

Validation using 3D CT of the new interpretation of Gerasimov's nasal projection
method for forensic facial approximation

by

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ABSTRACT

Approximating the facial features for forensic facial approximation is challenging, especially the nose. Numerous methods have been published to position the tip of the nose in profile with variable results. Gerasimov's two-tangent method is the most commonly used. However, a recent article published by Ullrich and Stephan (2011) states that the method was not properly performed and provides new guidelines. This research used a sample of CT scans from a Denmark population (N=66) to determine which of Gerasimov's literal translation or Ullrich and Stephan's (2011) new version of the two-tangent method is the most accurate. A combination of the two methods was also evaluated to determine the effect of each tangent independently, and the effect of intraobserver error. It was determined that the new guidelines result in smaller mean difference but no method can accurately position the tip of the nose due to the lack of experience from the practitioner.

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INTRODUCTION

The discovery of human remains necessitates an investigation to establish if they are archaeological or of forensic significance. In situations where the remains are deemed forensically significant, law enforcement officials have the duty to identify the individual and determine the circumstances surrounding his/her death. In some cases the remains are found in a state of extreme decomposition or are completely skeletonised. This hinders the ability to provide a positive identification for the remains. In such scenarios, investigators will often use methods that rely on the comparison of antemortem to postmortem records of the individual. These include fingerprinting, dental records and/or a genetic profile depending on the state of the remains. However, the process requires that law enforcement has a putative identification to request any available antemortem records. If there is no presumed identity, the expertise of the forensic anthropologist can be used to create a biological profile. The anthropologist uses osteological knowledge and techniques generally accepted in the scientific community as accurate to estimate the age, sex, ancestry and stature of the individual. However, the biological profile does not equate to a positive identification but is an important and useful tool to create more specific investigative leads by narrowing down the search for a positive match.

In situations where a large number of cases match a single biological profile, the police can use forensic facial approximation, which refers to the process of applying clay to the skull or replica of the skull to produce an estimate of the visage. A forensic or medical artist uses the information contained in the anthropologist's biological profile (age, sex, ancestry) to choose the appropriate guidelines and methods to approximate the face. The resulting face is widely published in the media with the hope that a friend or

family member will recognize the individual. Forensic anthropologists and other practitioners emphasize that forensic facial approximation is not a method of positive identification but merely a tool used to generate leads (Snow et al., 1970; George, 1987; Rhine, 1990; Tyrrell et al., 1997; Fernandes et al., 2012).

Despite the fact that the process of facial approximation, based on a presumed relationship between the hard and soft tissue, has been criticized by many as being impossible (Suk, 1935; Montagu, 1947; Brues, 1958), many researchers have tried to evolve the process to be more accurate and precise, and to prove the existence of tissue correlation. Published tables of soft tissue thicknesses have changed over time from focusing on white Europeans (Welcker, 1883; His, 1895; Kollmann and Büchly, 1898) to incorporating a wide range of different population groups including South African black, South African mixed and Chinese (Phillips and Smuts, 1996; Cavanagh and Steyn, 2011; Chen et al., 2011). Facial approximation practitioners and biological anthropologists are continuously working toward improving traditional techniques and developing new techniques to more accurately portray different facial features. Finally, the scientific community is continually trying to improve its understanding of the relationship between the soft tissue of the face and the underlying bony structure.

A facial approximation based on accurate soft-tissue tables and craniofacial interrelationship is not considered successful until it is recognized. The facial recognition process is complex and is influenced by familiarity, the interrelationship between the facial features and the overall shape of the face (Bruce and Young, 1998; Starbuck and Ward, 2007). The eyes, mouth and nose are important features for recognition (Briggs and Martakis, 1998). Helmer et al. (1993) compared two facial approximations of the

same individual and concluded that the nose, as well as the mouth and eyes, can be reconstructed reliably, which is a conclusion also supported by Wilkinson et al. (2006). The shape, size and projection of the nose are the most important for a profile and three-quarter view of the face. In addition, the external nose is mainly composed of cartilages that rarely survive intense decomposition, making this facial feature difficult to approximate. Many guidelines used to predict nasal projection were initially based on a presumed relationship between the soft and hard tissues of the face (Stephan, 2003), and research on the accuracy of the different methods to predict the position of the tip of the nose are inconsistent. The validation studies, including the most commonly used method, the two-tangent method, also provided inconsistent results (Stephan et al., 2003; Rynn and Wilkinson, 2006; López et al., 2010; Rynn et al., 2010) and have also been criticized for being performed incorrectly (Ullrich and Stephan, 2011).

The two-tangent method is a simple and quick way to determine nasal projection and was the first guideline ever published (Gerasimov, 1971). However, there is a clear need for more research to understand why the accuracy results are inconsistent and to validate recently published claim (Ullrich and Stephan, 2011). Therefore the main goal of my research is to investigate how the two-tangent method should be performed in order to provide the most accurate nasal projection. To do so the two-tangent method, as initially tested by Stephan et al. (2003), Rynn and Wilkinson (2006), López et al. (2010) and Rynn et al. (2010) will be compared to the new method outlined by Ullrich and Stephan (2011) to determine which one produces an approximation of the nose that most accurately reflects an individual's true nose. Two additional two-tangent methods with combined tangent definition are also compared to better understand discrepancies in the

positioning of the nasal tip. Finally, there is a debate about the definition of the true nose, either defined according to the nasal spine line or the Frankfurt Horizontal plane (Rynn and Wilkinson, 2006). As a result, the accuracy of the method to approximate both definitions of the true nose will be evaluated. The research contributes to the forensic facial approximation literature by validating the recent claim made by Ullrich and Stephan (2011) that the current nasal projection validation studies are inadequate and filling a gap in knowledge about what affects the placement of nasal projection.

The first section of this research is meant to provide an overview of the current literature in the field of forensic facial approximation. It starts with a brief historical perspective and a review of the three main schools of thought to better understand the current research trend and gap in knowledge. This is followed with a summary of the existing nasal projection method and the use of computed tomography (CT) scans with an emphasis on Gerasimov's two-tangent method. The next two sections describe the sample and present the methodology, including the statistical analysis used to answer the research questions. These sections include a detailed step-by-step summary to allow for repeatability by other researchers. The results of the different statistical procedures performed on the recorded data are then presented. The discussion section explores the meaning of the statistical analysis in relation to the purpose of the research and highlights which tangents and overall methods result in less error, the effect of the experience of the practitioner, and discusses the presence of outliers in the data. In addition, there is a general discussion that places the results of this research within the broader forensic facial approximation literature. Finally, a few pages are dedicated to summarizing the research and conclusions reached.

LITERATURE REVIEW

During the last century, the process of applying clay to the skull or replica of the skull to produce a face has been referred to by researchers using different terms including; facial restoration, reconstruction, reproduction, reconstitution, and approximation. The terms most commonly used are facial reconstruction and facial approximation. However, Rhine (1990) rightfully argued that several terms have more than one meaning and are used to describe other processes. For example, the term reconstruction is most commonly used in anthropology to refer to the reassembly of skeletal parts from broken pieces. As a result, he recommends the adoption of the term facial reproduction because it is not used to refer to other processes within the fields of forensics, anthropology or medicine (Rhine, 1990). On the other hand, George (1987) explained that the term reproduction implies a perfect copy, which is not possible, and that the term approximation is more appropriate. In recent years, these different terms have been replaced by the term approximation by a several researchers in the field (Stephan, 2002a; Davy-Jow et al., 2012; Guyomarc'h et al., 2012), and is the term used in this research.

Facial approximation is based on the premise that there is a predictable relationship between the soft and hard tissues of the face, which allow the practitioner to approximate the visage of the individual from the skull. Forensic anthropologists and other practitioners emphasize that the face resulting from forensic facial approximation cannot be use to claim a positive identification but is a tool used for recognition and to generate investigative leads (Snow et al., 1970; George, 1987; Rhine, 1990; Tyrrell et al., 1997; Fernandes et al., 2012). The use of scientific approximation of faces for this

purpose has been carried out since the end of the 19th century with a varying degree of success (Verzé, 2009). The Russian anthropologist Mikhail Gerasimov (1907-1970) was one of the first to develop guidelines for facial approximation (Verzé, 2009) and claimed a success rate of 100% (Helmer et al., 1993). On the other hand, research and case studies from the end of the 20th century did not perform as well (Reichs and Craig, 1998). Nevertheless, the scientific community continued working toward developing better techniques to predict facial features, collecting more soft tissue depth data, better understanding of its relationship with the under laying hard tissue, and improving methods to evaluate the success of facial approximations.

The different methods of forensic facial approximation can be divided into manual and computerized techniques and can be applied to both two-dimensional and three-dimensional approximations. The computerized approximation techniques were initially developed to remove the perceived subjectivity introduced by the forensic artist (Wilkinson, 2004). However, the computerized approaches require manual intervention, such as choosing the facial templates, features, and sculptural distortions, thereby greatly inhibiting the goal of decreasing subjectivity (Wilkinson, 2005). The computerized methodology for facial approximation will not be discussed in this study since the process is based on the same theories dictating the manual approaches (Claes et al., 2010). The following section will provide a detailed review of the three most prominent schools of thought in the field of facial approximation. There will be a discussion of the two main critiques related to approximating the shape and position of the different facial features: the lack of standardization and the unpredictability of subtle facial features (George, 1987; 1993; Helmer et al., 1993; Reichs and Craig, 1998; Stephan, 2005).

Finally, there will be an in-depth review of the existing methods to predict the position of the tip of nose and a review of the previous research testing the accuracy of these methods with a focus on Gerasimov's work.

History of facial approximation

The anatomist Hermann Welcker was the first to study the relationship between the soft and hard tissues of the face with the goal of improving the process of facial [approximation]. In 1883, Welcker measured the soft tissue thickness using a thin blade (Tyrrell et al., 1997). Similarly, in 1895, the German anatomist Wilhelm His used a thin sharp needle with a piece of rubber. The facial soft tissue thickness of cadavers was measured from the displaced rubber when pushed into the soft tissue at a right angle with the bone (Krogman and İşcan, 1986). The data was used to perform the facial approximation of the famous composer Johann Sebastian Bach (Wilkinson, 2004). In 1898, following His and Welcker's steps, the anatomist Julius Kollman added to the existing soft tissue data by measuring the soft tissue thickness of 99 women and 46 men (Prag and Neave, 1997). In 1899, Kollman, with the help of the sculptor W. Büchly, recreated the face of a Stone-Age woman from Auvénier, France (Wilkinson, 2004). This is considered the first scientific approximation because it used the soft tissue data from a large sample and Kollman provided technical guidelines to the sculptor.

The facial approximations of historical individuals, including Bach by His (1895) and Dante by Kollman (1898), were compared to existing portraits and the identification confirmed from the likenesses (Verzé, 2009). However, in 1913, the anthropologist Heinrich Von Eggeling devised an experiment to objectively test the likeness of the approximations with results opposite to previous approximations (Eggeling, 1913). The

double blind study resulted in no resemblance and consequently, many people believed the process was unreliable (Prag and Neave, 1997). Since then, there have been differences in opinion on the value of facial approximation as an aid to identification, as well as debates on the validity of the claim that the underlying hard tissue can help determine the facial soft tissue. Suk (1935), Montagu (1947) and Brues (1958) were among the first to criticize the process. Suk (1935) believed that it was a great mistake to think that there was a correlation between the facial features and the underlying skeletal structure. Similarly, Montagu (1947) emphasized that it is impossible to reconstruct the facial features, skin creases and facial expression, and that accurate reconstructions are highly improbable. Brues (1958:562) concluded that facial approximation “is probably best left to the ample literature of detective fiction.”

Despite these negative reviews, starting in the 1920s, Gerasimov worked on a technique for facial approximation (Wilkinson, 2004). He created what is referred to as the ‘Russian method’, which emphasized the need to model the facial muscles on the skull (Gerasimov, 1971). It was not until 1946 that the American anthropologist Wilton Krogman proposed different guidelines for facial approximation using facial tissue depth data (Wilkinson, 2004). The forensic anthropologist Clyde Snow and medical artist Betty Pat Gatliff developed what is now known as the ‘American method’ based on the work of Krogman (Snow et al., 1970). The American method involves the use of tables of average facial soft tissue thickness data (Krogman and İşcan, 1986). Finally, the ‘UK Manchester’ method was developed by British medical artist Richard Neave, which combines the Russian and the American method (Prag and Neave, 1997). For each approach, the

individual's sex, age, ancestry, body build, and other anatomical peculiarities need to be determined first by the anthropologist.

Russian/Anatomical method

The first school of thought/approach, based on Gerasimov's work, is known as the Russian or anatomical method. The terms Russian and anatomical are used interchangeably to describe the modern facial approximation approach where the musculature of the face, as well as other soft tissue structures are built on the skull without the help of average soft tissue depths (Stephan, 2006). The method is based on the theory that the skull provides enough information on the origins and insertions of the facial muscles to allow each muscle to be accurately reproduced. As a result, the forensic artist requires extensive training and experience with human anatomy or to work in close collaboration with a specialist in human anatomy (Taylor, 2001). Gerasimov is considered to be the originator/founder of this muscle-by-muscle approach (Taylor, 2001). However, the anatomical method, as currently used, is not the same as Gerasimov's initial approach. The traditional Russian method does not require that the whole facial musculature be reproduced accurately. Gerasimov simply states: "There is no doubt that the masticatory muscles can be accurately reconstructed. They are highly individual in size, volume and shape so that their form can be in each particular case determined from the skull" (Gerasimov, 1971:53). Stephan (2006) reports that Gerasimov only included the masseter and temporalis muscles on each side for his facial approximations.

The traditional Russian method is divided into two stages: 1) The reproduction of the head itself, where the most important masticatory, neck and shoulder muscles are

reconstructed, and 2) The modeling of the facial features, which necessitates special training and extensive experience (Gerasimov, 1971). According to Gerasimov (1971), the nasal bone, the shape of the piriform aperture and the “character” of the upper jaw provides the most important information for the reconstruction of the nose. Similarly, the alveolar portion of the upper jaw, the width of the dental arch, and the morphology of the teeth determine the shape of the mouth. The details of the eyes are highly associated with ancestry and the muscles surrounding the eyes. Finally, Gerasimov (1971) explained that the mastoid process, the direction of the ascending ramus, the auditory meatus and the temporal bone are important for reconstructing the external ear. However, the details of the ear have to be intuitively reconstructed. Gerasimov reported that his method has been successful in all of his 140 forensic cases (Helmer et al., 1993).

American/Tissue depth method

The second approach is the American or tissue depth method, which relies on tables of average soft-tissue depths from specific age, sex and ethnic groups to build the face of the deceased. The appropriate soft-tissue depth table is selected using the information on age, sex and ancestry provided by the anthropologist (Gatliff and Snow, 1979). Rubber cylinders are cut to the average soft tissue thickness and glued to the skull at specific bony landmarks. Strips of modeling clay the thickness of the tissue depth markers are then use to connect the bony landmarks. Finally, the remaining open spaces are filled with clay maintaining the average thickness (Gatliff, 1984). After the clay has been applied to the skull, the location, size and shape of the facial features are measured and positioned.

Krogman followed a set of principles, referred to as rules of thumb, to approximate the four facial features (Krogman and İşcan, 1986). First, the width of the mouth is “approximately the same as interpupillary distance; or, alternatively, the distance between two lines radiating out from the junction of the canine and first premolar on each side” (Krogman and İşcan, 1986:430). Second, the apex of the cornea touches the centrally located tangent from the superior to the inferior margin of the orbit. Third, the width of the nasal aperture is approximately 3/5 of the external nose, and the projection of the nose is three times the length of the nasal spine. Finally, the length of the ear is equal to the length of the nose, and the most lateral part of the cartilaginous portion of the ear-tube is located superoposteriorly to the bony portion of the ear-tube. Krogman and İşcan (1986) published step-by-step instructions for the approximation of the facial and profile view. However, for a practical and detailed review of the American method, including a list of the necessary tools and supplies, one should refer to the book written by Lori Gibson (2008), *Forensic art essentials: a manual for law enforcement artists*.

Law enforcement agencies seem to favor the American method because it is based on published data, which can be referenced in court and is rapid, reducing the overall monetary cost (Gibson, 2008). In addition, a forensic artist might have less anatomical training compared to a medical artist and would not be in a position to accurately use the muscle-by-muscle approach. Nevertheless, the accuracy of the method has been successfully tested. Gatliff and Snow (1979) reported that since 1967, 70% of their 33 facial approximations using the American approach resulted in the positive identification of the victim. Wilkinson (2004) and Prag and Neave (1997) state that the American

method, as practiced by Gatliff, actually resulted in a success rate of 65% and 72% respectively. Even if the reported success rates are inconsistent, it appears that the method is successful beyond chance. The most prominent critique of this technique is that the use of average soft tissue depth generalizes the face instead of individualizing it (Stephan, 2005).

The first studies measuring facial soft tissue thickness focused on European populations (Welcker, 1883; His, 1895; Kollmann and Büchly, 1898), a group that is still extensively studied. The lack of soft tissue measurements for other groups has been a recurrent critique of this method (Helmer et al., 1993; Reichs and Craig, 1998). However, there are now tables available for a variety of other ethnic groups such as North American Blacks and Hispanics, and numerous African and Asian populations (Fernandes et al., 2012). Wilkinson (2004) provided all the soft tissue tables published before 2002 and is a good reference book. More recent soft tissue studies include Slovak (Panenková et al., 2012), Chinese (Chen et al., 2011) and South African black females (Cavanagh and Steyn, 2011). Starbuck and Ward (2007) created three facial approximations using the exact same facial features but modifying the soft tissue thickness from emaciated to normal and obese. Many observers believed that the faces were from different individuals. These results demonstrate the importance of choosing the appropriate tables with accurate measurements. It is generally agreed that the age, sex, ancestry and body mass index (BMI) influence the soft tissue thickness (Manhein et al., 2000; De Greef et al., 2006; 2009). Others have argued that the differences between the means might not be enough to justify using separate tables (Stephan et al., 2005; Stephan and Simpson, 2008).

Since the 19th century, the techniques to measure soft tissue thickness have greatly evolved. Initially performed on cadavers using needles, modern techniques favor the use of imaging technology such as ultrasound, computed tomography (CT) or magnetic resonance imaging (MRI) on living subjects (Stephan and Simpson, 2008). The use of cadavers presents obvious problems due to the different processes affecting the body after death, including the loss of muscle tone and shrinkage (Wilkinson, 2004). Embalming also causes significant changes in facial soft tissue depths (Simpson and Henneberg, 2002). Finally, gravity affects the soft tissue of the face differently in the supine position (cadavers) compared to the upright position (living) (Stephan and Simpson, 2008). As a result, most recent studies have favoured living subjects. Stephan and Simpson (2008) did a review of the published soft tissue data and provided a table with the advantages and disadvantages of all soft tissue depth measurement techniques.

Manchester/Combination method

In 1973, Neave was asked to perform the facial approximation of a pair of Egyptian mummies as part of the Manchester Museum Mummy Project (Prag and Neave, 1997). He used the soft tissue depth data of Kollman and Büchly (1898) but also gave attention to the areas of muscle insertion and their effect on the face (Prag and Neave, 1997). The success of his approximation triggered the development of what is known as the Manchester method. The method combined both the anatomical and the soft tissue depth method. It took several years after the mummy project for Neave to refine his methodology (Prag and Neave, 1997). During this time, he also qualitatively and successfully tested the accuracy of his approach using cadavers that were used for dissection from the University of Manchester Medical School (Neave, 1979). Prag and

Neave (1997) stated that all facial approximation methods would result in a success rate between 50 and 60%, and that the Manchester method was no exception. However, Wilkinson (2004) reported that Neave claims a success rate of 75%. Regardless of the actual number, the combination method seems to take advantage of the best aspects of each method. The soft tissue depth markers provide guidelines to limit artistic interpretation and the study of the muscle attachments and other details of the skull allow a better individualization compared to soft tissue means (Taylor, 2001).

The combination method, as practiced by Neave, can be divided into three stages: the preparation of the skull, the modeling of the shape of the face, and the modeling of the facial features (Prag and Neave, 1997). During the first stage, a cast of the skull is created to keep the original as a reference. The second stage involves the placement of the soft tissue depth markers and the sculpting of the main muscles and muscle groups based on the position and strength of the muscle insertion. Prag and Neave (1997:28) stated that: “the exact dimensions of a muscle is not critical as it is the thickness of the soft tissue that finally determined the fatness or thinness of the face, but their position and direction of pull and approximate strength are crucial to the reconstruction process” . Finally, the facial features are modeled using guidelines from Gatliff (1984), Krogman and Işcan (1986) and George (1987).

Facial features

It is clear from the historical review that there is not a standardized approach to forensic facial approximation. The success rates reported by the practitioners are also highly variable across methods. The great number of published methods to determine the size, shape, and location of the different facial features also reflects the lack of

standardization and universal guidelines within the general field of facial approximation. A limited number of methods to determine facial features have been scientifically tested and the many guidelines were initially based on a presumed relationship between the soft and hard tissues (Stephan, 2003). By the end of the 20th century, researchers have tried to address the critique that subtle facial features cannot be predicted. Helmer et al. (1993) compared two facial approximations of the same individual by different practitioners and concluded that the areas with the most discrepancies were the mouth and eyes. They concluded that the discrepancies were due to the lack of adherence by the practitioner to the standardized principles of approximation. Nevertheless, according to a study using computed tomography (CT) scans performed by Wilkinson et al. (2006), the majority of the facial approximations showed less than 2.5 mm error and that the nose, eyes, jaw line, forehead and chin can be reconstructed reliably.

The recognition of an individual depends partly on the shape of the face as a whole (Starbuck and Ward, 2007), but the interrelationship between the features is also important (Bruce and Young, 1998). “As faces become familiar, there is a shift in memory so that the internal face features become relatively more salient” (Bruce and Young, 1998:157). Humans have the ability to perceive subtle differences in shape and proportions of soft and hard tissues. Even a small difference in facial features can make a substantial difference in appearance of the face as a whole (Enlow and Hans, 1996). Changes to the craniofacial skeleton and the associated tissues influence the perceived age according to the observer’s personal concept of growth and aging (Todd et al., 1980). In addition, changes to the facial proportions alter the spatial relationship between the facial features, which is critical for recognition (Neave, 1998). The three most significant

features for recognition are the eyes, the mouth and the nose (Briggs and Martakis, 1998). The shape, size and projection of the nose are the most important for a profile and three-quarter view of the face.

The nasal region is an area of great interest since it is mainly composed of cartilages (Anderson et al., 2008), which do not survive decomposition, and is one of the rare facial features that never stops growing due to the cartilaginous composition (Neave, 1998). These two characteristics make nasal morphology difficult to approximate based on the hard tissue of the face and have resulted in numerous studies on the anatomy of the nose and the relationship between the soft and hard tissue. The skeletal framework of the nose is comprised of the maxillae, the vomer, the ethmoid and the nasal bones (Anderson et al., 2008). However, the size and shape of the nose is mostly due to the soft tissues including; skin, fat, muscles, cartilages (septal, lateral, greater alar, lesser alar and sesamoid) and possibly a ligament, where the nasal septum provides the main support (Anderson et al., 2008). Anderson et al. (2008) dissected the nose of six male and female cadavers. Their results highlight the variability present in the nasal structure. They discovered that the amount and location of fat varies between individuals from root to tip of the nose. In addition, not all facial muscles associated with the nose are present in all individuals and the septal cartilage angles downward from the nasal bone. These results contradict Macho (1989), who stated that the septal cartilage and the nasal bone tend to follow the same angle.

The nasal tip progressively descends due to gravity and the weakening of the lower lateral cartilages, and the loss of skin elasticity (Friedman, 2005). Tip drooping relative to the position of the nasal bridge gives the illusion of a dorsal hump or pseudo-

hump (Zimblar et al., 2001; Friedman, 2005). In addition, the nasal tip becomes squarer due to the weakening of the interdomal ligaments connecting the left and right portion of the nasal tip. As a whole, the nose continues to grow forward and downward with age (Albert et al., 2007). The antero-inferior movement of the nose starts to be visible during the sixth decade of life of the individual (Friedman, 2005). As a consequence, the length of the nasal bones become less correlated with the soft tissue because the bone stops growing while the soft tissue continues to grow (Subtelny and Rochester, 1959; Chaconas, 1969; Genecov et al., 1990). The increased anterior projection of the nose after skeletal growth seems to indicate that the underlying skeletal hard tissue and soft tissue are independent (Subtelny and Rochester, 1959; Genecov et al., 1990). However, McClintock Robinson et al. (1986) did find that a number of soft tissue features significantly correlated with the underlying skeletal morphology. In their study, patients with straight nasal profiles tended to have straight noses and the same applied for convex and concave profiles (McClintock Robinson et al., 1986). Finally, Garlie and Saunders (1998) found a strong correlation for nasal length between growth and tissue thickness in subadult males and females.

Nasal projection method

The nasal tip has been extensively studied and there are currently six methods available in the literature to determine the position of the tip of the nose in profile (Gerasimov, 1971; Krogman and İşcan, 1986; Macho, 1986; George, 1987; Prokopec and Ubelaker, 2002; Stephan et al., 2003; Rynn et al., 2010). The first two methods published are also the most commonly used today by forensic facial approximation practitioners (Stephan et al., 2003). Similarly, they were both developed based on the experience of the

practitioner and presumed correlations between the soft and hard tissues surrounding the nose rather than on reliable anatomical studies (Gerasimov, 1971; Krogman and İşcan, 1986). The first method ever published and the most commonly used is the two-tangent method by Gerasimov, where the tip of the nose is positioned at the intersection of two tangents. The first tangent follows the general direction of the last third of the nasal bone and the second tangent is the continuation of the anterior nasal spine (ANS) (Gerasimov, 1971). The second method is the threefold-ANS method and was developed by Krogman. The nasal tip is positioned at three times the length of the ANS plus the average soft tissue depth, following the direction of the nasal spine (Krogman and İşcan, 1986). The length is measured from the vomer-maxillary junction which is easier to determine on the actual skull compared to a replica or 3D model (Stephan et al., 2003; Rynn and Wilkinson, 2006).

In the following decades, the methods published by Macho (1986), George (1987), Prokopec and Ubelaker (2002), Stephan (2003) and Rynn et al. (2010) were developed based on the analysis of various craniometric measurements from lateral cephalographs or head computed tomography (CT) scans instead of experience. This new approach to the nasal projection method emerged from the need to validate the presumed craniofacial relationship on which the two previous methods were based on. Out of the five new methods, two are based on the input of distances and angles measured from the hard tissue and put into regression equations (Macho, 1986; Stephan et al., 2003); one positions the tip of the nose by using the morphology of the nasal aperture (Prokopec and Ubelaker, 2002); and one uses a sex specific percentage of hard tissue linear

measurements (George, 1987). Finally, the last method uses both regression equations and nasal morphology to determine nasal tip morphology in profile (Rynn et al., 2010).

The two methods using only regression equations are very similar. Macho (1986) uses the distance between nasion and the anterior nasal spine (ANS), the projection of rhinion (most distal point on the nasal bone) in relation to the nasion-spina plane (NSP) to determine the height and length of the external nose. The nasal depth is calculated using additional measurements such as the distance between rhinion and the ANS, the distance between nasion and the most prominent point of the nasal bone, and finally the height of rhinion based on NSP. There are separate regression equations for males and females and the age of the individual is input into the equation. Finally, the method takes into consideration the thickness of the soft tissues. Similarly, Stephan et al. (2003) created a regression equation using linear distances, such as between the tip of ANS and rhinion to the border of the nasal aperture, to determine pronasale height for males and females combined, and two equations for pronasale projection for males and females independently. Unlike Macho (1986), the regression equations necessitates angles measured from Frankfurt Horizontal Plane (FHP), such as nasal spine angle and nasal bone angle and are independent from age.

In the same way, the method by Gorge (1987) uses linear measurements to determine nasal soft tissue measurements. The method was developed using craniometric measurements taken on lateral radiograph of a sample of white Americans. According to his research, the horizontal nasal length or nasal projection can be calculated using the vertical nasal length (nasion to the point of most flexion on the maxilla in profile). The nasal projection is equal to 60.5% for males and 55% for females of the vertical length

and is placed along a line parallel to FHP. Unlike the previous three methods, the guidelines developed by Prokopec and Ubelaker (2002) do not only provide the position of the most projecting point of the nose but the complete nasal profile. To do so, seven measurements are taken from a line drawn at rhinion and parallel to the nasion-prosthion plane to the edge of the nasal aperture. These measurements are then mirrored on the other side of the line and two millimeters is added to account for soft tissue thickness. The ends of each measurement are then joined to create the nasal profile.

Finally, the most recent method combines the use of linear distances between easily definable bony landmarks entered into regression equations and the nasal morphology (Rynn et al., 2010). Rynn et al. (2010) explain that the biggest issue with the two-tangent method is that the practitioner subjectively determines the position of the tangents. Consequently, they realized that “metrical limitations on the nasal dimensions would allow the two tangents to be taken into account and incorporated into a method of estimating the profile of the nose without necessitating the measurements of angles.” (Rynn et al., 2010:21) In other words, the goal is to minimize subjective error from the two-tangent method by combining it with six strict regression equations to predict the nasal profile dimension. The practitioner has to enter three distances (nasion to acanthion, rhinion to subspinale, nasion to subspinale) into the different regression equations to determine pronasale anterior projection, vertical height from nasion, projection from subspinale, nasal length, nasal height and nasal depth. Gerasimov’s two-tangent method is then performed to complete a more accurate nasal projection.

All the methods available to determine nasal projection are clearly very different from one another and it can be difficult for the practitioner to decide which one to use. In

addition, the accuracy and precision of the different methods have been tested with varying results (Stephan et al., 2003; Rynn and Wilkinson, 2006; López et al., 2010; Rynn et al., 2010). The inconsistent results between studies have been partly attributed to unclear methodological descriptions (Rynn and Wilkinson, 2006). Stephan et al. (2003) were the first to test the accuracy of four of the previously published methods to determine nasal projection using lateral cephalograms from 29 males and 30 females of European ancestry. They used profile tracings of the cephalograms and a Cartesian axis parallel to the Frankfurt Horizontal Plane (FHP) and perpendicular to nasion in order to calculate deviation from true nasal position. They concluded that both the two-tangent and the threefold-ANS method did not perform well. The poor results with the threefold-ANS method were attributed to the fact that any error in the measurement of the anterior nasal spine (ANS) will be magnified by the multiplication factor. Finally, the methods by Prokopec and Ubelaker (2002), and George (1987) performed well with the latter being the best out of the four. Stephan et al. (2003) concluded their study by providing a new method based on regression equations and state that it performed better than the four methods previously tested.

Rynn and Wilkinson (2006) used the same approach as Stephan et al. (2003) to evaluate the accuracy of all the previously published methods using a sample size of 122 Caucasoid individuals. Their results are for the most part inconsistent with the conclusion by Stephan et al. (2003) with the exception of the threefold-ANS method, which performed the worst. The authors concluded that the methods by Prokopec and Ubelaker (2002), Macho (1986), George (1987) and Stephan et al. (2003) did not accurately predict nasal projection, with the latter being impractical due to the numerous linear and angular

measurements required. They stated that the method by George (1987) overestimates nasal projection but is a good method for damaged skulls with broken nasal bones or ANS. Finally, Rynn and Wilkinson (2006) concluded that Gerasimov's method is the most accurate to predict a point on the tip of the nose and the variation in results compared to Stephan et al. (2003) might be due to how the tip of the nose is defined, whether using FHP or the nasion-prosthion plane (NPP). It was recently stated that "the NPP as a vertical alignment plane enables fairer analysis of nasal projection" (Rynn et al., 2012:198). The study also demonstrated that the overestimation of the position of the nasal tip can be accounted for by the positioning of the first tangent, following the last third of the nasal bone versus the end of the nasal bone (Rynn and Wilkinson, 2006).

CT and facial approximation

In 1972 Godfrey Hounsfield invented the first CT scanner that was initially used for clinical applications (Lou et al., 2007). Within the last decade, technological advancements have allowed for CT scanners to be commonly used in anthropology to digitize the skull and associated soft tissues (Claes et al., 2010), thereby opening the door to groundbreaking research into the relationship between the soft and hard tissues of the face. The resolution of CT scan data has increased greatly since its invention and it is now possible to create a 3D model of defined anatomical structures, such as the skull, from the scan. It is important to remember that during the data acquisition, process errors due to things like limited scanning resolution, will inevitably be introduced and a perfect copy of the skull is not possible (Claes et al., 2010). In spite of this, Wilkinson et al. (2006) demonstrated that the reconstructed skull from CT scans can be used to produce a reliable approximation of the face and that the nose is one of the most accurate

approximated areas. Lee et al. (2011) produced comparable results and concluded that reliable facial prediction is possible. Finally, two other studies compared measurements between the 3D model and the original object scanned. Sakuma et al. (2010) used a ready-made box and Hildebolt et al. (1990) used skulls to confirm that 3D-CT scans can provide accurate measurements.

The study performed by Rynn et al. (2010) was the first to use CT technology instead of lateral radiographs to determine the accuracy of the nasal projection methodology. Rynn et al. (2010) used clinical head CT scans from 79 North American individuals of varied ancestry. They specified that individuals over the age of 50 years were excluded to limit the effect of age-related changes in nasal morphology on the results. Their results are consistent with the previous research by Rynn and Wilkinson (2006), where the two-tangent method has a good level of accuracy, with an error of ± 2 mm, and that the threefold-ANS method is effective in approximating nasal projection. Finally, López et al. (2010) used 34 cephalograms and concluded that George's (1987) method performed the worst, and Prokopec and Ubelaker's (2002) method performed the best. The two-tangent and threefold-ANS methods rated in second and third position, respectively. However, the authors state that all methods underestimated the anterior projection of the nose and had low level of accuracy (López et al., 2010).

In summary, the threefold-ANS method consistently produced bad results (Stephan et al., 2003; Rynn and Wilkinson, 2006; López et al., 2010; Rynn et al., 2010) and its use should be discontinued. All the other methods, with the exception of the two-tangent method, have variable accuracy results but are mostly considered to be inaccurate. The two-tangent method is the most promising method to determine the

position of a point on the tip of the nose. Rynn and Wilkinson (2006) and Rynn et al. (2010) found that the two-tangent method is the most accurate and determined that the poor results by Stephan et al. (2003) were due to how the authors defined the tip of the nose. Finally, López et al. (2010) positioned Gerasimov's (1971) method in second position after Prokopec and Ubelaker's (2002) method. In addition, from a practical point of view, the two-tangent method is a quick and simple method to perform.

Gerasimov's two-tangent method

Ullrich and Stephan (2011) stated that the studies by Rynn and Wilkinson (2006) and Stephan et al. (2003) were not adequate tests of Gerasimov's method because the two-tangent method was not applied correctly. Gerasimov's book, *The face finder* (1971), translated from German by Alan Houghton Brodrick, clearly indicates that the two tangents used to project the nose follow the last third of the nasal bone and the general direction of the nasal spine (Gerasimov, 1971). However, Ullrich and Stephan (2011) argue that in practice, Gerasimov did not strictly adhere to these guidelines. Gerasimov used the last 1-2 mm of the nasal bone for the first tangent and "followed the general direction of the left or right floor of the anterior part of the nasal aperture (maxillary bone) laterally adjacent to the anterior nasal spine and vomer bone" (Ullrich and Stephan, 2011:473) for the second tangent. Rynn and Wilkinson (2006) have demonstrated that the use of the literal translation of the first tangent (last third of the nasal bone) compared to the new interpretation (last 1-2 mm) results in an overestimation of the projection of the nose. As a result, all previous studies which use the translation defining either one or both tangents should be dismissed (Ullrich and Stephan, 2011). Consequently, the accuracy of Gerasimov's two-tangent method has not yet been accurately tested.

The issue surrounding the use of Gerasimov's nasal projection method arises from; 1) The absence of detailed and accurate published guidelines to determine nasal projection, 2) The presence of minimal information about Gerasimov's methodology used after *Vosstanovlenie lica po cerepu* (Gerasimov, 1955) was published, and 3) Errors about the method's underlying principles in the English translation (Ullrich and Stephan, 2011). Gerasimov's memoir, *Ich Suchte Gesichter* (1968), is his only published and translated work (Gerasimov, 1971), and is the only written account referenced for his facial approximation methodology. Gerasimov's earlier work, *Vosstanovlenie lica po cerepu* (1955), is rarely cited within the English forensic facial approximation literature (Stephan, 2010; Stephan and Cicolini, 2010; Ullrich and Stephan, 2011; Guyomarc'h and Stephan, 2012). With Gerasimov's death, it is impossible to get clarification concerning his methodology. However, clarification can be sought from his former students such as, Galina Viacheslavovna Lebdinskaya, Tatyana Sergeevna Balueva, and Elizaveta Valentinovna Veselovskaya (Lebedinskaya et al., 1993), or with individuals who spent some time working with Gerasimov such as Herbert Ullrich (Ullrich and Stephan, 2011). In other words, there is a need for an in-depth review of Gerasimov's non-translated work, and discussion with his former students. In addition, efforts should be directed towards properly translating the work written by Gerasimov (Gerasimov, 1955), as well as other individuals who had direct contact with him (Ullrich, 1958; 1966; 1967; Lebedinskaya, 1998)

MATERIALS

Based on the current literature pertaining to nasal projection, there is a clear need for additional validation studies. Consequently, the main objective is to determine the accuracy of the method presented by Ullrich and Stephan (2010). To do so, this research used a database of 137 postmortem CT scans from a modern Danish population. The CT scans were obtained from the Department of Forensic Medicine at the University of Copenhagen and were collected as part of standard postmortem procedures. CT is a medical imaging method that uses X-rays to collect cross-sectional data about an object from many different directions (Kak and Slaney, 2001). An X-ray source is rotated around the object or patient to produce one-dimensional thin slices at a number of different angles. These thin slices are then reconstructed to form a two-dimensional image of high resolution with workable contrast between different soft and hard tissues. Finally, neighboring slices can be used to reconstruct a three-dimensional model (Webb, 2002). In other words, the internal structure of an object can be visualized with high resolution in three-dimensions using thin X-ray slices.

Lateral X-rays of the head have generally been used to test the different nasal projection methods for forensic facial approximation since it is a commonly available medical imaging technology (Stephan et al., 2003; Rynn and Wilkinson, 2006; López et al., 2010). However, CT scans provide definite advantages over lateral radiographs such as; the ability to isolate anatomical structures, to take apart and reassemble the image and to create accurate 3D models (Vannier et al., 1985). As a result, CT technology provides more detailed soft and hard tissue information required for accurate research. This study followed the work of Rynn et al. (2010), which successfully used CT scans to investigate

the relationship between the soft and hard tissues of the nose.

Two criteria were used to determine if an individual CT scan was included in the sample for this study. First, the hard tissue of the nasal region, which includes the nasal bone, the anterior nasal spine and the floor of the nasal aperture, had to be clearly visible and not be affected by antemortem trauma or pathology. Second, the soft tissue of the nose could not be distorted due to postmortem processes, such as the loosening of support structures. This was to ensure that it was possible to determine the true position of the tip of the nose. Consequently, a preliminary rendering of the hard and soft tissues in 3D for each individual was undertaken to assess the presence of distortion, trauma or pathology and to determine if each scan met the two criteria. After the preliminary evaluation, 31 scans were excluded due to distortion of the soft tissue of the nose (Fig. 1), 35 scans were excluded because there was missing soft tissue (Fig. 2) and three scans were excluded because the nasal bone exhibited damage (Fig. 3).

Figure 1: Excluded scan, nasal soft tissue distortion

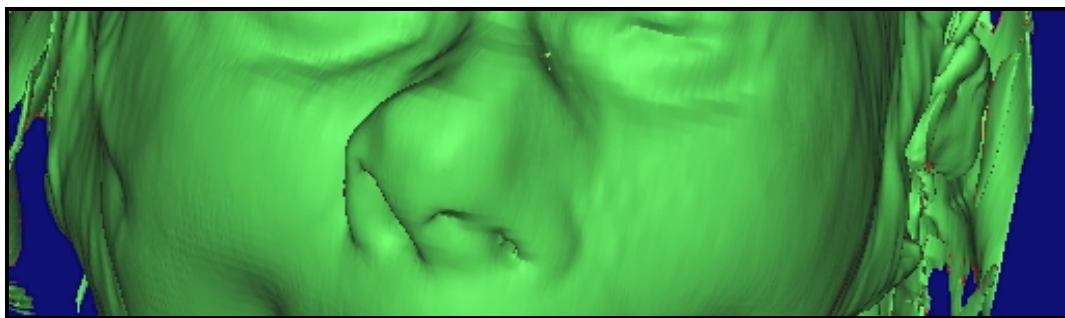


Figure 2: Excluded scan, missing nasal soft tissue

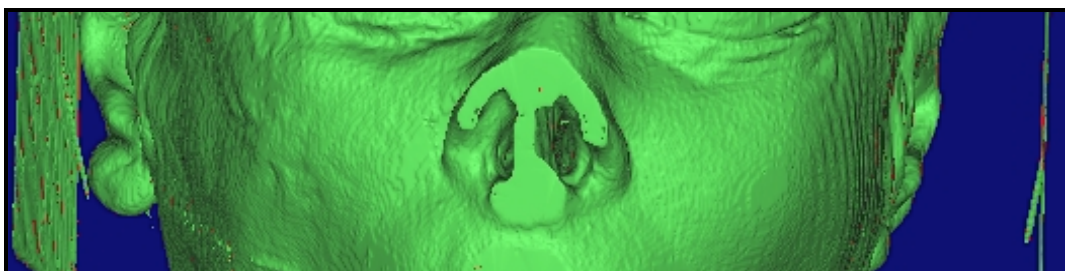
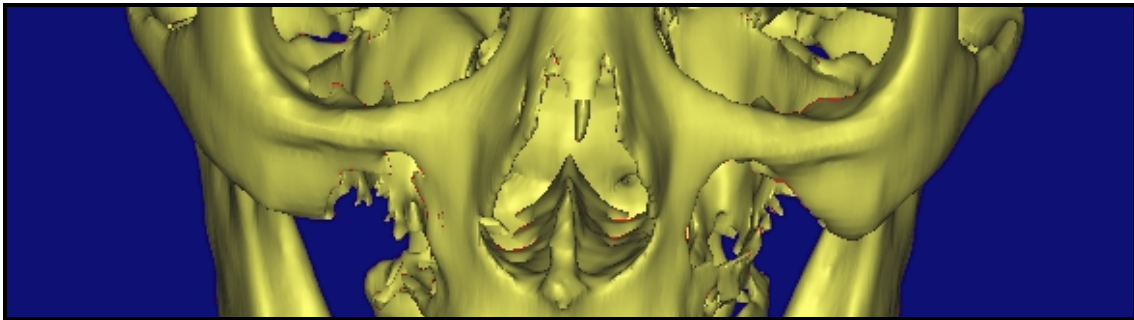


Figure 3: Excluded scan, damaged nasal bone.

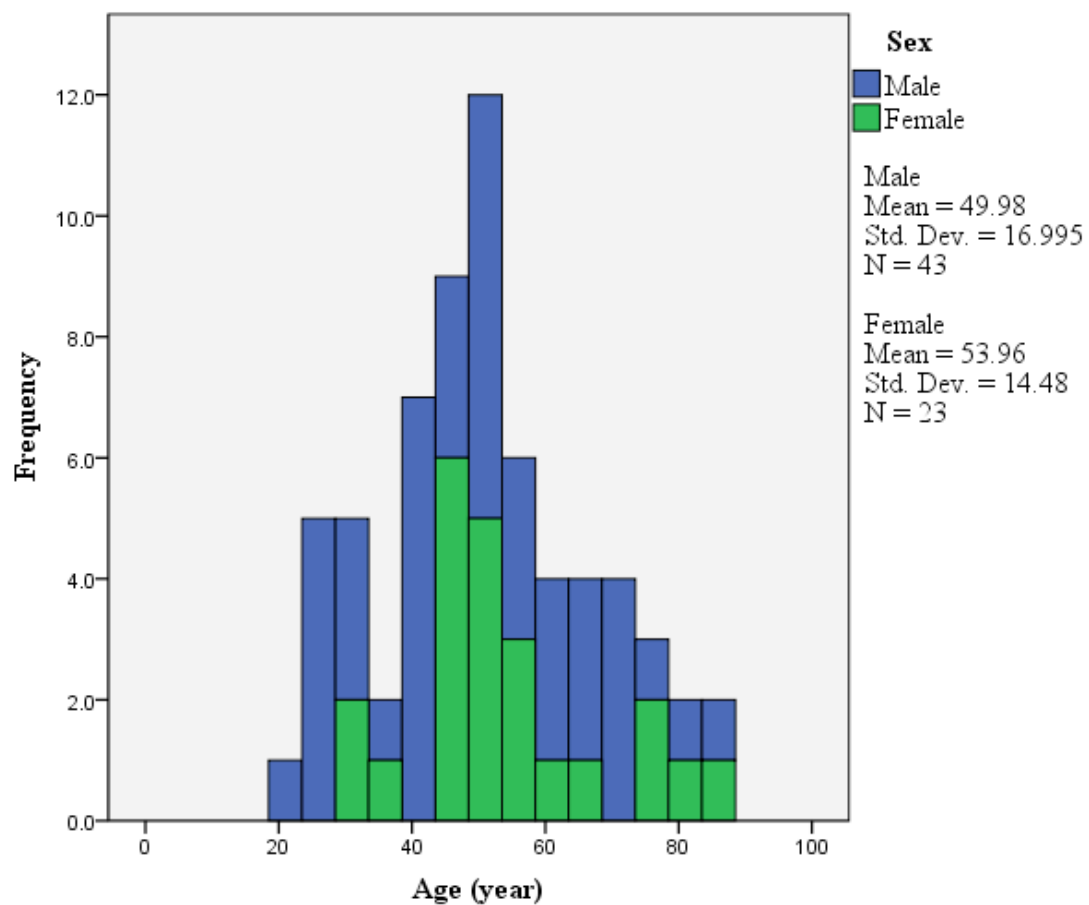


Other studies testing nasal projection for forensic approximation also used age as an exclusion criterion (Stephan et al., 2003; Rynn et al., 2010). The age of the individual is not only important because the basic methods of facial approximation are ideal for an age range of 25 to 35 years (Taylor, 2001), but also because the nose is one of two features that continues to grow due to its cartilaginous composition (Neave, 1998). The nasal tip progressively descends due to the weakening of the lower lateral cartilage and surrounding support structures and starts to be visible when individuals are in their 60s (Friedman, 2005). As a whole, the nose continues to grow forward and downward with age (Albert et al., 2007). Ideally, every individual of 50 years and older should be excluded from the sample. However, an additional two individuals were excluded from the original sample because they did not have a recorded age and less than 50% of the remaining scans were from individuals under 50 years of age. Consequently, it was decided to include all ages and to determine if there is a positive correlation between age and the difference between the predicted and actual nasal projection.

The only other information available for each individual was sex and was recorded to determine if sex influences the accuracy of the results. Previous studies have separated males from females in their analysis with similar results for both (Stephan et al., 2003; Rynn and Wilkinson, 2006; Rynn et al., 2010). Due to the limited amount of

information available, it is not possible to account for differences due to body size or ancestry. In spite of this, Gerasimov's method is applicable to all populations, regardless of origin (Gerasimov, 1971). Nevertheless, it was assumed that the modern Danish sample is homogenous. A total of 71 scans were excluded due to issues identified on the scans and lack of additional information. The final sample size was 66 with 23 females (mean age: 53.96) and 43 males (mean age: 49.98). The overall age range was from 21 to 87 years old (Fig. 4). An independent sample t-test showed there was no statistical difference between mean age for females and males ($t=-9.52$, $df = 64$, $p = 0.344$).

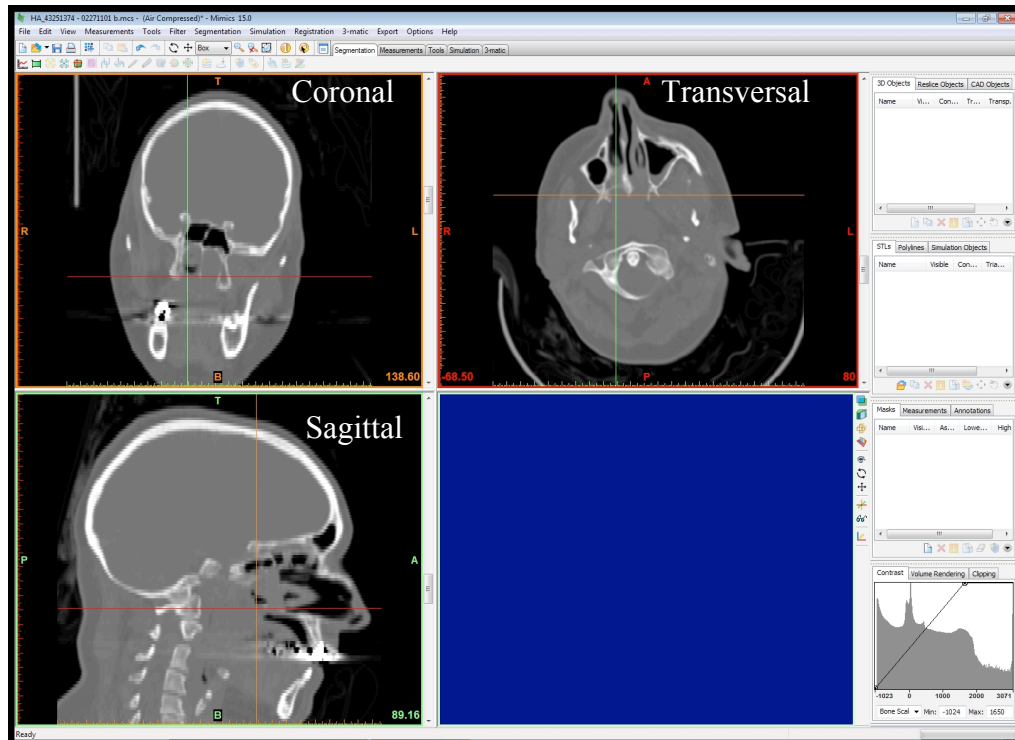
Figure 4: Age histogram male and female



METHODS

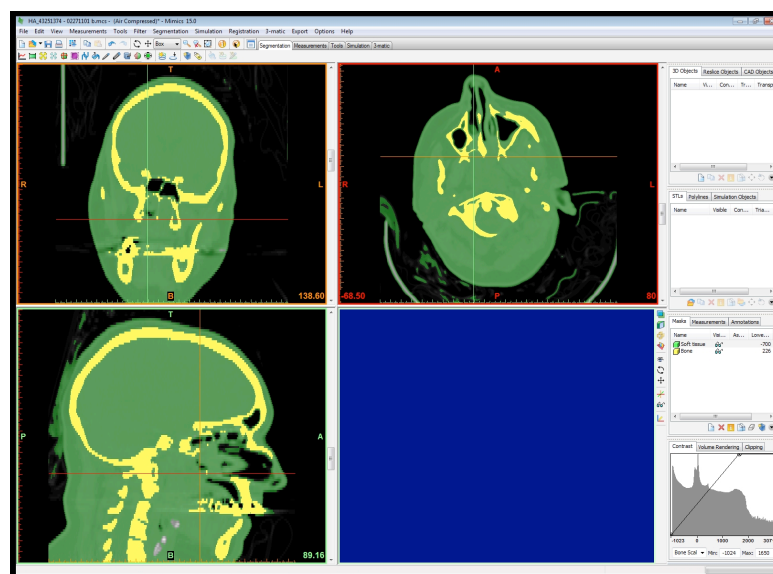
The CT scans of each individual were stored on the computer as DICOM (Digital Imaging and Communication in Medicine) data (Lee et al., 2011) and were imported into MIMICS. The MIMICS software allows the operator to visualize anatomical structures and create 3D models of the skull and surrounding soft tissues (Wilkinson et al., 2006; Davy-Jow et al., 2012; Fernandes et al., 2012). Each set of scans was prepared for analysis through the process of thresholding, segmentation, and 3D rendering. The MIMICS interface lets you to see and rotate through the CT scans following the coronal, sagittal and transverse plane (Fig 5). The first step was to identify and separate the hard from the soft tissue within each scan using the thresholding and segmentation functions in MIMICS.

Figure 5: DICOM file with CT scan views



The region of interest was defined using grayscale values, which are determined in Hounsfield Units (HU) based on the density of the tissue, which is the same between different scans (Tilotta et al., 2009). A low threshold or range of values is commonly used to select soft tissue and high thresholds for dense tissue (Lee et al., 2011). For the purposes of this research, the soft tissue of the face and the skull was segmented using MIMICS' predefined density threshold, which was -700 to 225 HU for the soft tissue and 226 to 3071 HU for the skull. Segmentation refers to the process of separating the image in multiple segments, or sets of pixels sharing the same characteristics, where a threshold defines the boundaries. All pixels within that defined range are highlighted and a mask or selection including only the defined pixels is created. At the end of this stage, the pixels representing the skull were selected and highlighted in colour, with each segment having a unique assigned colour (Fig. 6). The nasal cartilage was not included in either mask to allow visual clarity of the bony structure. The different masks were then used to calculate a 3D mask and rendered a 3D model of the region of interest.

Figure 6: Soft and hard tissue mask



Preliminary 3D models were created of the skull and the face independently to determine if the individual met the inclusion criteria. After the final sample was identified, two 3D models were used in this study. The first one was the skull only, to test the different nasal projection methods without being biased by the presence of the nasal soft tissue (Fig. 7). The transparency of the model was adjusted to high to be able to easily identify the nasal floor for the new interpretation of Gerasimov's nasal projection method (Ullrich and Stephan, 2011). The second model combined the soft and hard tissue masks, where the transparency of the soft tissue was increased to medium to visualize the underlying hard tissue (Fig. 8).

Figure 7: 3D model of skull with Nasion and measurement

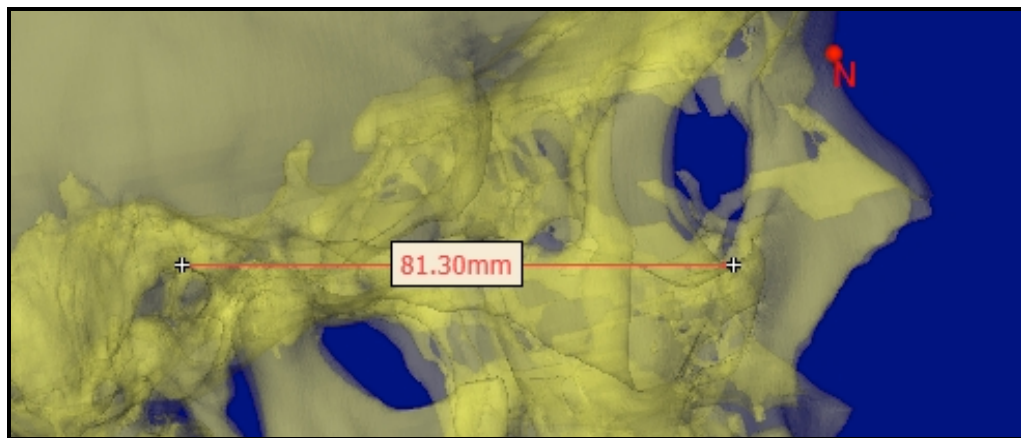


Figure 8: 3D model of soft and hard tissue



MIMICS does not provide the necessary tools to draw and calculate the position of the tip of the nose. Consequently, the resulting 3D models had to be imported into another software program. This study used Adobe Illustrator, which is a vector graphic editing software, although the majority of facial approximation studies use Adobe Photoshop (Stephan, 2002b; 2003; Stephan and Henneberg, 2003; Rynn et al., 2010). A measurement was taken using the basic measuring tool in MIMICS to help position the 3D model in the Frankfurt Horizontal Plane (FHP) and scale the image after it was imported in Illustrator (Fig 7). A point was manually placed on the image to indicate nasion to be used as the origin of a Cartesian axis. Finally, a screen shot of the model, including the measurement and nasion, was saved in JPEG format as image A (skull model) and image B (skull and soft tissue model). Image B had to be taken immediately after image A, despite the risk of introducing bias, to maintain identical positioning and view of the model to allow perfect superimposition. The screen shot of the 3D model mimics a lateral X-ray.

Each individual has an associated image A and image B which were imported into Illustrator as two separate working layers. Layers allow the manipulation of the elements within one layer without affecting other layers using the lock function. In addition, each layer can be viewed or hidden independently of each other. The following steps were repeated for each individual. After image A was imported, two vertical guides were positioned, using the rulers integrated within Illustrator's worksheet, at the measured distance on the scan to correctly scale the image up or down (Fig. 9). After the image was correctly scaled, Illustrator provides you with the exact position of the image on the work sheet in X and Y, and the new height and width (Fig. 10).

Figure 9: Image A (not to scale) with scaling guides

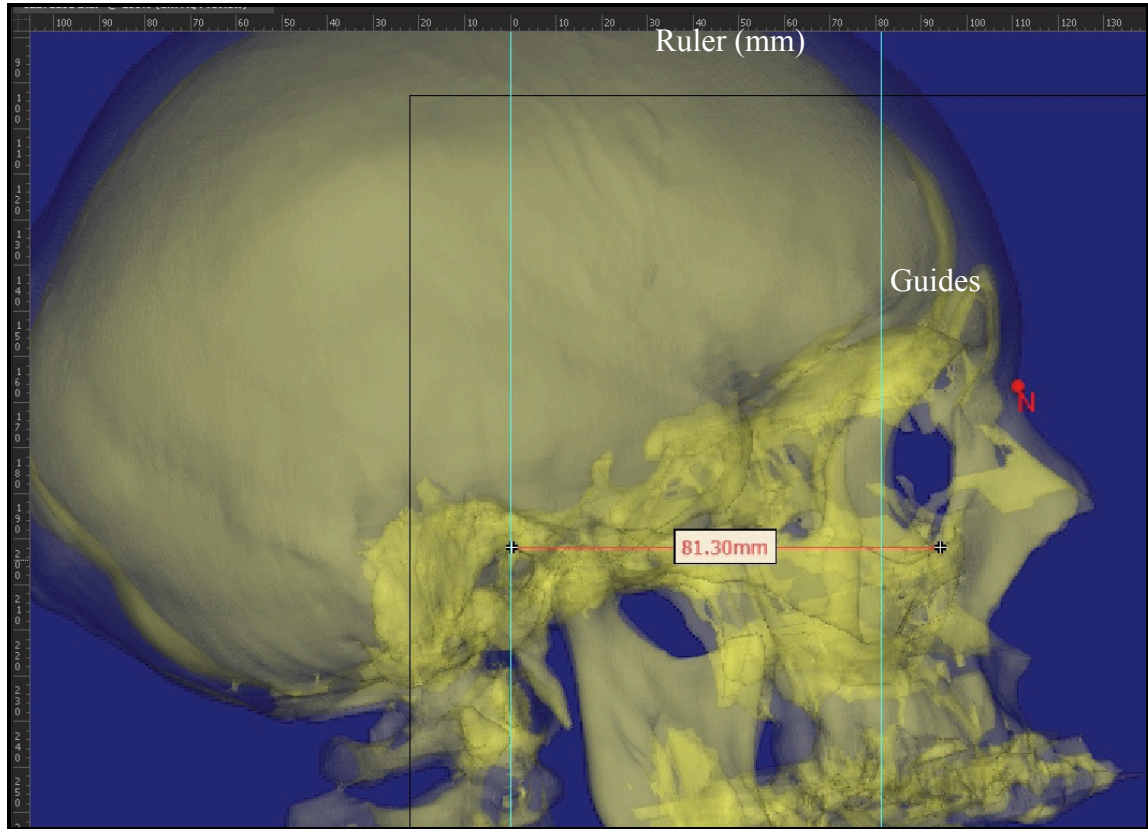
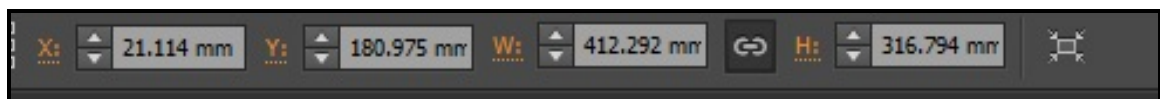
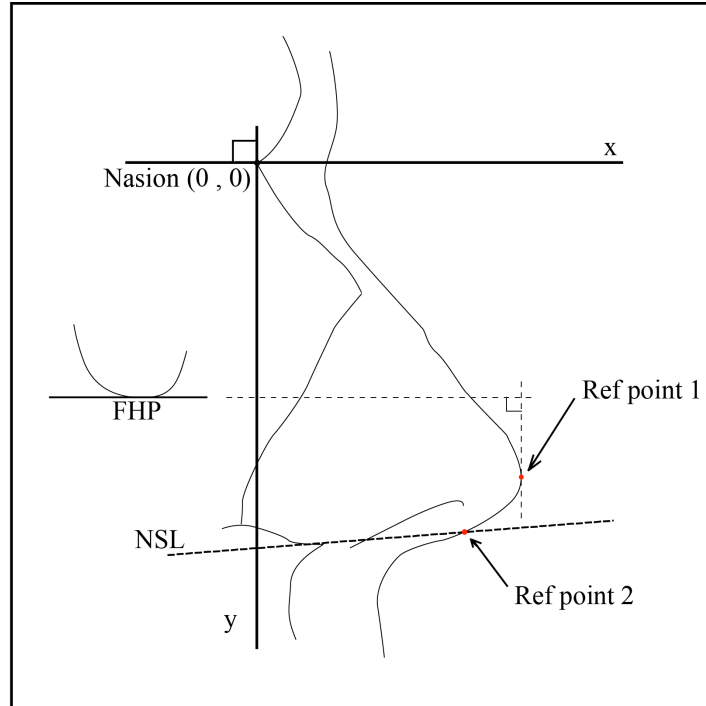


Figure 10: Position and size numbers after scaling



These numbers are essential to superimpose image B over image A. After image B was imported on its own layer, the numbers from image A were imputed for image B, to appropriately scale and position it. Finally, the zero of the horizontal and vertical ruler was placed on Nasion and was used as the center of the coordinate system to measure the nasal projection as a distance in X (horizontal) and Y (vertical) (Fig. 11). The X-axis was parallel with the FHP. The unit used was millimeters (mm) and Illustrator provided coordinates (X, Y) for any points identified. The images were then ready to be used for testing the different nasal projection methods.

Figure 11: Cartesian axis and reference point



Nasal projection testing

The literal translation from Russian of the two-tangent method in Gerasimov's book, *The face finder*, states that: "The profile of the nose is projected by two straight lines, one at a tangent to the last third of the nasal bones and the other as a continuation of the main direction of the point of the bony nose. The point intersection of these two lines will generally give the position of the tip of the nose" (Gerasimov, 1971:54). A tangent refers to a straight line, which makes contact with a curve or surface at a single point without cutting across it. However, the shape of the nasal bone and nasal spine are rarely a perfectly flat or curve surface where it is easy to identify the location of the tangent. As a result, the positioning of the tangent line can be a difficult task and might be the reason for the variable results from the two-tangent method. The new interpretation of the method, argued to be the correct version by Ullrich and Stephan (2011), modifies the first

tangent from following the last third to the last 1 – 2 mm of the nasal bone. This interpretation is also supported by Rynn and Wilkinson (2006). In addition, the second tangent is modified from following the direction of the anterior nasal spine to “the left or right floor of the anterior part of the nasal aperture (maxillary bone) laterally adjacent to the anterior nasal spine and vomer bone” (Ullrich and Stephan, 2011:473).

To test Ullrich and Stephan’s (2011) claim and evaluate how each tangent contributes to the deviation from the actual nasal tip, four tangents were drawn on the image A (skull only) of each individual using the pen tool in Illustrator (Fig. 12). Tangent 1 follows the last third of the nasal bone and tangent 2 follows the general direction of the nasal spine. These two tangents are exactly as defined in *The face finder* (Gerasimov, 1971) and used in previous validation studies (Stephan et al., 2003; López et al., 2010). Tangent 3 follows the last 1-2 mm of the nasal bone as suggest by Rynn and Wilkinson (2006) and Ullrich and Stephan (2011). Finally, tangent 4 follows the direction of the nasal floor to the right of the anterior nasal spine (Ullrich and Stephan, 2011). The method using the combination of tangent 3 and 4 represent the new interpretation of the two-tangent method as explained by Ullrich and Stephan (2011). Method 1 uses tangent 1 and 2, and is Gerasimov’s original guideline. Finally, Method 2 and 3 represent the two other possible tangent combinations (Table 1). The four methods, covering all the possible tangent combination, resulted in four intersecting point, each representing the possible location of the tip of the nose. To determine which method is the most accurate, the four intersecting points had to be compared to a gold standard or true nasal tip.

Figure 12: Nasal projection tangents

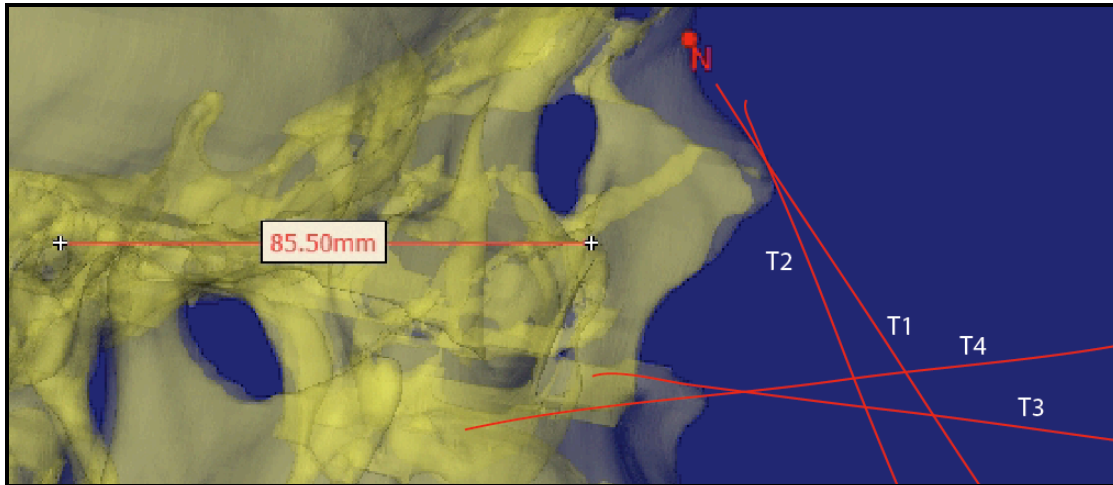


Figure 13: Reference points



Table 1: Four tangent combinations

<i>Method #</i>	<i>1st tangent</i>	<i>2nd tangent</i>	<i>Description</i>
1	T1 (last 1/3 bone)	T2 (nasal spine)	Literal translation
2	T1	T4	Combination 1
3	T3	T2	Combination 2
4	T3 (last 1-2 mm)	T4 (nasal floor)	New interpretation

The definition of the true nasal tip is paramount to testing the accuracy of the method. One important thing to consider is that Gerasimov did not specify that the nasal tip should be defined in the FHP (Rynn et al., 2006). As a result, for the purpose of this research, the approximated nasal tip position was compared to two different soft tissue reference points as the actual nasal tip position (Fig. 11). Reference point 1 was defined as the most projecting point while the skull is in the FHP, or pronasale. This is the most commonly used reference point in other research (Stephan et al., 2003; Rynn and Wilkinson, 2006; López et al., 2010; Rynn et al., 2010). Reference point 2 was the point where the nasal spine line (NSL) or second tangent crosses the surface of the soft tissue profile in the area of the tip of the nose (Rynn et al., 2006). Consequently, for each individual the X and Y coordinate were recorded for the four intersecting points and the two reference points (Fig. 13).

The data recorded was then used to calculate two sets of numbers. First, the difference between true nasal tip and the estimated nasal tip was calculated by subtracting the coordinates of the intersecting point to the coordinates of the reference point (true – approximated nasal tip = difference). As a result, a positive difference indicates that the method underestimates the nasal tip and a negative difference indicates that it overestimates the nasal tip along a specific axis. Second, the difference was used to calculate an absolute distance between the estimated tip and the reference tip, which allows for a better evaluation of the accuracy of each method without directionality. Scatter plots were created to identify outliers and visualize the data distribution. A scatter plot is used in statistics to display a data set based on Cartesian coordinates. In addition, two box plot graphs were created using the absolute distance to confirm the presence of

outliers without directionality bias. Box plots also provided visual information about the dispersion and skewness of the data. The presence of outliers can impact statistical analysis if they are not robust against such outliers (i.e. the t-test). Consequently, statistical analyses were performed with and without the outliers.

The recorded data was analyzed using two different statistical procedures with the software IBM SPSS Statistics version 20. First, six repeated-measures ANOVA followed by a pair-wise comparison were used to compare the mean absolute distance of each method to one another, as well as the mean differences in X and Y, for reference point 1 and 2 independently. The tests determined if there is a significant statistical difference between each method and to help identify which method is better based on the sample mean difference. A Bonferroni correction was applied to the pair-wise comparison to control for the problem of increased family wise error rates that arise using multiple comparisons and to keep the Type I error rate to $p < 0.05$. The usual assumption of ANOVA is that the data from each method is independent. However, in situations where there are repeated measures, this assumption is automatically violated and another assumption has to be made. The assumption of sphericity “refers to the equality of variance of the differences between treatment levels” (Field, 2005:428). The Mauchly's test was used to test that the null hypothesis of equal variances of the differences, which is rejected if the probability value is less than 0.05. When the assumption is not met the Greenhouse-Geisser or Huynh-Feldt correction can be used to produce a valid F-ratio.

The second procedure was a one-sample t-test using the difference in X, Y and the absolute distance between the approximated and true nasal tip. This additional analysis is important to determine if the method can accurately determine the position of the tip of

the nose. The t-test examines the null hypothesis that the sample's mean differences are not different from zero. The test value is zero because if the methods perfectly estimate the position of the tip of the nose, the difference with the true tip would be zero.

Consequently, the t-test using the difference in X and Y determined how each tangent influenced the approximated nasal tip and the t-test using the absolute distance if the method is accurate. The assumption for the t-test is that the sample has to be normally distributed and it is not a robust method against outliers, as previously mentioned.

Statistical procedures can be used to determine normality (i.e. Kolmogorov-Smirnov test). However, the procedure produces significant results for small deviations from normality with large sample sizes. Nevertheless, Moore and McCabe (2006) state that a sample size of >40 is large enough to use the t-test even if the distribution is skewed.

Overall, the ANOVA identifies if there is a difference between each method but the t-test determines if the method is able to identify the position of the true nasal tip.

Additional variables

Two additional sets of data were collected following the initial nasal projection method testing to help identify factors influencing the accuracy of the estimate. First, the last 1/3 of the nasal bone of each individual was characterized as straight or curved. Second, slight distortions of the nasal bone in frontal view, which would not have been significant enough to necessitate its exclusion from the sample, were identified as present or absent. As a result, it was possible to determine the effect of age, sex, nasal shape and nasal condition on the accuracy of the estimated position of the nasal tip. An independent-sample t-test was used to evaluate all the additional variables after removal of outliers. Groups were identified as 0 and 1 for nasal shape (straight = 0, curved = 1),

nasal distortion (absent = 0, present = 1) and sex (male = 0, female = 1), and 50 years was used as the cut off point for the age groups (<50, >=50). Individuals were separated into these two age groups based on the time the nasal structure is affected by aging as previously mentioned. The samples have to be independent with a normal distribution and an equal population variance. In the same way as other t-tests, the procedure is robust against non-normality. The Levene's test was used to determine equality of variance, where the null hypothesis is that all the groups have equal variance. The t-test's null hypothesis is that the difference between the means is due to chance.

Intraobserver error

After the data were recorded for the entire sample, the nasal projection methods were reapplied twice to the first 10 individuals in order to test intraobserver error for a total of three trials. The 10 individuals were initially tested on November 12th and 13th, 2012. The second trial was carried out 16 days later on November 29th, shortly after the entire sample had been tested. Finally, the last trial was on January 14th 2013. The use of more than two samples indicates the necessity to use a repeated-measures one-way analysis of variance (ANOVA) with post-hoc procedures to determine if there were a significant difference between each group. As previously mentioned, the repeated-measures ANOVA has to meet the sphericity assumption. A Bonferroni correction will also be used on the pairwise comparisons. If there is a difference between trial 1 and 2, it will be indicative of the presence of a learning curve for the practitioner. If there is a difference between trial 2 and 3, it will support the presence of intraobserver error.

RESULTS

The results of the statistical procedures used to analyze the data recorded will be presented in this section starting with a graph to help visualize the recorded data, followed by the repeated-measures ANOVAs and the t-test outcomes. Finally, the analysis of the additional variables are presented. First, Four overlay scatter plots were created to visualize the differences between the estimated and actual nasal tip positions calculated using each method. Method 1 is Gerasimov's literal translation, Method 2 and 3 are tangent combinations, and Method 4 is the new interpretation presented by Ullrich and Stephan (2011). Figure 14 shows the calculated differences between the estimated nasal tip from Method 1 and the actual nasal tip defined using reference points 1 (blue circle) and 2 (green circle). The data is similarly dispersed along the X-axis for both reference points with two outliers (individual 9011340 and 11181145). The data represented in Figures 15 to 17, respectively Method 2, 3 and 4, is also dispersed along the X-axis and individual 9011340 is still identified as an outlier for Method 3 and 4. The data representing the difference between the estimated nasal tip position and reference point 2 tend to cluster around zero on the Y-axis across all methods, which is expected since the actual tip of the nose is defined using the 2nd tangent.

Figure 14: Scatterplot Method 1

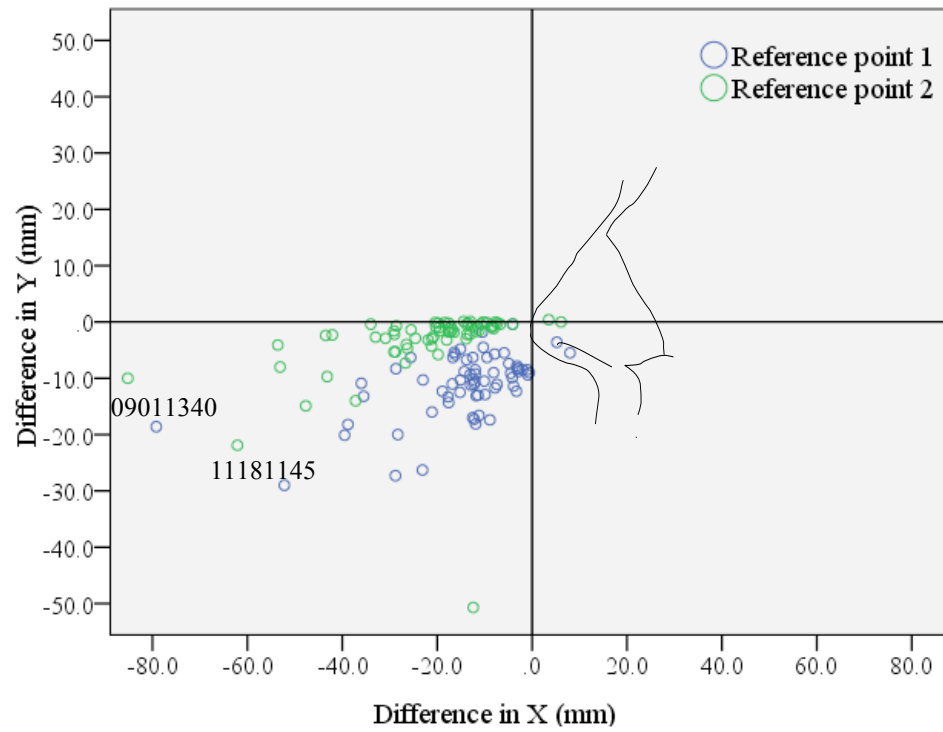


Figure 15: Scatterplot Method 2

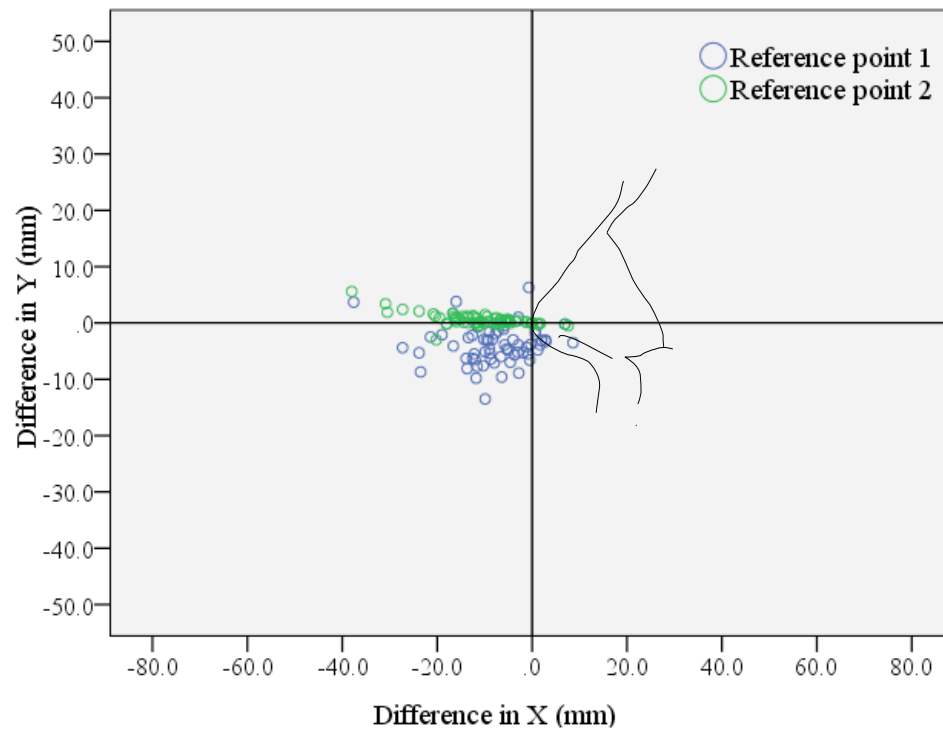


Figure 16: Scatterplot Method 3

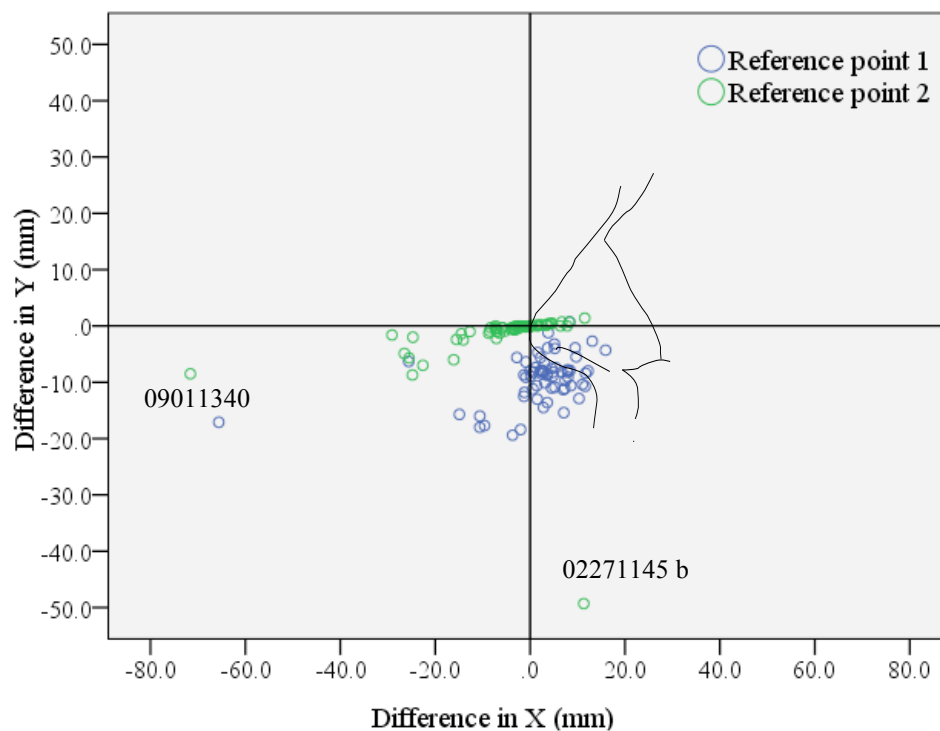
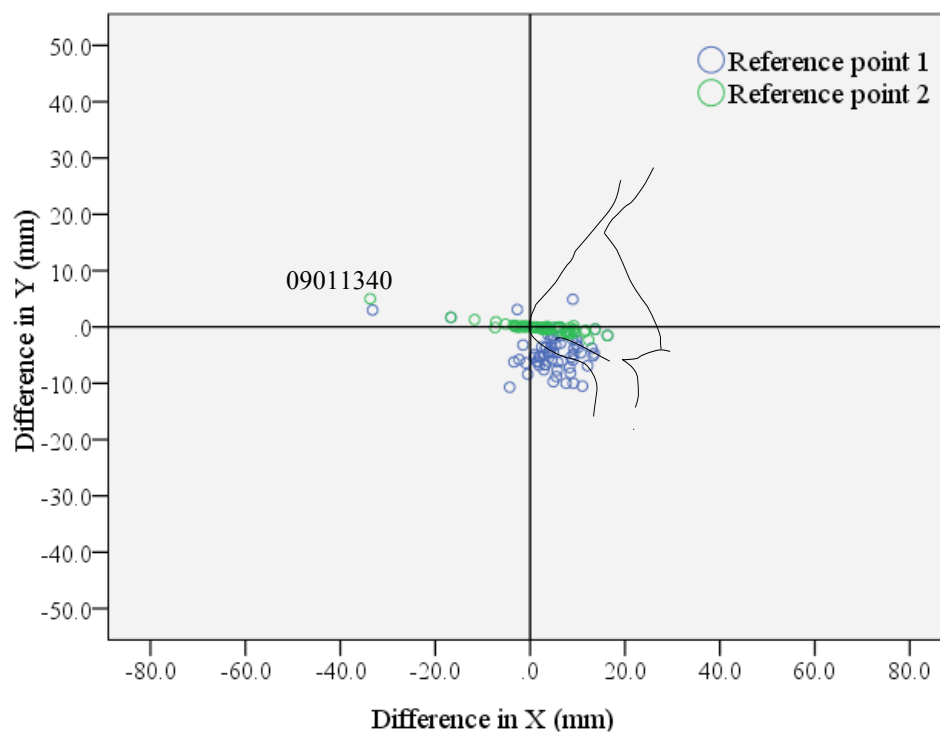


Figure 17: Scatterplot Method 4



The data exhibit asymmetry, with the majority of the points situated within the fourth quadrant for Method 1 and 2, within the third and fourth quadrant for Method 3, and within the third quadrant for Method 4. In other words, the majority of the data is situated forward and downward or backward and downward compared to the true nasal tip, which is situated at (0, 0) (Fig 18). The box plots also identified individual 9011340 as an outlier across all groups (Figs. 19, 20). Individual 11181145 and 02271145 b were deviating from the rest of the data respectively using Method 1 compared to reference point 1 and using Method 3 compared to reference point 2. A star on the graph identifies these three individuals. Finally, the graphs illustrate a decrease in data dispersion from Method 1 to Method 4.

Figure 18: Nasal tip position from differences and quadrants

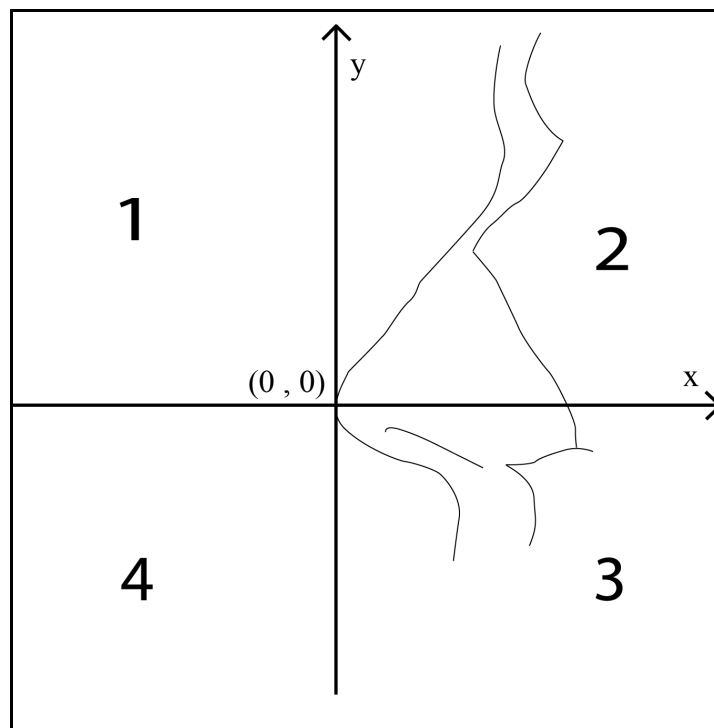


Figure 19: Boxplots of absolute distance from Ref point 1

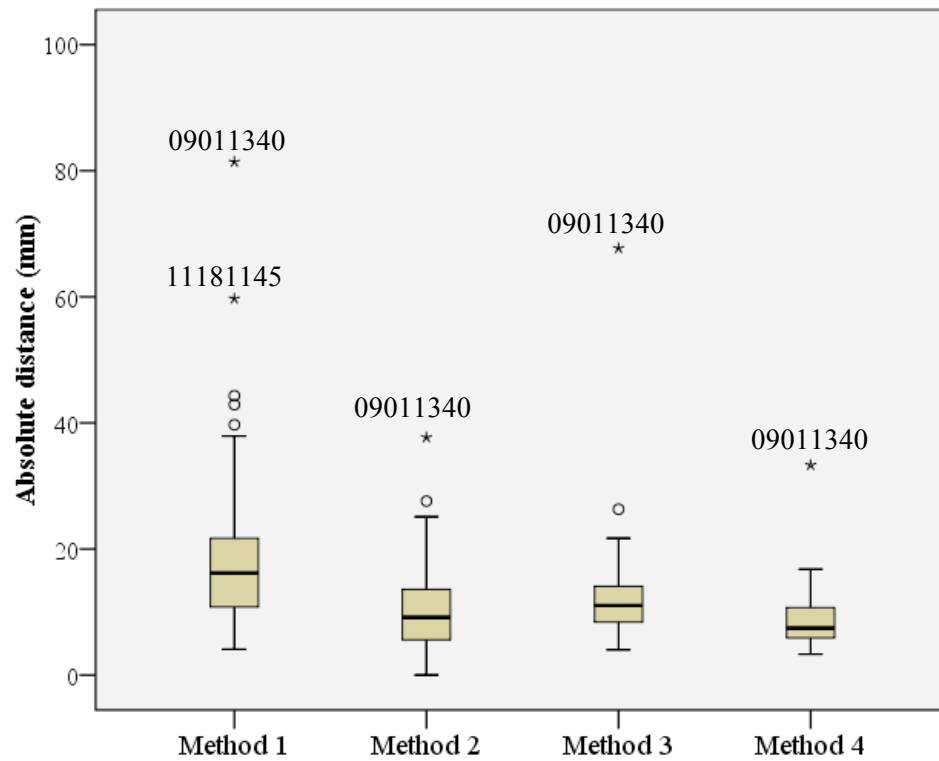
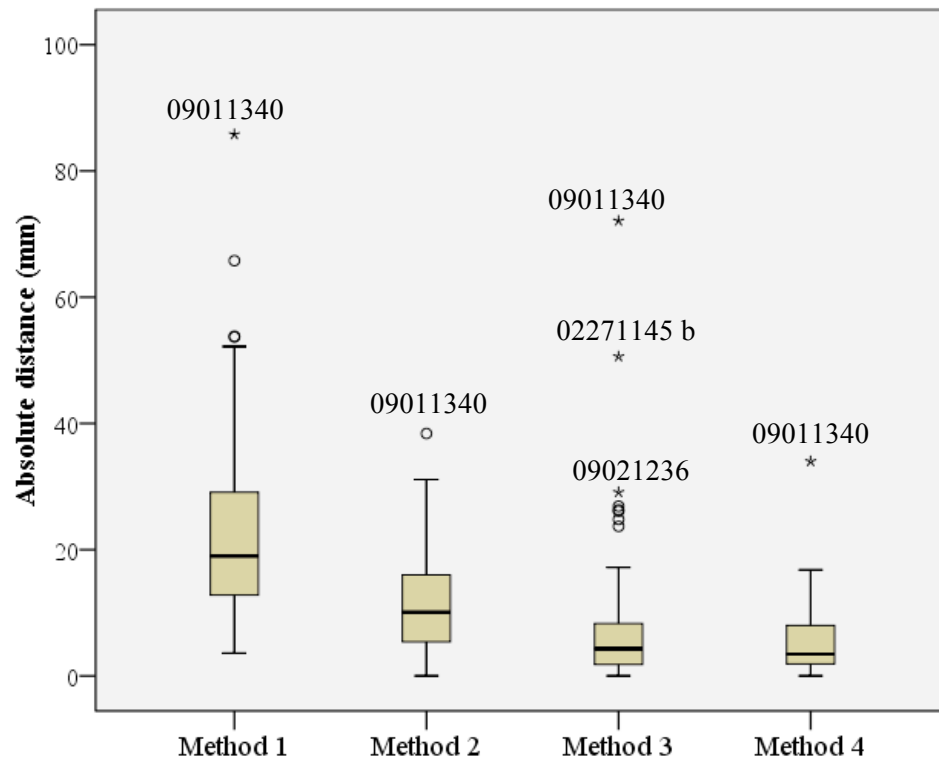


Figure 20: Boxplots of absolute distance from Ref point 2



Repeated-measures ANOVA

The first statistical procedure performed was the repeated-measures ANOVAs. The first ANOVA used the absolute distance and compared the mean difference of each method to determine if there was a difference in predicting the position of pronasale (reference point 1). The analysis indicates that there was a statistically significant difference between the means. The assumption of sphericity was not met ($W = 0.086$, $df = 5$, $p = <0.001$) but the significance was <0.001 across all F-ratios before and after correction. The pairwise comparisons with Bonferroni correction indicated that Method 1 was statistically different ($p = <0.001$) from the other three, and that Method 3 was different ($p = <0.001$) than Method 4. Method 2 had a mean difference of -2.092 and 1.488 compared to Methods 3 and 4 respectively, and were the only pairwise comparisons not statistically significant (Table 2).

Table 2: Pairwise comparison distance from reference point 1			
Method #	Mean difference	Std. error	Sig
1 vs 2	9.026	1.030	<0.001
1 vs 3	6.933	1.134	<0.001
1 vs 4	10.514	1.549	<0.001
2 vs 3	-2.092	0.922	0.159
2 vs 4	1.488	0.867	0.544
3 vs 4	3.580	0.658	<0.001

The second repeated measures ANOVA also used the absolute distance but to determine the difference in positioning the tip of the nose along the nasal spine line (reference point 2). The procedure generated similar results as the first ANOVA.

Mauchly's test was significant ($p < 0.001$) but the F-ratio remained significant after correction ($p < 0.001$). In the same way as the pairwise comparisons of the absolute distance to reference point 1, Method 1 continues to be statistically significantly different from all other methods. In addition, Methods 2 and 3 are also not different from one another. The major difference is that the mean absolute distance of Method 3 is not statistically different from Method 4 (Table 3).

Table 3: Pairwise comparison distance from reference point 2			
Method #	Mean difference	Std. error	Sig
1 vs 2	11.986	1.352	<0.001
1 vs 3	14.439	1.190	<0.001
1 vs 4	17.495	1.887	<0.001
2 vs 3	2.444	1.368	0.473
2 vs 4	5.509	1.176	<0.001
3 vs 4	3.085	1.200	0.078

The last four repeated measures ANOVA used the difference along the X-axis and Y-axis for both reference points. All the analysis resulted in the rejection of the assumption of sphericity with a significance of $p < 0.001$. Consistent with the previous analysis, the F-ratio remained statistically significant after Greenhouse-Geiser and Huynh-Feldt corrections (Table 4). The only pairwise comparison not statistically significant was the mean difference along the Y-axis compared to reference point 2, between Methods 3 and 4 ($p = 0.300$). Now that we have identified which method is different from each other, the t-test will determine if the method is accurate.

Table 4: Repeated-measures ANOVA, difference X and Y				
Reference point	Axis	Correction *	df	Sig.
1	X	GG	1.911	<0.001
		HF	1.968	<0.001
	Y	GG	1.119	<0.001
		HF	1.125	<0.001
2	X	GG	1.896	<0.001
		HF	1.951	<0.001
	Y	GG	1.114	<0.001
		HF	1.120	<0.001
* GG = Greenhouse Geiser, HF = Huynh-Feldt				

One sample t-test

The one-sample t-test compared the distance in X (forward, backward) and Y (upward, downward) independently for every estimated nasal tip position to determine if and in which direction the different methods over- or underestimated the true nasal tip. Only two groups (M3R1X, M4R2Y) showed no statistically significant differences from zero. In other words, Method 3 resulted in a nasal tip position that was not statistically different from reference point 1 along the X-axis and Method 4 was not statistically different from reference point 2 along the Y-axis (Table 5). All the methods had a larger mean difference anteroposteriorly (X-axis) compared to vertically (Y-axis) with the exception of Method 3 compared to reference point 1.

Table 5: T-test of differences (test value = 0)									
	t	df	Sig.	Mean Diff.		t	df	Sig.	Mean Diff.
M1R1X	-8.614	65	<0.001	-14.3697	M3R1X	1.546	65	.127	2.0515
M1R1Y	-16.077	65	<0.001	-11.0939	M3R1Y	-18.199	65	<0.001	-9.2515
M1R2X	-11.545	65	<0.001	-21.7591	M3R2X	-3.566	65	.001	-5.3394
M1R2Y	-4.034	65	<0.001	-3.5152	M3R2Y	-2.155	65	.035	-1.6697
M2R1X	-7.865	65	<0.001	-7.8258	M4R1X	5.323	65	<0.001	4.5773
M2R1Y	-8.897	65	<0.001	-3.7394	M4R1Y	-11.049	65	<0.001	-4.3985
M2R2X	-9.577	65	<0.001	-10.3470	M4R2X	2.276	65	.026	2.0530
M2R2Y	4.138	65	<0.001	.5424	M4R2Y	-1.071	65	.288	-.1136

The absolute distance was used to confirm the previous results without directionality bias. The one-sample t-test performed using a test value of zero resulted in a rejection of the null hypothesis for all eight absolute distances (Table 6). In other words, each method resulted in a nasal estimate statistically different from the true nasal tip. All the statistical analyses (ANOVA, t-test) were also performed after removal of individual 9011340, identified as an outlier across all methods, without any changes to the relationship between the data.

Table 6: T-test of absolute distance (test value = 0)									
	t	df	Sig	Mean Diff.		t	df	Sig.	Mean Diff.
M1D1	12.100	65	<0.001	19.3667	M1D2	11.926	65	<0.001	22.9333
M2D1	12.578	65	<0.001	10.3409	M2D2	10.989	65	<0.001	10.9470
M3D1	12.301	65	<0.001	12.4333	M3D2	5.720	65	<0.001	8.5030
M4D1	15.839	65	<0.001	8.8530	M4D2	8.238	65	<0.001	5.4379

Additional analysis

The final analysis needed was to determine if there were differences in the means caused by other variables. The difference between males and females was tested with an independent samples t-test using the absolute distance. Three distances failed Levene's test for equality of variances; the distances between Method 2 and the true nasal tip defined using reference point 1 (M2D1) and 2 (M2D2) and the distance between Method 3 and the true nasal tip position using reference point 2 (M3D2). The difference between males and females was not statistically significant with the exception of Method 2 using reference point 1 (M2D1) (Table 7). The three other variables (age, nasal shape, nasal distortion) all had equal variance between groups and showed no differences between the sexes.

Table 7: Independent samples t-test for sex					
	Levene's Test		t-test for Equality of Means		
	F	Sig.	t	df	Sig. (2-tailed)
M1D1	2.559	.115	1.000	64	.321
M2D1	7.122	.010	2.215	63.610	.030
M3D1	1.745	.191	.584	64	.561
M4D1	1.537	.220	.465	64	.644
M1D2	3.200	.078	.948	64	.347
M2D2	5.096	.027	1.754	63.141	.084
M3D2	4.442	.039	1.465	61.407	.148
M4D2	2.617	.111	1.730	64	.088

Finally, with respect to intra-observer error, the Mauchly's test of sphericity was statistically significant ($df=2$, $p=0.024$). Therefore, the assumption for the repeated-measures ANOVA was not met. However, the F-ratio was still statistically significant after correction using Greenhouse-Geisser ($F=33.315$, $df=1.698$, $p<0.001$) and Huynh-Feldt ($F=33.315$, $df=1.768$, $p<0.001$) indicating the presence of a statistical difference between the three trials. The pairwise comparisons indicated that trial 1 was statistically different from the rest ($p<0.001$), but there was no difference between trial 2 and 3 ($p=0.728$), indicating the presence of a learning curve in performing the methods.

DISCUSSION/CONCLUSION

This research provides empirical evidence to evaluate two previously published claims. First, Ullrich and Stephan (2011) stated that previous research (Stephan et al., 2003; Rynn and Wilkinson, 2006) performed Gerasimov's two-tangent method incorrectly and consequently, did not provide valid accuracy testing. This critique of nasal projection testing also applies to the study by López et al. (2010) and Rynn et al. (2010). The two-tangent method developed by Mikhail M. Gerasimov in the 1960s is performed by drawing a first tangent following the general direction of the last third of the nasal bone and a second tangent following the direction of the anterior nasal spine. The approximated nasal tip is situated at the intersection between of the two tangents. These guidelines, used by many forensic facial approximation practitioners, are from the English translation of Gerasimov's book *Ich suchte Gesichter* (1968), known as *The Face Finder* (Gerasimov, 1971). However, Ullrich and Stephan (2011) argue that Gerasimov himself did not follow these exact guidelines. They claim that Gerasimov used the tip of the nasal bone at rhinion (last 1-2 mm) for the first tangent and the general direction of the anterior part of the nasal floor beside the anterior nasal spine and vomer bone (Ullrich and Stephan, 2011).

The second claim is that Gerasimov's two-tangent method is accurate to predict a point on the nasal tip and not necessarily the most projecting point as defined by the Frankfurt Horizontal Plane (FHP). Previous research (Stephan et al., 2003; López et al., 2010) defined their gold standard as the most projecting point when the skull is placed in the Frankfurt Horizontal Plane. However, Gerasimov did not specify how the cranium needed to be placed and did not provide a definition of nasal tip. Rynn and Wilkinson

(2006) determined that the two-tangent method was accurate for approximating the tip of the nose when it was defined using the nasal spine line and inaccurate using FHP. The difference in nasal tip definition is the reason for poor results in the research by Stephan et al. (2003).

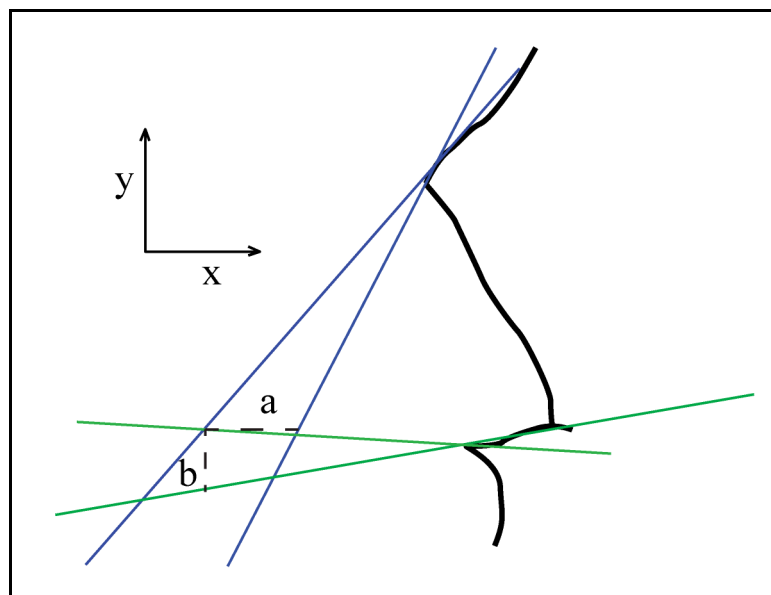
The results of this research validate the statements made by Ullrich and Stephan (2011), and confirm previous finding by Rynn and Wilkinson (2006) and ultimately establish which method is the most accurate. To begin, the first section of this chapter will discuss the error between tangent 1 (last third of the nasal bone) and tangent 3 (last 1-2 mm of the nasal bone), and the error between tangent 2 (anterior nasal spine) and tangent 4 (nasal floor). Following this, the accuracy of each method to approximate the nasal tip defined by FHP (reference point 1) compared to NSL (reference point 2) is discussed. The third section discusses the effect of intraobserver error and the experience of the practitioner on estimates. Finally, the last section examines in more detail the outliers observed in the present study.

Tangent selection

The direction of the tangent following the nasal bone mostly affects the position of the tip of the nose on the anteroposterior plane. The position of the first tangent will increase or decrease the difference with the true tip along the X-axis (Fig. 21). Consequently, by comparing the mean difference in position of X calculated for Method 1 versus 3 and again for Methods 2 versus 4, it is possible to determine the overall effect of the nasal bone tangent on facial estimation of the nose. A repeated-measures ANOVA shows that all the mean differences in the position X are statistically different from one another (Table 4). However, the methods which use tangent 1 (last third of nasal bone)

consistently resulted in greater means compared to the method using tangent 2 (last 1-2 mm) independently from the other tangent or true nasal tip used (Table 4). In other words, using the general direction of the last third of the nasal bone is less accurate. This supports the statement made by Rynn and Wilkinson (2006) and reiterated by Ullrich and Stephan (2011) that the general direction of the last 1-2 mm of the nasal bone should be used for the first tangent.

Figure 21: Direction of error from tangents



In the same way, if we compare Methods 1 to 2 and Methods 3 to 4 using the difference in Y, the effect of the other tangent can be determined (Fig. 21). A repeated-measures ANOVA indicates that all the mean differences along the Y-axis are statistically different from each other with the exception of one ($p=0.300$). The mean difference using reference point 2 is not statistically different between Methods 3 and 4. In other words, using the general direction of the nasal floor instead of the anterior nasal spine does not result in a more accurate approximation of the nasal tip along the NSL. Nonetheless, the mean difference is consistently smaller for the methods that use tangent

4. Consequently, despite the fact that Methods 3 and 4 do not result in statistically different approximations, Method 4 is slightly better in positioning the tip of the nose along the Y-axis by about 1.5mm.

Nasal projection methods

Based on the previous tangent analysis, it is expected that as a whole, Method 1 would have performed the worst and Method 4 the best. This is supported by the mean absolute distance for each method. Method 1 has the largest means (19.3667 and 11.926), or deviation from the true position of the nose, for both reference points. It is consistent with the tangent analysis that identified the two tangents defined by the literal translation as introducing the largest amount of error. Method 4 has the smallest means for both reference points (8.8530 and 5.4379), which is again expected from the t-test and ANOVA of the differences in the estimation of the nose tip in both the X and Y axis. Finally, the mean difference was not found to be statistically different between Methods 2 and 3, independent of the reference point. This is consistent with the fact that these two methods use a combination of the old and new tangent definitions. It is possible to conclude that overall, the new interpretation of Gerasimov's two-tangent method provides more accurate results than the literal translation. However, the new interpretation is only slightly better at approximating the true nasal tip as defined by NSL, compared to the tangent combination of the last 1-2 mm of the nasal bone and the general direction of the nasal spine by an average distance of 3.065 mm.

Despite this improvement, all the absolute distances and calculated differences in X and Y for all the methods are statistically significantly different from zero. In other words, none of the methods tested can correctly approximate the position of the nasal tip

despite one method having a significantly smaller mean difference than the others. Using the reference point 1, all methods underestimated the tip of the nose along the vertical plane (Y-axis). Methods 1 and 2, which both use tangent 1, consistently overestimated the tip along the anteroposterior plane (X-axis). On the other hand, Methods 3 and 4, which used tangent 3, tended to underestimate the position of the tip. It was anticipated, based on the studies by Stephan et al. (2003), Rynn and Wilkinson (2006) and López et al. (2010) that all the methods would not be able to accurately determine the position of pronasale. On the other hand, Method 3, which used the last 1-2 mm of the nasal bone and the nasal spine, was previously found to be highly accurate to predict a point on the tip of the nose (Rynn and Wilkinson, 2006) but was not supported by this research. In addition, the two studies report significantly smaller mean differences from the true tip compared to here (Table 8). It is possible that these differences are the result of the inexperience of this investigator as a facial approximation practitioner, the impact of which will be discussed in more detail in the following section.

Table 8: Comparison of mean differences (mm)						
	Method 1 (FHP)		Method 3 (FHP)		Method 3 (NSL)	
	Stephan et al. (2003)	Current study	Rynn and Wilkinson (2006)	Current study	Rynn and Wilkinson (2006)	Current study
X male	6.2	-13.372	-0.91	3.092	-0.16	-4.320
X female	4.3		-0.9		n/a	
Y male	7.5	-10.978	-3.61	-9.131	-0.34	-1.565
Y female	6.7		-3.54		n/a	

Intraobserver error

The original guidelines for the two-tangent method seem to be very clear and should be easily applicable by the practitioner. However, the guidelines were criticized by Stephan et al. (2003), where the two-tangent method was found to be inaccurate. According to them, “this was not surprising, since the technique seemed rather subjective and imprecise because it relied on the “general directions” of two bones”. (Stephan et al., 2003: 245) Similarly, Rynn et al. (2010) explained that the inaccuracy is due to the fact that the method “utilizes lines projected at tangents to curved bone, the angles of which are evidently indicative of the form of the nose, but the placement of which is subjectively determined by the practitioner.” Consequently, subjectivity results in inaccuracy (Rynn et al., 2010) and is the probable cause for the unrepeatability, as identified by Ullrich and Stephan (2011) and Gerasimov, himself (Gerasimov, 1955). For that reason, a significant difference between all three trials was expected. However, there was not a statistically significant difference between the second and third trial according to the repeated-measures ANOVA ($p=0.728$). This suggests that there is a greater learning curve for the inexperienced practitioner since the first trial was significantly different than the following trial. Nevertheless, after that initial experience, the methods were repeated with an average difference of 0.678 mm. The inexperience of this researcher may account for the higher mean differences observed in this study as compared to other studies when performed by extremely experienced practitioners of forensic facial approximation (Table 8). In particular, a small error in the angle of the tangent at the nasal bone results in an error of several millimetres at the other end of the tangent.

Outliers

Individual 09011340, an outlier removed from the dataset, is a great example of the need for experience by the practitioner and how the subjectivity identified by Stephan et al. (2003) and Rynn et al. (2010) is not only caused by the curved morphology of the nasal bones. Individual 09011340 is an 87 year old male that exhibited a very straight nasal bone (Fig. 22), where the general direction is the same using the last third or last 1-2 mm of the nasal bone. The tangent following the general direction of the nasal bone is easily placed because the bone is straight. However, it greatly overestimates the true tip of the nose. As seen in Figure 23, a modified placement of the tangent to only touch the extreme end of the nasal bone provides significantly better results.

Figure 22: Nasal bone of Individual 09011340

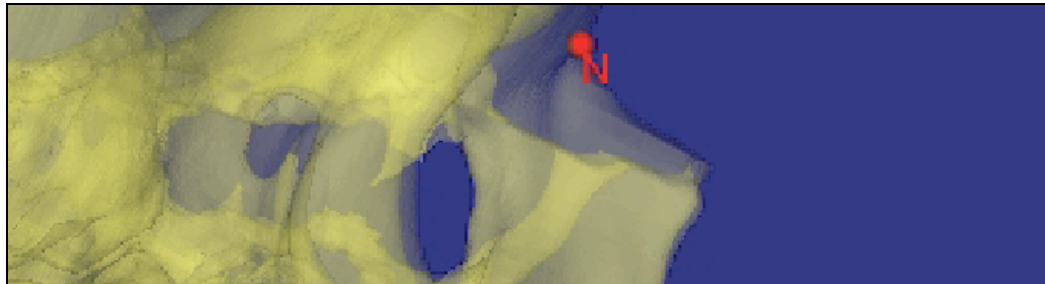
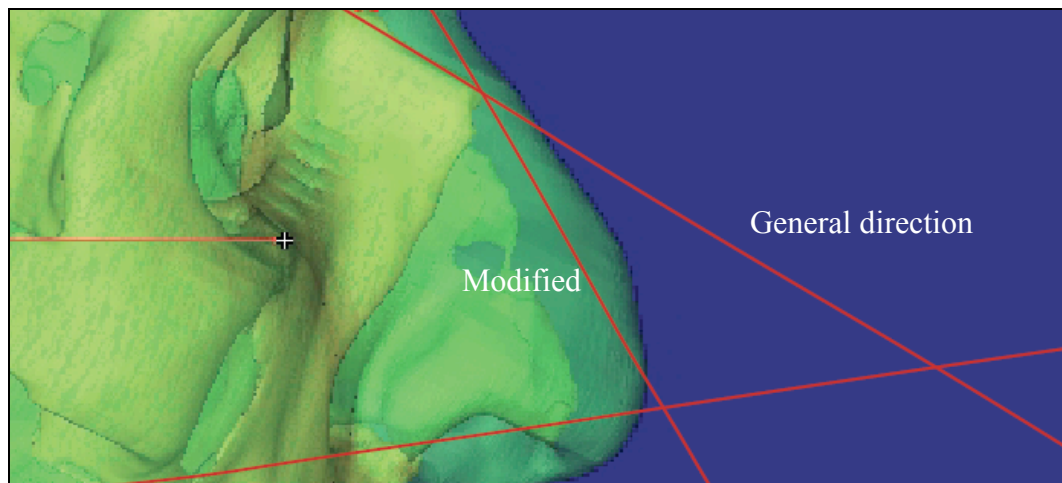
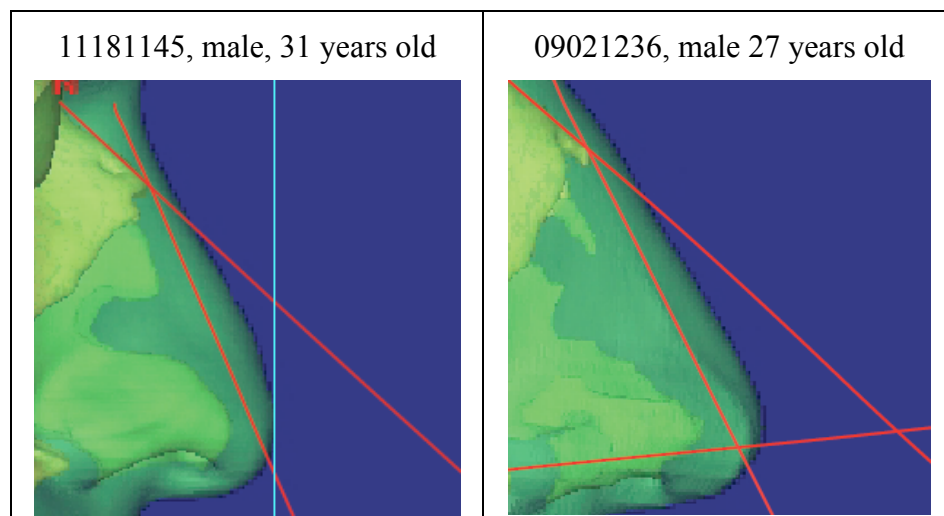


Figure 23: Tangent placement for individual 09011340



Two additional individuals with straight nasal bones were identified in Figures 18 and 19, with an asterisk, both outliers but only for some of the methods. The placement of the tangent resulted in the same problem as the previous example and can be solved by using a modified tangent that follows the edge at the end of the bone, angling downward (Fig. 24). The modified tangent is also supported by the analysis of dissected noses of six males and six female cadavers by Anderson et al. (2008). They noticed that “the superior border of the septal cartilage does not form a linear extension of the profile contour of the nasal bones but angles downwards.” (Anderson et al., 2008:212)

Figure 24: Additional example of modified tangent



Finally, individual 02271145b, with a curved nasal bone, was also identified as an outlier due to the placement of the first tangent following the nasal bone. It is suggested that an experienced practitioner, who has seen numerous nasal bones and their associated soft tissue, could have been able to identify the issue and correctly placed the tangent. These specific cases confirm that the guidelines provided by Gerasimov to follow the general direction of the nasal bone is imprecise and support the claim made by the other

practitioners that the original guideline is not accurate (Rynn and Wilkinson, 2006; Ullrich and Stephan, 2011)

General discussion

Helmer et al. (1993) explained that the discrepancies between facial approximation is due to the lack of adherence by practitioners to standardized principles and the lack of universal guidelines. This problem also affects the positioning of the nasal tip. Practitioners have the choice between a total of six different methods with the two-tangent method being the most commonly used. However, putting into place universal guidelines is not necessary for successful approximations as more than one method can be equally reliable. Ullrich and Stephan (2011) argued that previous accuracy testing of the two-tangent method are invalid because they did not perform the method as Gerasimov intended. They even dismissed the results of Rynn and Wilkinson (2006) who determined that a combination of the old and newly defined tangents provides more accurate nasal projections. On the other hand, this current research establishes that there are no statistical differences between the tangent combination (Method 3) as tested by Rynn and Wilkinson (2006) and the new interpretation of the two-tangent method (Method 4). In other words, using the general direction of nasal floor or the anterior nasal spine does not provide statistically better results. This support the fact that a universal guideline might not be the solution to better facial approximations and that Ullrich and Stephan (2011) may have too readily dismissed the previous research. The most important thing is that the method is accurate, regardless of how Gerasimov truly positioned the two tangents.

From a practical point of view, the tangent following the nasal floor provides slightly better results than the nasal spine tangent. Therefore, in theory, the nasal floor should be used for the two-tangent method. However, the craniums used for actual forensic cases are affected by a wide range of postmortem processes and are not necessarily in perfect condition. Since there is no statistical differences between the two tangents, the practitioner can choose between the two tangents depending on the presence or absence of damage on the nasal spine or the nasal floor. The fact that craniums are often damaged emphasizes the need for a list of reliable facial feature guidelines to choose from in situations where a number of cranial structures are missing or damaged. However, accurate facial features do not necessarily equate to successful facial approximations because in the end, the approximated face has to be recognized by someone to create an investigative lead.

The nose is one of the three most significant features for recognition (Briggs and Martakis, 1998). Rynn et al. (2010) stated that the two-tangent method has good accuracy with an error of ± 2 mm. López et al. (2010) used a cut off point of ± 5 mm to differentiate between successful and non-successful nasal projection. However, neither specifies their reasoning for choosing that specific cut off point. It is known that the interrelationship of facial features is important (Bruce and Young, 1998) and that small differences can result in substantial changes to the facial features (Enlow and Hans, 1996). Consequently, how much error can be allowed before it has a significant impact on the recognition process? In addition, when the approximated face is disseminated in the media, the goal is for it to be recognized by a family member or a friend and the facial features become more important with familiarity, or when the individual is not a stranger

(Bruce and Young, 1998). Similarly, changes to the soft tissue of the face can influence the perceived age of the individual (Todd et al., 1980) and can affect the recognition process. This research very consistently positions the tip of the nose more forward and downward compared to the true nasal tip. It is known that the nose continues to move forward and downward with age (Albert et al., 2007), which raises the question that if the nasal tip is overestimated will it make the individual look older and interfere with recognition?

Nevertheless, this research provides important validating information about the two-tangent nasal projection method. Like any research, there are limitations due to the sample and advantages stemming from the use of CT scans. Comparable to the majority of research in forensic facial approximation, the sample used here is from a Caucasian population. The use of a Caucasian sample limits the extrapolation of the results to other population groups. Within the nasal projection literature, only Rynn et al. (2010) used a sample that included more than one ancestral group (White, Asian and African American) and resulted in accurate nasal projections using the two-tangent method. The other issue with the sample used for this research is that body mass index (BMI) information was not available. It was apparent from the 3D rendering of the face that some individuals fell within a higher BMI range than others, though that could not be confirmed. This missing information could influenced the accuracy of the two-tangent method for some individuals since the amount and location of fat on the nose varies between individuals (Anderson et al., 2008). BMI has also been found to affect facial approximations in general because of its effect on soft tissue thickness (De Greef et al., 2009).

The scans used for this research were from deceased individuals and they were scanned at 2.0 mm slice intervals with a 3.0 mm slice thickness. The type of scanner used and parameters such as slice thickness and interval directly affects the image resolution (Cavalcanti et al., 2004). Previous research in forensic anthropology and forensic facial approximation have used scans with slice thicknesses ranging from 0.9 mm to 3 mm (Cavalcanti et al., 2004; Pfaeffli et al., 2007; Ferrant et al., 2009; Ramsthaler et al., 2010; Sakuma et al., 2010). The smaller the slice thickness, the more detailed information is recorded and the more accurate the volume rendering. However, multislice CT scanning of individuals to very high accuracy level means the use of potentially dangerous doses of radiation (Quatrehomme et al., 1997; Nelson and Michael, 1998). As a result, the CT databases are limited to patient data, incomplete scans or deceased individuals. In addition, CT images of deceased individuals are acquired in a horizontal or supine position, when we most often view people while in a standing upright position. Consequently, due to gravity, the shape of the face visualized from the CT images will differ from the typical upright face of a living individual (Claes et al., 2010).

The effect of gravity on facial soft tissues might have affected this research. The majority of individuals included in this research resulted in larger overestimations of the nasal tip compared to previous validation studies that used lateral radiographs (Table 8). The overestimation might have increased due to the supine position of the individuals during scanning. However, this problem may be avoided with the recent development of a new type of CT scanner. Cone-beam CT (CBCT) can produce scans with slice thicknesses as small as 0.1-0.2 mm (Sakuma et al., 2010) with significantly less radiation than the multislice CT (Lee et al., 2011). In addition, the subject can be scanned in an

upright position (Claes et al., 2010). Consequently, "the 3D image of a face taken from the CBCT may also allow a comparison between the face of a subject and the facial reconstruction without the soft tissue distortion caused by gravity and body position." (Sakuma et al., 2010:320) Finally, the use of CBCT can also reduce artifacts caused by dental modifications such as fillings. CT scan of live subjects have been used in more recent research (Tilotta et al., 2009; Lee et al., 2011) and is likely the future of accuracy testing for anthropological and forensic facial approximation methods.

Future directions

During the last decade, the use of CT scans and 3D volume rendering has gained popularity in the field of forensic anthropology. Identification of human remains is sometimes based on the study of anthropometric characteristics (Cavalcanti et al., 2004). Forensic anthropologists study the skeleton and use tested methods to determine age, sex and ancestry. However, the majority of these methods have been developed on populations that lived decades ago and there is a lack of recent bone collections. However, studies have shown that volume rendering from CT scans provides accurate information for sex determination (Ramsthaler et al., 2010) and age estimation (Ferrant et al., 2009). There is a clear need for research using different ancestral groups but a lack of databases available to do so. CT scans, especially with the development of CBCT, is a solution to create new datasets of recent populations from various populations (Claes et al., 2010; Ramsthaler et al., 2010). Improvement of the traditional anthropological methods using these new databases will directly impact the field of forensic facial approximation by providing more accurate biological profiles.

CT scanning also provides the opportunity for follow up research using the same sample but analyzing different anatomical structures and measurements that might not be possible from a radiograph. As an example, the difference in the nasal projection results between this research and other validation studies might be caused by the use of deceased individuals. However, the variability can also be caused by the subjectivity in placing the tangent and possibly correlated lack of experience. It is realistic to assume that the forensic facial approximation practitioner might not have seen numerous craniums with the associated soft tissue to gain experience about the interrelationship of soft and hard tissue. A solution needs to be provided to reduce subjectivity and eliminate the effect of experience. The goal of Rynn et al.'s (2010) research was to create regression equations that would provide metrical limitations to the shape of the nose while using the two-tangent method. Despite the fact that the regression equations need to be validated, it would be useful to determine how the new interpretation of the two-tangent method performs within these metrical limitations using the same sample as this research.

Finally, another aspect of forensic facial approximation and nasal projection that needs additional research relates to the process of recognition. There is a great amount of research about facial recognition in the psychological literature (Bruce and Young, 1998). However, there is an obvious need for additional research with practical applications for forensic facial approximations such as investigating the maximum deviation or error allowed in the position, size and shape of the facial features, including the nose, before it starts affecting recognition to the point of non-identification. Overall, there is a need in research to shift from traditional radiographs to CBCT in order to have access to highly

accurate reconstructions from living individuals and use that to better test the accuracy of facial approximations based on successful recognition.

Conclusion

This research used a database of CT scans from deceased Danish individuals to determine how to perform the two-tangent method in order to achieve the best accuracy for approximating the position of the tip of the nose. The main goal was to compare Gerasimov's two-tangent method, as described in his work translated in English (Gerasimov, 1971) to the new guidelines presented by Ullrich and Stephan (2011). The literal translation of the two-tangent method uses the intersection of a first tangent following the last third of the nasal bone and a second tangent following the general direction of the nasal spine (Gerasimov, 1971). The new guideline is based on the claim that Gerasimov did not adhere to the translated guideline but instead used the general direction of the nasal floor and the last 1-2 mm of the nasal bone (Ullrich and Stephan, 2011). It is clear that the definition of the tangents directly correlates with the success of the method. Similarly, the accuracy depends on the comparison to the true nose which can be defined in multiple ways. As a result, the research also had two secondary goals to better evaluate the success of the two-tangent method.

The first secondary goal was to determine how each tangent independently affected the resulting nasal projection. To do so, two methods using a combination of the translated and new tangent definition were compared. The second secondary goal was based on the results from the accuracy study by Rynn and Wilkinson (2006). The nasal tip is usually defined as the most projecting point when the skull is placed in the Frankfurt Horizontal plane (FHP), also known as pronasale. However, Gerasimov did not

specify how to place the skull. Rynn and Wilkinson (2006) argued that the two-tangent method can accurately approximate a point on the tip of the nose, as defined using the nasal spine line (NSL), but not using the FHP. As a result, the approximated nasal tips were compared to two different true nasal tips (NSL and pronasale) to determine which point on the nose is better approximated by the two-tangent method.

The four versions of the two-tangent method were performed on a total of 66 individuals and compared to pronasale and the point on the tip of the nose crossed by the nasal spine line. Almost every method overestimated the position of the nose anteroposteriorly, vertically or both, with the exception of the NSL nasal point using the new interpretation of the two-tangent method (Table 9). The same method also had the smallest mean difference between the approximated and true nasal tip using the absolute distance. However, statistical analysis established that there was not a significant difference between Methods 3 and 4 for NSL (Table 3). In addition, when the mean differences were compared to a test value of zero, it was determined that none of the methods could accurately approximate nasal projection (Table 6). These results are in contradiction to previous studies that have found good accuracy for the two-tangent method (Rynn and Wilkinson, 2006; López et al., 2010).

Table 9: Summary of the data										
Method*	Mean difference (mm), overestimate +, underestimate --									
	Pronasale / FHP					NSL				
	X		Y		Absolute	X		Y		Absolute
1	-14.370	+	-11.094	+	19.367	-21.749	+	-3.515	+	22.933
2	-7.826	+	-3.739	+	10.341	-10.347	+	0.542	--	10.947
3	2.052	--	-9.252	+	12.433	-5.339	+	-1.670	+	8.503
4	4.577	--	-4.398	+	8.853	2.053	--	-0.114	+	5.438
* 1= Literal translation, 2 = First combination, 3 = Second combination, 4 = New Interpretation										

Despite these negative accuracy results, the research does provide answers to the main goal and two secondary goals initially set. The main conclusions are that:

- 1) The new interpretation of the two-tangent method is better than the original translation.
- 2) The tangent following the nasal bone causes most of deviation from the true location of the nasal tip with greater accuracy using the last 1-2 mm.
- 3) The new two-tangent method is better at approximating a point on the tip of the nose (NSL) than pronasale.

In addition, using the general direction of the nasal floor was slightly better (3.085 mm) but not statistically different than using the anterior nasal spine. Consequently, from a practical point a view, the nasal floor should be prioritized but the nasal spine is a good alternative if the skull is damaged. Finally, it is important to mention that the two-tangent method was not significantly affected by intraobserver error, but was more so by the level of experience of the practitioner. The importance of experience is consistent with the problem of subjectivity in placing the tangents as identified in previous research (Stephan

et al., 2003; Rynn et al., 2010). As a result, a good follow up would be to combine the new interpretation of the two-tangent method with Rynn et al.'s (2010) regression equations, which have been created to provide metrical limitations and to reduce subjectivity in the shaping of the nasal tip.

This research helps to fill a gap in the knowledge of facial approximations by providing empirical data to fully understand the effect of tangent positioning and researcher experience on nasal projections using Gerasimov's two-tangent method. It also validated claims previously published in the forensic nasal approximation literature (Ullrich and Stephan, 2011).

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