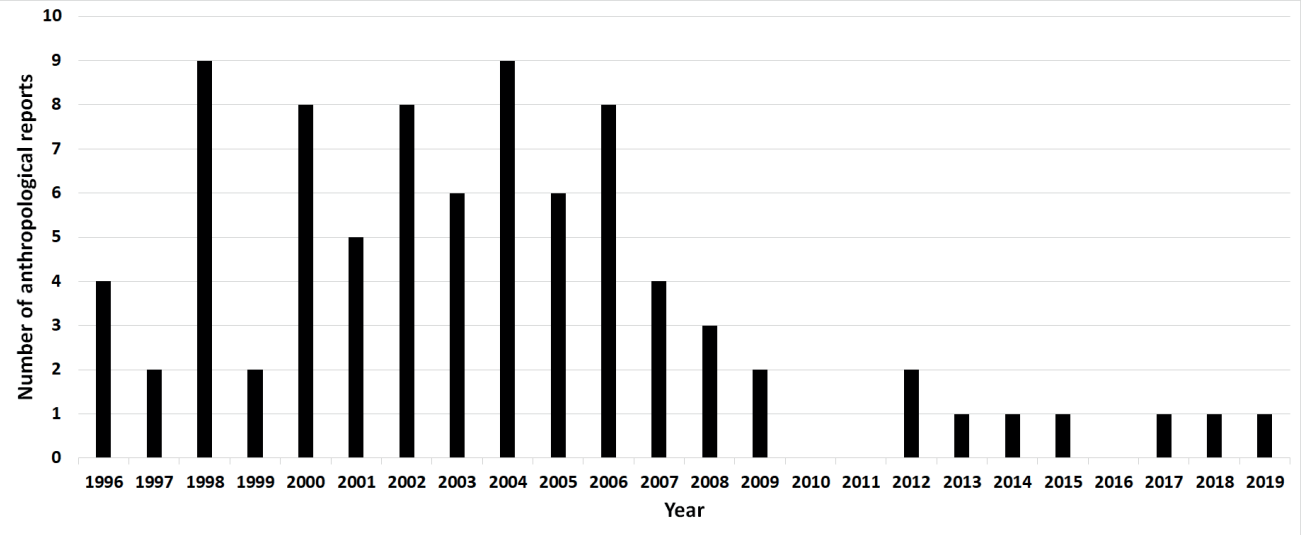


Fig. 6.- Number of personal identification reports performed by the Operative Unit of Anthropology of Chieti per year.

Requesting Institutions

In all, 96.4% of the requests of forensic reports related to personal identification came from the Public Prosecutor's Office (55; 65.5%) and Preliminary Investigations Judges (26; 30.9%), while 3.6% of the requests came from the Institute of Legal Medicine (1; 1.2%) and the lawyers of a victim (2; 2.4%). No requests came from law enforcement agencies (Table 1).

Table 1. Personal identification reports per requesting Institution.

Institution	Number	Proportion (%)
Public Prosecutor's Office	55	65.5
Preliminary Investigations Judge	26	30.9
Law enforcement agencies	0	0
Institute of Legal Medicine	1	1.2
Lawyer of a victim	2	2.4
Total	**84**	**100**

Type of crime/ felony committed

Robberies (including mugging, snatch theft) represented 85.7% (72) of the forensic reports that the different Institutions requested for the resolution of personal identification cases. The other crimes and felonies represented a relatively small number of cases (12; 14.3%) (Table 2).

Table 2. Personal identification reports per crime or felony.

Crime/ felony	Number	Proportion (%)
Bank robbery	64	76.2
Retail store robbery	7	8.3
Motor vehicle theft	1	1.2
Terrorist act	5	5.9
Homicide	3	3.6
Agression	1	1.2
Extortion	1	1.2
Unknown subject near a crime scene	2	2.4
Total	**84**	**100**

On the other hand, 96.4% (81) of the forensic reports represented cases of personal identification of living subjects who were suspected of participating in the different crimes evaluated, while only 3.6% (3) related to the identification of cadavers. In the latter, these three cases referred to were criminal homicides in which the victim to be identified was in an advanced state of decomposition or was completely skeletonised.

Number and type of personal identification techniques performed

Of the 84 forensic anthropological reports related to personal identification processes, 26 (31.0%) were related to the identification

of a single subject at a single crime scene (e.g. robbery at a retail store by a single subject, identification of a cadaver at the scene of a crime). The remaining 58 reports (69.0%) corresponded to multiple identifications, which ranged from simpler investigative situations (e.g. bank robbery by two unknown subjects, and with two suspects to be identified) to more complex situations (e.g. robberies in eight different banks by eight unknown subjects, with unequal participation of each in the robberies, and with six suspects to identify). In this way, the level complexity of each of the forensic anthropological reports led to a total of 476 personal identification processes.

From these 476 forensic facial comparisons (Table 3), for 151 (31.7%) it was not possible to carry out facial imaging analysis due to diverse factors that affected the images and facial features of the subjects being analysed and compared (see below). Of the remaining comparisons (325; 68.3%), the facial imaging comparison techniques used for identification from the video recordings and photographic images were: morphological analysis (174/325; 53.5%); metric analysis (1/325; 0.3%); combination of morphological and metric analysis (143/325; 44.0%); photographic superimposition in combination with morphological and metric analysis (4/325; 1.2%); and facial approximation (3/325; 0.9%).

Table 3. Comparisons performed per facial imaging technique applied.

Facial imaging technique	Number	Proportion (%)
Facial imaging analysis not performed	151	31.7
Morphological analysis	174	36.6
Photo-anthropometry analysis	1	0.2
Facial superimposition	0	0
Morphological analysis + photo-anthropometry analysis	143	30.1
Morphological analysis + photo-anthropometry analysis + facial superimposition	4	0.8
Facial approximation	3	0.6
Total	**476**	**100**

Source of reference images

Excluding the three cases of facial approximation, of the 473 forensic facial comparisons carried out using images, photographic images were provided for the forensic analysis in only 10 cases (2.1%) (Table 4). These images corresponded to analogue images (photographs) printed on photographic paper. Most of the images analysed (330; 69.8%) corresponded to video recordings, which were mainly from closed-circuit television systems (CCTV). Of these, 296 (89.7%) originated from images from consumer-level analogue video recordings on magnetic tape cassettes, in either VHS or Betamax format, while for 34 (10.3%), they were recordings obtained with digital video cameras, as .mov or .mpeg files. These videos corresponded to reliable analogue and digital copies of the original videos that recorded the different crimes or felonies.

Table 4. Source of reference images for forensic facial image comparisons.

Image source	Image form	Number	Proportion (%)
Video	Analogue	296	62.6
	Digital	34	7.2
Photography	Analogue	10	2.1
	Digital	0	0
Film frames	Extracted (analogue video)	113	23.9
	Extracted (digital video)	20	4.2
Total		**473***	**100**

*The three cases related to facial approximation were excluded from this analysis.

In a relatively large number of these forensic facial comparisons carried out using images (133/473; 28.1%), the requesting institutions did not provide copies of the originals, but provided film frames extracted from the original video. These film frames were provided on different media: printed on coloured or black-and-white photographic paper (56; 42.1%), printed on inkjet paper (13; 9.8%); and film frames converted to digital images as .bmp, .jpg or .tiff files (64; 48.1%).

Limiting factors that affect the personal identification process

As indicated above, the imagery came from a wide range of sources. To accurately interpret

the content of an image for facial image comparison, it is imperative to recognize the limiting factors that can occur during the image capture. Table 5 shows the main factors that affected the facial appearances of the subjects in the images for the different forensic facial comparisons performed.

In 31.9% of the cases (151/473, excluding the three cases related to facial approximation; Table 3), the process of facial image comparison was not completed due to critical factors that affected the images and the facial features of the subjects being analysed and compared. The impact of one or the combination of some of these factors precluded the process of facial image comparison, such as facial expressions, occlusion of facial features and aging, as well as extrinsic factors, such as image quality and illumination, camera viewpoint and geometry of the scene (Table 5). In the rest of the cases (322; 68.1%), despite the combined impact of some of the factors on the facial appearance of the subjects, it was possible to proceed with the facial image comparisons.

As a whole (473), the main limiting factors that affected the images and the facial features of the subjects were: occlusion (266; 56.2%); image resolution/ distance from camera (221; 46.7%); image compression (167; 35.3%); camera/ angle pose (104; 22.0%); and number of available images for analysis (61; 12.9%) (Table 5). The other factors involved to a lesser extent (<10%) were: facial expression, growth and aging of the subject, and exposure and illumination of the crime scene.

Identity determination

The evidence in forensic science must be presented in a way that can be accommodated within the proof process used by judges and juries (Ligertwood and Edmond, 2012). This is a non-mathematical inductive process that seeks "the inference to the best explanation" to a test standard of "beyond reasonable doubt". In the field of facial imaging comparisons, to express the identification value of the comparisons, we used the four-point qualitative scale of support of confidence used by both the *Polizia Scientifica* of the *Polizia di Stato* (Scientific Police, of the State Police Force) and the *Ragruppamento Carabinieri Investigazioni Scientifiche* (Scientific Investigations Department of the Military Police Force) (Table 6).

Of the 322 facial image comparisons performed, 204 (63.4%) excluded the subject under investigation as the one who committed the crime or felony (Table 7). Only 53 (16.5%) cases allowed positive identification of the subject investigated, which was mainly due to distinctive facial marks, dental features and ear morphometrics. In 52 (16.1%) cases, the facial comparisons only provided presumptive or tentative (13; 4.0%) identification.

Table 5. Factors affecting facial appearance.

Facial image comparison						
	Not performed		Performed		Total	
Factor	**Number**	**Proportion (%)**	**Number**	**Proportion (%)**	**Number**	**Proportion (%)**
Image resolution/distance from camera	97	64.2	124	38.5	221	46.7
Image compression	94	62.3	73	22.7	167	35.3
Exposure	8	5.3	8	2.5	16	3.4
Lighting	5	0.4	0	0	5	1.1
Occlusion	121	80.1	145	45.0	266	56.2
Camera angle/pose	70	46.4	34	10.6	104	22.0
Number of available images	37	24.5	24	7.6	61	12.9
Expression	2	1.3	5	1.6	7	1.5
Growth and Ageing	0	0	18	5.6	18	3.8

*The three cases related to facial approximation were excluded from this analysis.

Table 6. Qualitative scale of support of confidence used for personal identification.

Scale	Definition
Non-compatibility (negative identity)	In the two images depicting the subjects in the comparison there is at least one feature (not artificial or alterable through time) that allows it to be excluded that the two subjects in the analysis portray the same subject.
Affinity	The poor definition and/or visibility of at least one of the two images in the comparison does not allow detection of facial features to allow a positive judgment of comparison to be reached; however, there are some similar facial features in both of the subjects in the comparison.
Compatibility	The facial components of the two subjects in the comparison make it possible to detect numerous similar facial features for both of the subjects. However, given the poor definition of at least one of the images in the comparison, it is not possible to highlight distinctive marks (e.g., scars, freckles, moles, acne, birth marks, bruises, abrasions, characteristic folds) in the two subjects compared that would lead to a judgment of non-compatibility or, conversely, of total compatibility.
Total compatibility (positive identity)	The two subjects in the comparison images are similar in shape and proportions for all of the facial features visible. There are also singular anatomical features and distinctive marks seen for both of the subjects in the comparison.

Table 7. Strength of the forensic facial image identifications performed.

Scale of support of confidence	Number	Proportion (%)
Non-compatibility	204	63.4
Affinity	13	4.0
Compatibility	52	16.1
Total compatibility (positive identity)	53	16.5
Total	**322***	**100**

* This number corresponds to the number of facial image comparisons performed, excluding the three cases of facial approximation and the 151 cases where none of the facial identification techniques could be applied.

DISCUSSION

According to the criminologist Paul Tappan, "crime is an intentional act or omission in violation of criminal law, committed without defence or justification, and sanctioned by the state as a felony or misdemeanour" (Tappan, 1960). Thus, crime is a deviation from the social norms administered by law that adversely affects the society in which we live, and there is the need to accurately identify the perpetrators of such criminal acts. Personal identification of the living from images is becoming highly relevant due to the increasing number of crimes recorded as videos or photographs (Porter, 2011; Evans, 2014). Thus, forensic investigations require rigorous, accurate and validated techniques to evaluate facial features from images, which can consequently allow comparisons between living subjects and subjects depicted in images, to verify whether a subject seen on a specific image is the same subject as the suspect of the crime. Regardless of the technique chosen for forensic facial image comparison, the reproducibility and accuracy of the conclusions that can be drawn from comparisons of images are directly related to the quality of the images (FISWG, 2019a).

An image can often be difficult, and sometimes almost impossible, to interpret due to various factors that have a negative effect, such as technical factors (e.g. camera resolution and angle, image compression, lens distortion), environmental factors (e.g. illumination of the scenario, occlusion of facial features by objects or clothing) and the facial expression, pose, growth and ageing of the subject, among other aspects (Wilkinson and Evans, 2009; Kaur et al., 2015; ENFSI, 2018; FISWG, 2019b). All of the images analysed by the Operative Unit of Anthropology included one or a combination of some of these factors that affected their quality. Approximately one third of the comparisons performed (31.9%) were far from ideal, and were not useful for the application of any of forensic facial identification techniques because of the poor quality of the imagery. However, as Bromby (2003) asserted, the face of an offender can be identifiable in images if

the quality of the video recording or photograph is sufficient to appreciate the details of the face. In our forensic casework, approximately two thirds of the comparisons performed (68.1%) were based on sub-optimal images, although these still allowed the application of forensic facial comparison techniques.

Although this retrospective analysis extended to the year 2019, the vast majority of the analysed images (88.6%) were obtained from analogue photographs, CCTV cameras or small-scale security systems based on magnetic tape cassettes, like VHS and Betamax tapes. The quality of the images from these systems was low, but their massive spread into the security of our everyday life has resulted in the wide use of such images in forensic contexts for personal identification purposes (Oxlee, 2007; Caplova et al., 2018). In all, 11.5% of the images came from digital sources; however, these systems of video surveillance had also often been installed with little attention to optimisation of the illumination conditions or the viewing angle. All of these situations mean that when a video recording or an image is needed for evidence, such as after a crime, it is not always useful for these personal identification processes.

The different facial image comparison techniques that can be used not only require a minimum of training for the competency of the forensic examiner, but also an understanding of the strengths and weaknesses of the various techniques available. As a consequence, the accuracy of any conclusions that can be drawn from forensic facial image comparison are directly related to the level of training achieved by the forensic examiner (Oxlee, 2007; FISWG, 2010; Evans, 2014). Active working groups such as FISWG and ENFSI recommend morphological analysis as the primary method of comparison, and the use of superimposition techniques only in conjunction with morphological analysis (FISWG, 2012; ENFSI, 2018). However, both working groups and other studies (e.g. Kleinberg et al., 2007; Moreton and Morley, 2011) do not recommend the use of photo-anthropometry for forensic facial comparison.

In the evaluation of our forensic casework, morphological analysis was used as the only technique for personal identification in 53.5% of the facial comparisons, with only photo-anthropometry used in 0.3% of comparisons, with the superimposition technique not used in these cases. However, photo-anthropometry and superimposition were used in conjunction with morphological analysis in 44.0% and 1.2% of the comparisons, respectively. Although photo-anthropometry is not considered reliable for positive identifications, if combined with morphological analysis, it can potentially provide indications for exclusion of identity (Moreton and Morley, 2011; Arbab-Zavar et al., 2015; Gibelli, et al., 2016). For example, in one of our forensic anthropological reports, both the offender of a bank robbery and the suspect of this criminal act shared similar facial features. In addition, both had a scar on the right parietal of the head. However, although these subjects shared similar facial features, the size and topographic location of the scar with respect to the right ear allowed the suspect to be excluded as the perpetrator of the bank robbery.

According to Ali et al. (2010), even though there is a consensus in the categorisation of the different forensic facial image comparison techniques to be used, there are currently no defined standard procedures or specific guidelines within the forensic community. Conclusions based on such comparison processes can be very subjective, and the opinion of one forensic examiner can be different from that of another (Evans, 2014).

Christensen and Anderson (2013) stated that personal identification usually includes tentative, circumstantial, presumptive and positive types. The first three of these indicate that the actual identification cannot be excluded, and therefore image-based evidence might represent a particular individual. Positive identification, however, represents a higher standard of probability, and indicates that the facial features being examined and that are shared by both the offender and the suspect of a criminal act are sufficiently exclusive or unique to enable an identification. Current terms used to qualify an identification (e.g. “circumstantial”, “positive”, “consistent with”, “presumptive”, “possible”, “probable”) are also relatively problematic and

can create numerous inconsistencies between forensic disciplines and in the law courts. Thus, no consensus exists within the forensic community as to the use of these terms (Anderson, 2007; Evans, 2014). Furthermore, there needs to be continual awareness of any situations where misidentification might occur. Great caution is needed in the interpretation of forensic facial image comparisons, as misidentification can produce dire consequences, not only from a societal and legal standpoint, but also through the substantial impact on the families and friends of a suspect (Prahlow, 2010).

We use a simple four-point qualitative scale of support of confidence that is used by the Italian law enforcement agencies to quantify the strength of any image-based identification. Following this scale, we reached positive or negative identifications in 79.9% of the cases here with a reasonable degree of scientific certainty. The facial comparisons provided tentative or presumptive identifications in only 20.1% of these cases. Note that the determination of positive or negative identification was mainly based on the value of exclusive, unique or highly variable anatomical variables, such as distinctive facial marks (e.g. scars, skin marks), dental features (e.g. loss of teeth, patterns of displaced teeth, unusual rotation) and morphological and metric characteristics of the ears.

On the other hand, a related field in the context of forensic identification is forensic facial approximation. Starting with the skull of a body, this technique aims to reproduce the loss of the unknown face of the subject for recognition or identification purposes (Wilkinson and Neave, 2001; Wilkinson, 2007). Three cases referred to in this retrospective analysis were criminal homicides, where the victim was in an advanced state of decomposition or was completely skeletonised. Despite the advances in the techniques of facial approximation, this technique cannot be used directly for positive identification itself, although it is used to communicate with the public in an effort to collect information about missing persons who shared particular visual and demographic characteristics with the recovered remains (Ubelaker et al., 2019).

From the results of this retrospective analysis, it is evident that the Operative Unit of Anthropology is a reference laboratory for the different regions in which the Republic of Italy is structured and for the different Institutions and Agencies that need investigators in the field of forensic anthropology. From 1996 to 2009 there was a fluctuating trend, with small increases and decreases across alternating time periods for the number of personal identification cases investigated (76; mean of five reports per year). However, there was a clear trend for fewer cases in the first decade of the 2010s (8; mean of one report per year in this period). It is not surprising that this analysis reveals that robberies represented 85.7% of the forensic reports for the resolution of personal identification cases, where the majority of cases analysed were bank robberies (76.2%).

According to Dugato (2014), although there has been a decrease in the number of attacks and in the incidence of crimes committed by professional criminals, bank robbery remains a relevant problem in most European cities. Indeed, within Europe, Italy consistently records the highest number of bank robberies. In Italy, the average bank has a 7% risk of attempted robbery in any given year (Maheshri and Mastrobuoni, 2018). Some Italian studies have argued that unemployment can lead to crime, as a result of the feelings of deprivation, rejection and personal failure (Marselli and Vannini, 1997; Masciandaro, 1999). It is also claimed that unemployment can generate mental stress, apathy and illness, factors that could indeed pave the way to criminal behaviour.

Despite the period of general economic decline observed in the world markets during the late 2000s and the early 2010s, the decreasing trend for forensic anthropological reports of bank robberies to date might also be due to an increase in the joint work of banks and law enforcement agencies in the development of crime prevention and security systems. Indeed, the main results of a survey conducted by the *Centro di Ricerca dell'Associazione Bancaria Italiana sulla Sicurezza Anticrimine* (Ossif-ABI; Research Centre of the Italian Banking Association on Anti-Crime Security; https://www.ossif.it) showed that

between 2007 (first year of data collection) and 2018, bank robberies decreased by 92% in Italy, from 3,364 in 2007, to 264 in 2018. According to Ossif-ABI, Italian banks invest over 600 million euros every year to protect their banks better and to make them safer, through the adoption of increasingly modern and effective protection measures. This includes anti-theft systems and helping with the investigative activities of the law enforcement agencies. This argument is also in line with the results of the present study.

When a criminal action is recorded by a video surveillance system, the first operation performed by the investigator who deals with facial imaging comparisons is to scientifically analyse the videos seized at the crime scene in an attempt to identify the faces of the perpetrators or the interactions between them and the environment. The use of images of the suspected perpetrator of the crime/felony who will be investigated and then accused is provided for in Article 361 no. 2 of the Italian Code of Criminal Procedure, which reads: "People, things and objects are presented [...] in image to those who must carry out the identification".

When the subject of a dispute involves issues that cannot be resolved based on the notions of common sense, the Judge can be assisted by Experts or Technical Consultants with particular technical competence in facial identification through imagery. The figure of the Expert or Technical Consultant in the criminal justice system is regulated by Articles 220 to 232 and 508 of the Italian Code of Criminal Procedure.

From a jurisprudential point of view, the growing availability of recordings of images relating to the dynamics of criminal events, and the urgent applications from the Judicial Authority to ascertain the identity of the perpetrators of the crime/felony, testify to the admissibility of this means of proof in judicial practice giving rise to copious jurisprudence.

The probative validity of facial imaging comparisons, in the absence of a specific rule, is governed by the orientation provided by a sentence of the Italian Supreme Court of Cassation: "The so-called anthropological report is based on a method tested over time and now acquired by the patrimony of the scientific community: so that its results —where the relative technical operations have been correctly performed— can constitute evidences against to the suspects and accused persons. Of course, the "anthropological compatibility" cannot alone constitute serious evidence of guilt; and however such judgment is certainly suitable to reinforce the evidence constituted by the recognition made by a witness; as well as a judgment of 'incompatibility' decreases or even nullifies the scope of that element of proof" (Corte di Cassazione, sentence no. 83, 20 January2004).

Therefore, as regards the probative validity of facial imaging comparisons, the most modern doctrine supports full admissibility in accordance with the principle of freedom of proof, although framing anthropological comparisons as a means of investigation not endowed with autonomous efficacy but to support the personal recognition and of photographic recognition as possible sources of evidence. The Expert's reasoning will determine to what degree the outcome of the process of facial comparison influences the opinion of the Judge: belief in the evidence be high if the Expert's reasoning is convincing, while, if the process is of low reliability, room remains for doubt.

To date, the authors have no knowledge that a video recording has been used successfully, and a recent European directive explicitly states that it is not possible to convict an individual on the sole basis of a video recording. On the other hand, it can certainly be used as a subsidiary fact-finding tool.

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