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The Evolution In Forensics- A Review

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ABSTRACT

Forensic science has undergone significant transformation in recent years driven by technological advancements and interdisciplinary research. Digital radiography, facial reconstruction, DNA analysis,Artificial intelligence and dental record management are some of the more recent developments in forensic odontology that are highlighted in this overview. The accuracy and effectiveness of forensic odontology have increased with the incorporation of newer technology and methodologies, making it an essential instrument in contemporary forensic science. The assessment also looks at how new technology like artificial intelligence and 3D printing can be used in forensic dentistry. This review's overall goal is to present a thorough analysis of the most recent developments in forensic odontology and their consequences for the discipline.

KEY WORDS : Forensics,oral and maxillofacial, DNA Analysis.

INTRODUCTION

Over the years, dentistry has expanded its branches and continues to do so in the age of newly developing professions. Forensic dentistry is one of these specialties. Forensic dentistry was described as "that area of forensic medicine which, for the sake of justice, deals with the appropriate handling and examination of dental evidence as well as the appropriate evaluation and presentation of the dental findings." [1]As teeth are hardest known tissue &differ from other bodily parts in their composition, Forensic is one of the most trustworthy options for inquiry in medicolegal situations and catastrophe victim identification.This article examines several newer identification techniques like ameloglyphics, facial reconstruction,denture identification method and recent developments in age estimation, Bite marks, cheiloscopy, Rugoscopy,sex determination and radiography as well as DNA technology, digital forensics, and artificial intelligence applications in forensic science.Forensic dentistry not only aids in human identification but also contributes to legal support.

FORENSIC DENTISTRY IN HUMAN IDENTIFICATION

Comparative dental identification

Each person's tooth morphology and arrangement are distinct.

The primary principle of dental identification is the identification of the necessary personnel by comparing the ante-mortem and post-mortem data**.**

Teeth can undergo adverse post-mortem changes which can degrade and disrupt other body tissues .

The dental evidence utilized in the comparison includes dental caries, restorations, implants, dentures, prostheses, tooth changes like talon cusps, developmental defects like dentinogenesis imperfecta and amelogenesis imperfects, and dental fluorosis.

The rubber dam punch is used to mark the films in order to prevent any mistake between the antemortem and post-mortem recordings.

Given the likelihood of the so-called non-restorative cases being increasingly prevalent, a systemic criterion of comparison is required.

This is accomplished by looking at every tooth and the tissues that surround it.

Concerns about similarities and differences should be raised during the comparison process.

The four conclusions listed below are the only ones that the American Board of Forensic Odontology will accept as valid during dental identification.

1. Positive identification: the antemortem and postmortem records match in enough detail to provide proof of the same person's identity, and there are no inexplicable differences there. At least 12 coinciding features ought to be present. There is a 1/10,000 chance of a coincidence with someone else.

2.Potential identification: despite similar characteristics, the identity cannot be conclusively confirmed based on the caliber of the antemortem or postmortem evidence.

3. Inadequate evidence: there is not enough data to draw a conclusion.

4. Exclusion: The antemortem and post-mortem records are obviously inconsistent. [2,3]

RUGOSCOPY

Rugoscopy is defined as the analysis and study of shape, length, number, merging pattern and direction of palatal rugae.

The ridges, folds, or wrinkles on either side of the mid palatine raphe on the anterior part of the hard palate are known as palatal rugae.

The palatal rugae are shielded from decomposition and combustion by the Bichat's fat pad, lips, maxillary bones, and teeth. Each person, including twins, has unique palatal rugae, which are generated during the third month of intrauterine development and last throughout life like fingerprints.

Rugae patterns can be classified as diverge, converge, curve, wavy, straight and circular.

The examination of palatal rugae can be enhanced by the presence of additional components such the incisive papilla, the palatal tori, and the morphology of the mid-palatal raphe.

A study conducted on the Japanese population revealed that females have less palatal rugae than males.[4]Rugoscopy identification can be as accurate as 94% of the time.[3]

CURRENT TREND:

AI and machine learning are now used to analyse rugae patterns digitally, improving accuracy and reducing human error.

High resolution 3D laser scanners and CBCT allow detailed visualization and comparison of palatal rugae.

3D printing of palatal rugae models helps forensic experts reconstruct oral structures from remains.AI assisted rugae pattern classification are also recently evolved.

CHEILOSCOPY

Lip prints are crucial pieces of evidence at the crime scene, much like fingerprints.

Every person has a distinct lip print since they are permanent and consistent, with the exception of monozygous twins.[3]

Cheiloscopy is the study of the distinctive pattern of the lips, which is made up of a number of elevations and depressions.

Renaud's classification divides lip prints into ten categories, which are denoted by the letters A through J, capital letters for upper case and lower case for lower lip.

Tsuchihashi et al.[1] divided lip grove patterns into six categories.

Type 1 consists of distinct vertical grooves that run the length of the lip; Type I is comparable to Type I but does not cover the entire lip;

Type II is branching

Type III is intersected

Type IV is reticular

Type V is morphologically undifferentiated.

In their study of dentistry students, Rachna V. Prabhu et al. 1 found that the type V pattern was the most prevalent and noted trifurcation, bridge or H pattern, horizontal lines, cartwheel, pineapple skin, and multiple branching appearances for the first time.[1]

Thus, highlighting the necessity of type V subclassification for a more precise inquiry. A criterion for sex determination using lip prints was proposed by Vahanwala et al.[4]

CURRENT TREND:

Lip prints are being combined with other biometric markers like fingerprints and DNA analysis for comprehensive forensic profiling. Recently use of 3D scanning technology allows for more detailed lip print analysis, especially in cases where prints are distorted on different surfaces.

AI and machine learning algorithms are being used to enhance the classification and comparison of lip prints ,reducing human error and improving accuracy.

RADIOGRAPHY

Radiographic characteristics are very useful for estimating age.

Because different ages have distinctive dental characteristics that may be detected on a radiograph, it is easy for the investigator to determine the required individual's age.

For instance, the pulp chamber begins to shrink with age, and third molars only appear in people beyond the age of 18.

Several radiographic techniques, including intraoral periapical radiographs, lateral oblique radiographs, panoramic radiographs, and cephalograms, are used to estimate parameters such as the eruption sequence

appearance of tooth germs, extent and degree of mineralization, degree of crown and root completion, degree of root resorption of deciduous teeth, open apices, pulp to tooth ratio, volume of pulp chambers and root canals, and third molar.

All these methods require X-ray images of developing teeth.[1]

CURRENT TREND:

1. **Postmortem Computed Tomography (PMCT):** This technique, which provides thorough imaging of skeletal injuries, foreign objects, and gas embolisms, has emerged as a useful tool in forensic investigations.

Because it is non-invasive, thorough exams can be performed without compromising the integrity of the evidence.

When it comes to firearm injuries, blunt force trauma, and identifying human remains, PMCT is especially helpful.

2. **Magnetic Resonance Imaging(MRI):** The use of MRI in forensic investigations is growing, particularly in angiographic, cardiovascular, and musculoskeletal examinations.

Additionally, it is used for age assessment, imaging living people in child abuse situations, and surviving strangulation.

3. **Virtual Autopsy (Virtopsy)**: This method creates three-dimensional (3D) representations of the body by combining imaging modalities such as CT, MRI, and photogrammetry.

By maintaining the integrity of the body and producing readily shareable data, it provides a non-invasive substitute for conventional autopsy.

Around the world, forensic investigations are increasingly using virtopsy as a common method.

4. **Postmortem Angiography:** By combining angiography and imaging methods, the vascular system can be seen in great detail.

This is essential for locating bleeding sources, vascular damage, and other conditions that are not visible with conventional imaging.

5.Spectral Imaging: Spectral imaging, also known as dual-energy imaging, analyzes energy-dependent attenuation features to improve material discrimination.

In forensics, it helps identify and describe foreign objects such as glass pieces, knife tips, and bullets, offering comprehensive information on wounds and causes of death.

BITE MARKS

Numerous investigations have established that each person's human dentition is unique.

A bite mark is the impression left on a material by the teeth's cutting edges as the jaw closes.[5]

In the teeth marks, a core zone of contusion is seen.

Because of the pressure the teeth put on the tissues, extravascular bleeding can be visible flowing from the bite mark's exterior inward.[3]

The diameter of a normal human bite ranges from 25 to 40 mm.[3]

The attacker or the offender may have bite marks on them.

They are occasionally discovered on inanimate things at the scene of the murder.[5]

The most typical places for victims to have bite marks are on their skin and soft tissues throughout their body.[5]

Males get bite marks on their arms and shoulders, while girls get them on their breasts and thighs as a result of sexual assault. [5]

The bite mark's demographics, location, shape, size, color, type of damage, and any other pertinent information at the time of dental evidence collection are all described in the record.[5]

Photos, salivary swabs, imprints, and tissue samples are among the evidence gathered from the victims.

The saliva deposits in the skin at the moment of biting should ideally be collected using the double cotton swab technique.

The amylase test is used to find dry saliva because it is difficult to find.

The suggested impression materials for registering all of the abnormalities the teeth create on the skin and obtaining imprints for fixed prostheses include vinyl, polysiloxane, and polyether.

There are three different types of bite marks: tooth pressure, tongue pressure, and tooth scrape mark.

In order to analyze bite marks and investigate crimes, Vander Veldon A. et al.[1] employed picture perception technology.

Pseudo three-dimensional imaging and additional picture coloring turned out to be the benefits of this method, increasing its accuracy.

CURRENT TREND:

The application of AI for bite mark analysis, which was intended to detect bite marks in a variety of forensic situations.They converted the 32-bit bite mark sample to an 8-bit grayscale (0-255), with 0 denoting the darkest and 255 the brightest.

Afterwards, each image's contrast was modified using Contrast Limited Adaptive Histogram Equalization.[6]

DNA TECHNOLOGY IN FORENSICS

DNA can be extracted from saliva, oral mucosal cells, and teeth since the oral cavity is a valuable source of this material.

Blood is the primary source of DNA, yet in certain circumstances it might not be accessible for examination.

Pulp tissue is the most popular choice because to its abundance and resistance to being impacted by non-human DNA.[3]

Three methods are used to collect pulp tissue: endodontic access, horizontal or vertical tooth sectioning, and crushing.[3]

Dentine or cementum are utilized as a substitute when the pulp is endodontically obturated.

Genomic DNA is located in the cell's nucleus. Red blood cells lack DNA because they have a nucleus deficiency.

Even after the other bodily tissues have broken down, the architecture of the enamel, dentine, and pulp remain intact.

Therefore, it is crucial to extract DNA from the calcified tissues. Teeth are an exceptional source of DNA; in fact, even teeth with root fillings offer enough biological material for PCR analysis.[2]

The sequence of cellular building units known as mitochondrial DNA (mt DNA) aids in identifying.

Because most cells have a large number of mitochondria, each cell has a high copy number of mt DNA.

Mt DNA will be abundant in situations when the genomic DNA is too deteriorated to be examined.

CURRENT TREND:

Next-generation sequencing (NGS) has made it possible to analyze damaged and mixed DNA material with previously unheard-of precision.

By revealing information about tissue origin and environmental exposure, methods like forensic epigenetics and microbiome analysis have given DNA-based evidence additional dimensions.

Furthermore, on-site analysis is now possible because to developments in Rapid DNA technology, which drastically cuts turnaround times. [7]

AGE ESTIMATION

Dental structures can serve as helpful markers for establishing a person's age in years. By examining tooth development and then comparing it with developmental charts, one can ascertain the age of children, including fetuses and newborns.

Ubelaker 2 created the charts, which included all three forms of dentitions—deciduous, mixed, and permanent—and provided a pictorial representation of the development of the dentition from 5 weeks in utero to 35 years of age.

The real developmental phases of the teeth provide greater precision in these circumstances because the eruption dates of the teeth vary greatly when estimating the sub-adult ages.

The first technique to determine a person's age based on their teeth was reported by Gustafson [9] in 1950.

Six criteria were established based on changes in hard dental tissues that occur with aging: cement thickness, occlusal wear, secondary and tertiary dentin layers, the degree of root resorption, the length of the root transparency, and the height of gingival attachment.

Each of these factors was given a score between 0 and 3, which was determined by their intensity. Because the scores were not incorporated into an integrating scale, subjective results were documented.

However, Lamendin et al. [10] developed a method for estimating an adult's age based on their single-rooted teeth.

Gingival recession and root transparency were analyzed using this method.

People under the age of twenty lack root transparency, which is caused by hydroxyapatite deposits that grow inside the dentinal tubules. Since the vestibular side of the root was the most visible, the maximum length of root transparency was measured there.

Another technique tried to estimate age using the cementum layers that were overlaid.

The amount of cementum layers deposited and the age at which teeth erupted were used to calculate an individual's chronological age. [3]

Czermak et al.[3] employed software-mediated image acquisition to guarantee the optimal placement of cement layers at the microscopic level, reducing the human error factor brought on by technique fatigue and subjectivity.

Mohite et al. developed a technique based on histology and radiological alterations in the mandibular bone.[3]

The radiograph showed that the mandibular ramus grew longer with age, with the mental foramen serving as a reference point.

When assessed in a craniocaudal orientation, a decline in the alveolar processes was seen, and the process slowed down after the age of fifty.

As a result of the haversian canal system's enlargement due to increasing remodeling with osteons and declining osteoblastic activity with age, the porosity of the cortical bone increased.

Particularly among those over 50, the quantity of concentric laminas per osteons.[3]

CURRENT TREND:

AI-assisted dental analysis improves accuracy in estimating age in children and adults. Advanced dental imaging, including 3D CBCT (Cone Beam CT) scans, helps assess tooth development and root translucency for age determination.

Machine Learning on Dental X-rays: Algorithms assess pulp-to-tooth ratio and tooth mineralization for accurate age prediction.

SEX DETERMINATION

A study by Garn et al [4]confirmed that the mandibular canine showed greater extent of sexual respect of sexual dimorphism with respect to the maxillary canine in different ethnic groups whereas on the other hand Kuwana[4] in 1983, Mizuno [4] in 1990 concluded the opposite of this study.

Therefore, the controversy related to this matter still continues. The mesio-distal width of mandibular canines was significantly greater in males than in females as per the reports by Rao et al.[4]

Various anatomical structures like the mandible, foramen magnum, paranasal sinuses, frontal sinus, maxillary sinuses and mastoid processes are evaluated along with the canines as these structures too possess sexual dimorphism.

The mandible differs in shape and size amongst both the sexes. Attributed to the sex, nutrition and physical activity females have a smaller mandible and relatively a less thickened bone.

The difference in the masticatory forces between the males and females affects the expression of mandibular dimorphism in terms of the relative development like size, strength, and angulation of the masticatory muscles.

Females have downward and a backward rotation of the mandible which results in an increased value of the gonial angle whereas the males have forwardly rotated mandible and a lesser gonial angle.

The gonial angle shows variations in life- being obtuse at the time of birth, decreasing as the individual grows up and ultimately increasing again in the older age.

A CBCT can be useful in determining various factors like length and breadth of the ramus, gonion–gnathion length, gonial angle, bigonial breadth, and bicondylar breadth for sex determination.

A CBCT can be helpful in determining a number of characteristics, including the gonion-gnathion length, gonial angle, bigonial breadth, bicondylar breadth for sex determination, and the length and breadth of the ramus.[12]

The cranial base is resistant to physical insults because of its thickness, anatomical position and compactness due to this reason it acts as a guide in forensic dentistry Foramen magnum (FM) is a 3D aperture present within the basal central region of the skull.

It is a transition zone between the skull and the spine.[14] The usefulness of foramen magnum in sex determination was first reported by Teixeriain[13] the year 1982.

Gunay and Altinkok (2000)[14] assessed the area of FM in an inhomogeneous sample of male and female skulls and concluded that the mean area of FM is greater in the males however this information does not hold much significance in forensic dentistry.

Any physical harm to the skull and other cranial bones has no effect on the paranasal sinuses (PNS). Males have much larger jaw sinuses than females, according to several studies

.

Culbert and Law carried out the first radiological comparison of the PNS in the body in 1927.[12]

Wanzeler et al. used CBCT scans with FM measures in 2019[15] to co-relate the volumetric study of the frontal, sphenoidal, and maxillary sinuses.

Based on this correlation, a conclusion was drawn that After adding up the volumes of the frontal, sphenoidal, and maxillary sinuses, the accuracy rates for males and females were 96.2% and 92.7%, respectively.

When comparing the total of the three estimated PNS with FM measurements, the accuracy surpassed 100%.[12]

Even with monozygotic twins, each person has a distinct frontal sinus. The instrument used to determine sex is the frontal sinus index.

A lateral cephalogram radiograph is used for a horizontal analysis of the nasion–sella line. Additional parameters include the frontal sinus's height and width, anteroposterior diameter, total sinus width, inter-sinus width, separation between the highest points of two frontal sinuses, and the separation between the left frontal sinus's highest point and the maximum lateral limit measurements.

Choi et al. [16] in 2018 examined the various frontal sinus parameters using reconstructed CBCT images and found that the frontal sinus analysis can identify sex with an accuracy of up to 80%.

Similar to the paranasal sinuses and the foramen magnum, the mastoid process is immune to physical harm. The mastoid process is the region of greatest interest for macroscopic examination during investigation in cases where the skull is cracked.
Females have an inward-facing tip on their mastoid process, whilst men have a bigger, vertical tip. According to a study by Amin et al., this method's accuracy was 90.6%.

CURRENT TREND:

Mass Spectrometry for Protein Markers: The enamel of teeth contains sex-specific proteins, such as AMELY and AMELX peptides, which remain intact even in ancient or degraded remains.

The AMELX gene is present in both sexes, while AMELY is only found in males. This method is highly reliable for sex determination

Collagen and Other Dental Proteins: Studies suggest that differences in protein expression in dentin and cementum can help in sex identification.

FACIAL RECONSTRUCTION

This technique creates an image that closely resembles the departed person.[19]A laser video camera is used to capture the skull for the computerized facial reconstruction technique.

A 3D surface of skull data that is completely shaded is photographed. Computer programs such as Vitrea 2.3 version volumetric visualization software can be used to draw faces.

Compared to direct imaging on CT slices and the 2D CT approach, 3D CT is thought to be more accurate.[20]

DENTURE IDENTIFICATION METHOD

In forensic dentistry, the denture serves as a medium of identification due to its high degree of resistance to extreme temperatures.

Only when a denture is marked can it positively identify itself.

The two techniques that form the basis of markings are the inclusion method and the surface marking method.

The components of the inclusion method include metal identification bands, computer-printed denture mislabelling systems, lead paper labeling, embedding patient photos in dentures, denture barcoding, T bars, laser etching, lenticular card systems, radiographic identification tags, and electronic microchips.

Compared to surface markings, this technique yields more consistent results and lasts longer.[21]

Tongue prints: Similar to fingerprints, each person's dorsal tongue surface is morphologically distinct. For this method to work, the ante-mortem records must be accessible.

In forensic dentistry, the lingual impression and associated photographic recordings provide a safe means of identification.[22,23] The following methods can be used to record tongue prints:

1. Visual identification to examine the tongue's fundamental qualities, including color, surface texture, motility, and any additional unique traits.
2. Cast preparation after alginate impression
3. Using computer software to acquire digital pictures of the tongue.
4. Sublingual vein analysis
5. Histological examination [24]

AMELOGLYPHICS:

Ameloglyphics is the study of enamel patterns. Since the enamel rod pattern varies by gender and is unique to each person, it can help with human identification.

It also helps in age estismtion ,bite mark analysis ,victim and suspect linkage.It is useful when DNA or fingerprints are unavailable.

It can be applied to both living individuals and deceased bodies.

Enamel rod patterns can be visualized using acid etching, scanning electron microscopy(SEM), or polarized light microscopy .

It requires high magnification tools for clear pattern visualization.

After examining the enamel pattern of the left maxillary canine and first premolar in 30 male and 30 female volunteers using the cellulose acetate peel technique, Manjunath et al. came to the conclusion that the branched wavy sub pattern was the most prevalent kind by visual inspection.[1]

CONCLUSION

A variety of methods for identification, investigation, and analysis are now available in forensic dentistry, which has greatly advanced. Advances in DNA analysis,digital radiography,facial reconstruction and saliva analysis have enhanced this field’s capabalities.

Additionally, forensic specialists might benefit greatly from specialized procedures like denture labeling, rugoscopy, and cheiloscopy and more recently in artifial intelligence.

The use of forensic odontology in crime solving, victim identification, and prosecuting offenders will only increase as technology develops. To support the ongoing growth and efficacy of the discipline, dental professionals must keep thorough and accurate dental records, follow established protocols, and remain current with emerging methods and technologies.

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