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REVIEW

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A review on the advancements in chemical examination of composition of latent fingerprint residues

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Abstract

Background: There are notable developments in the field of DNA analysis and recognition, still fingerprint analysis remains the most preferred approach for obtaining substantial forensic evidences. The identification of individuals through pattern comparison has been used through ages, but it becomes less effective when the pattern is blurred, partial in nature or not found in database. Thus, recent advances in analytical techniques over the last decade will provide additional information to the evidence. In the view of forensic investigations, the compilation of individual chemical profiles with the pattern would enhance the evidentiary value of the latent fingerprints.

Main body: The review has been divided into different parts, describing the various influencing factors which affect the chemical composition of a fingerprint, i.e., lifestyle and occupation, age of an individual, types of substrate on which fingerprint is deposited, environmental conditions, contaminants, and the various advanced instrumental techniques utilized till now in the detection of chemical constituents of fingerprint have been discussed.

Conclusion: The present work aims to enlighten the missing gaps of knowledge in elucidating the detailed chemical composition of fingerprints and highlight the various analytical techniques used till date. Though, there are several analytical techniques employed till date to explicate the constituents of fingerprints, detailed information is still lacking. Therefore, advanced future research is need of the hour for identification of the fingerprints and determining their aging kinetics.

Keywords: Latent fingerprint residue, Component recognition, Chemical imaging, Exogenous substance, Forensic identification

Background

The chemical composition of a fingerprint is a complex mixture of endogenous organic, inorganic compounds and exogenous substances such as cosmetics, food residue, drugs, metabolites, and other contaminants from the environment (Su 2016). The physico-chemical interaction of constituents in finger with the substrate aids in its different visualization and identification techniques. The state of chemical composition of a fingerprint is affected by the metabolism of person and is quite variable as there are numerous influence factors (Girod 2012). The analysis of fingerprint in providing chemical information about the donor's age, ethnicity, gender, lifestyle, and occupation is an important aspect of fingerprint examination. The article aims to furnish updated review of the analytical techniques applied till date in the qualitative and quantitative examination of constituents in the fingerprint residues and the various factors which influence the composition of the residues.

Main text

Fingerprints are quite relevant in the field of forensic science as it is based on the Locard's exchange principle stating that when there is a contact between two objects,

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there is an exchange of trace materials between the two objects. Fingerprint result as a transfer of materials from the papillary ridges of the fingers to the surface during a contact. Latent prints are mainly composed of the human sweat secretion, i.e., apocrine, eccrine mainly and sebum, although other contaminants may be present on the fingers where the prints are deposited, e.g. food residues, cosmetics, skin cells (Ramotowski 2001).

Fingerprints have been proved to be gold standard for the individual identification in crime cases and law enforcement since long. But as the latent prints are invisible in nature, they require enhancement methods for their visualization. The numerous methods include optical, physical, and chemical methods which rely mainly on the components of the fingerprint residue and their physico-chemical interactions. The conventional methods are sometimes ineffective because of presence of complicated surfaces, health hazards, and their destructive nature (Su 2016). Thus, different novel techniques like immunogenic and nucleic acid reagents, nanoparticles, mass spectrometry imaging, spectroscopy and other electrochemistry approaches have been developed for the latent print detection in the recent years (Xu et al. 2014) (Becue A 2012). Through recent researches, it has been established that fingerprint does not provide just an image but additional information as well, when the endogenous and exogenous contaminants like drugs and explosives in the latent print are correctly identified, it could help in connecting the individual to the crime spontaneously (Hazarika and Russell 2012) (Xu et al. 2014).

Factors influencing the chemical constituents of fingerprint residues

Lifestyle and occupation of donor

In daily life, oils are applied on the skin as part of cosmetic which forms a lipid barrier on the surface of skin. The different types of fatty acids, i.e., lauric, oleic, palmitic, stearic, and myristic acids, are mainly used as intermediates in the manufacture of alkali salts, which are later used as emollients and lubricants in a variety of cosmetic creams, pastes, soaps, and cakes (Osol., 1980) Balsam (1972) (Eiermann 1986) (Creenberc 1954) (FDA 1981). The different concentrations of fatty acid in the cosmetic product range from 0.1 to 25%. Stearic acid is mainly found in makeup, shaving, and skin care category of cosmetics. Oleic acid can be mainly found in the eye makeup and hair coloring products. Palmitic, lauric, and myristic acids are contained in skin care, shaving, and non-coloring hair solutions and personal hygiene products. The different types of cosmetic-grade lauric, oleic, myristic, palmitic, and stearic acids occur as mixtures of fatty acids depending on their source and method of manufacture.

The presence of palmitic, stearic, and palmitoleic acid as the most abundant fatty acid was demonstrated and the presence of cosmetics was also detected in the female subject's prints using gas chromatography mass spectroscopy (Darke, D J and Wilson, J D 1979).

The identification of exogenous contaminants in the latent fingerprint is found to provide intelligent information for police investigation, safety control and court cases. In recent studies, MS imaging technique has proved to be successful in detecting explosive compound and gunshot residues in the fingerprint residue, and ion signals were also constructed to determine ridge pattern (Ifa D R 2008) (Forbes and Sisco 2014a) (Szynkowska M I 2010) (Forbes and Sisco 2014b)(Kaplan-Sandquist and LeBeau 2014).

There are many organic molecules identified in the fingerprint residues, such as phenol, urea, lactic acid, choline, urea, creatinine, and uric acid (Williams et al. 2011) (Connatser and Prokes 2010) (Hartzell-Baguley and Hipp 2007). Various drugs and their metabolites, like nicotine and its metabolite cotinine, heroin and its metabolite, cocaine and its metabolite, Δ9-tetrahydrocannabinol, methadone, and its metabolite have been found in the fingerprint residue (Leggett and Lee-Smith 2007) (Demian n.d.) (Ricci and Phiriyavityopas 2007) (Hazarika and Jickells 2010) (Boddis and Russell 2012). The presence of such compounds in the fingerprint residue enables not only its visualization but the collection of information on the personal lifestyle of a donor. It also has a potential for the medical diagnosis as demonstrated by Wolfbeis (OS 2009).

Jacob S, et al. identified the constituents of fingerprints from methadone-maintained opioid-dependent patients by ultra performance liquid chromatography (UPLC) mass Spectrometry. Methadone and its metabolite 2-ethylidene-1, 5 dimethyl-3,3-diphenyl-1-pyrroline (EDDP) were found in the fingerprint. Detection of EDDP in the patients indicated that it was in the form of metabolite and methadone was administered rather than due to external contamination (Jacob et al., 2018). Szynkowska I M. et al., investigated the application of time-of-flight secondary ion mass spectrometer (ToF-SIMS) for imaging and detection of exogenous constituents which are not present naturally on the skin and can be easily associated with a crime scene. The presence of arsenic, nickel, gun-shot residue, amphetamine drugs, etc. in the fingerprint residues on three different types of surfaces, i.e., aluminum, stainless steel, and brass was detected by the researchers, indicating the potential use of TOF-SIMS in the analysis of forensic fingerprinting. The application of chemical imaging aids in identifying suspects habitual in bomb making by identifying traces of bomb-making substances in the residue of the fingerprint.

Drug traces were detected in the residues of fingerprints and also integrated in the metabolism of an individual. In a study, drugs like sulfonamides, L-dimethylamphetamine were identified in the eccrine sweat secretion. Medications and diseases are also seen to influence the constituents of fingerprint residue. In a study, exogenous pharmaceutical contaminant of terbinafine, an antifungal medicine was detected and imaged utilizing SALDI-TOF-MS after developing using carbon black doped silica particles. The presence of traces of medicine in the latent fingerprint residue could provide information about a person's lifestyle and other vital information (Dam and Aalders 2014).

Variation in constituents with the age of donor

The composition of free fatty acid in sebum was found to change significantly with the increasing age of a person. In a 5-day-old newborn the approximate percentage was reported to be 1.5%. In young children of 1 month to 4 years, the value rises significantly to about 20–23%. The value becomes stable to 16–19% for adolescent and post-adolescent subjects (upto 45 years of age). The value of triglyceride was also found to vary significantly. The triglyceride composition is observed to be 52% of their sebum. In infants of 1 month to 2 years of age, the value reduced significantly to 38%. Consequently, the value was found to peak at 50% in young children of 2–4 years and then slowly decreased to 41% in post-adolescent subjects. The sebum wax ester is found to be 26.7% in newborns. The value begins to decrease in infants to 17.6% and continues to decrease between the ages of 4 to 8 years to value of 6.9%. The value then begins to rise to 17.8% in preadolescence and increases to 25% till 45 years of age. In preadolescence the value begins to increase to 17.8% and continues to rise to a value of 25% upto 45 years of age. The cholesterol level in sebum peaks to 7.2% in pre-adolescence. Newborns were reported to have 2.5% cholesterol in the sebum, whereas post-adolescence had the lowest value of 1.4%. Cholesterol ester composition tended to vary in 2.5%. Squalene composition is found to vary with the age of a donor, though it is not very significant. The squalene composition is found to be 9.9% in newborns and reaches to 6.2% in children aged 2–4 years. The concentration begins to slowly rise to 7.7% in children aged 4 years and is found to peak in post-adolescence to a value of 12% (Ramasastry 1970).

It is known that the chemical constituents of fingerprints depends on advancing age and is highly diverse between that of children and adults. In a study it was determined that the fingerprint composition from children was found to contain higher quantity of volatile unesterified free fatty acids while adults were found to contain higher quantity of less volatile fatty acids by using GC-MS (Girod 2012). Hemmila et al. investigated the use of FTIR reflectance spectra in combination with partial least square regression method the relationship between the constituents of the prints and age, with a substantial change around puberty (Hemmila 2008). Thus, the technique could be successfully utilized to determine the age of criminals who left a print and no other information is known.

Types of substrates

The type of substrate should be correctly identified for the successful development of latent fingerprint. The substrates could be separated into three classes mainly: porous, semi-porous, and non-porous.

Porous

The porous substrates are mostly adsorbent in nature and include materials like cardboard, wood, paper, and different types of cellulose. Fingerprints deposited on these types of substrates gets absorbed and are somewhat resilient. The amino acid technique can be utilized in this process, because the amino acids remain stationary when absorbed (Almog 2001).

Semi-porous

Semi-porous surfaces can be characterized by their character to absorb as well as resist fingerprint residue. The fingerprint residue may or may not get absorbed onto the substrate which includes glossy magazine covers, finished wood, glossy cardboard, and some cellophane (Yamashita n.d.).

Non-porous

These types of surfaces do not absorb. The various type of surface repels moisture and is polished in nature. The surfaces include glass, metals, plastic, aluminum cans, ceramic mugs, and painted wood on which the fingerprint development method of powder technique could be applied along with dye stains, cyanoacrylate, and vacuum metal deposition (Yamashita n.d.).

In a study conducted by Oak Ridge National Laboratory to study fingerprint residues, it was analyzed that children's fingerprint on non-porous surface did not remain for more than a few days (Noble 1995, Noble 1997). In some crime scenes, latent fingerprints on multicolored and patterned substrates may prove to be difficult to develop, so the use of gel-lifters or further enhancement methods in a laboratory was required. Ricci et al. obtained the IR chemical imaging of latent fingermarks lifted with the adhesive tapes from different surfaces (Peng and Q. W. 2015). Emmons et al. utilized the technique of automated background subtraction algorithm to substantiate the interference from the background for the detection of trace amounts of explosive contaminants in trace quantities in the fingerprint residues; thus, it may be possible to detect explosives and similar contaminants on most surfaces (Goode and M. J. 1983; Emmons et al. 2009).

Risoluti et al. developed a novel technique to investigate the efficacy of Lumicyano as a "one-step" treatment instead of cyanoacrylate/BY40 in the detection of fingerprint. The prints of sebaceous and eccrine nature, aged and fresh, and deposited on different non-porous surfaces were analyzed in the study. This technique was also capable in extracting the genetic profile from the same finger mark without affecting the nature of DNA (Risoluti and F. V. 2019).

The development of latent prints depends on the types of surfaces on which they are found. For such surfaces, the conventional methods of latent print detection become ineffective. The enhancement procedures for such prints can be categorized into (1) use of physical methods such as small particle reagent method, vacuum metal deposition method, (2) use of chemical reagents utilizing 1,2-indanedione, ninhydrin, 1,8 diazafluoren-9-one (DFO), and genipin method, (3) optical and spectroscopic method, and (4) combination of spectroscopic and chemical technique (Risoluti and F. V. 2019).

Alessandrini F, et al. investigated the influence of individual and exogenous factors on the amount of DNA recovered from different substrates of metal, wood, and glass and the aptness of DNA obtained from fingerprints for forensic identification. The amount of DNA recovered was between 0.04 and 0.2 ng. The amount of DNA was reduced significantly because of hand washing prior to taking fingerprint. Secondary transfer contaminants, stutters, spurious alleles, and other artifacts were observed to affect correct DNA profiles (Alessandrini et al. 2003)

Worley G C, et al. investigated the spatial elemental imaging characteristic of Micro-X-ray Fluorescence to acquire elemental spectra and directly image both visible and latent fingerprint by the aid of inorganic elements present in the fingerprint residue. The eccrine and sebaceous prints were identified by the presence of potassium and chloride elements. The prints covered in lotion, saliva, banana, and sunscreen were also detected indicating the potential of MXRF in visualizing fingerprints on varied surfaces that are sometimes problematic using other analytical methods (Worley et al. 2006).

Environmental conditions

Blasdell in his study noted that the fingerprint of a child disappeared sooner than that of adult as they have a large amount of volatile esters. The level of cholesterol in children was found to be higher in children (Blasdell 2001). In a study conducted at ORNL, the presence of nicotine was detected in the fingerprint samples of an adult. It was initially thought as environmental contamination by handling of tobacco products but analysis of samples indicated that the individual had quit smoking sometime ago. Williams et al. studied children's fingerprint as a function of temperature and time by utilizing FTIR microspectroscopy and concluded that due to thermal stability, the salts in the residue of fingerprint were more stable than the esters. Thus, it could be easily located and measured with respect to time (Williams et al. 2011).

In a study through Fourier transform infrared spectroscopy (FTIR) analysis, it was demonstrated that in higher temperatures of environment, the degradation of ester and urea occurred rapidly. (Ricci and Bleay 2007). Rise in temperature of the environment was also found to have a significant impact on the amino acid in the fingerprint residue (De Paoli 2010).

Miscellaneous contaminants

The contaminants from environment are also identified in the analysis of fingerprint residues. In such cases, caution should be practiced to determine whether the compound is an external contaminant or obtained from endogenous source. There can be sometimes overlaying between the compounds which are present in the extraneous substance and that of endogenous nature, which leads to overestimation of quantity of the compounds. Cosmetics, hair products, perfumes, body and face creams are some commonly recognized contaminants. Odorology is a technique which can be utilized to extract and investigate the human scent and establish the connection between the object/subject or if the suspect has handled an object (Pomara et al. 2015; Maglietta et al. 2017; Sessa et al. 2018; Ferrara et al. 2019; De Simone et al. 2019). This application could be utilized to link a culprit to scene of crime. Moreover, it could also aid in investigation of identity of missing persons.

Instrumental techniques

Mass spectrometry

It is the most prevalent method for obtaining information about the elemental composition of samples including their molecular structure, qualitative, and quantitative composition of complex mixtures, the composition and structure of isotopic properties of atoms in samples (We Q et al. 2016). It is an analytical technique in which the atoms are separated, ionized according to their m/z ratio. The major MS techniques which have been applied for the fingerprint analysis are matrix-assisted desorption ionization mass spectroscopy (MALDI-MS), laser desorption ionization mass spectroscopy (LDI-MS, electron impact mass spectroscopy (EI-MS), and surface-assisted laser desorption ionization mass spectroscopy (SALDI-MS). These were mainly utilized to study the aging and degradation of fingerprints, use of nanoparticles in the enhancement, development of their chemical profiles and development of new MALDI matrices (Gonzales, M., 2020).

Gas chromatography mass spectrometry

In contrast to other mass spectrometric technique, separation is carried out in gas chromatography and liquid chromatography only, as it is quite laborious. Many steps are required for the preparation of sample, to develop and optimize a method. Moreover, they require expensive inputs and apparatus, but they have been well established as a standard in the forensic analysis of evidences, namely ink, soil, paint, fingerprints and others.

Archer E N, et al. studied the chemical changes in lipid component of a fingerprint over time by aid of GCMS. Tetradecanoic acid, palmitoleic acid, oleic acid, squalene, and cholesterol were observed to vary at different levels. The loss of squalene was noted at a reduced rate in the prints stored in the dark (detected even after 33 days) than in the prints stored in the light (not detected after 9 days of storage) (Archer et al. 2004).

Michalski S, et al. identified possible fatty acids, which aid in the profiling of an individual. By the aid of GC–MS, individuals of different gender and races were classified on the basis of varying ratios of fatty acid methyl esters. Moreover, the intravariability and intervariability of some compounds were recorded to be high, suggesting the possibility to individualize on the basis of chemical profile. Two-dimensional GC proved to be beneficial due to its ability to separate complex organic mixtures based upon classes of compounds present (Michalski et al. 2013).

Cadd J S, et al. investigated differences between the extraction and separation methods of fatty compounds from fingerprints to obtain a range of sebaceous substances. Sebaceous and eccrine prints were considered, and seven solvent systems previously used in literature were explored to determine their extraction efficiency. The outcome recommended the use of MeOH/TMSCl for the derivatization of fatty acids followed by the use of $CHCl_3$ for the extraction of squalene, cholesterol, FAMEs, and wax esters (Cadd et al. 2015).

Shi Jun-Wen, et al. employed the use of air-flow assisted desorption electrospray ionization mass spectrometry imaging in four kinds of fingerprints, i.e., sweat, inked, sunscreen, and foundation, for the analysis of constituents of fingerprint and for obtaining its high-resolution image. The overlapped fingerprints were distinguished in accordance with the chemical information obtained in the results (Jun Wen et al. 2019).

Matrix-assisted laser desorption ionization–mass spectroscopy imaging and laser desorption ionization

MALDI-MS is a particular technique which is highly efficient in the detection of high molecular weight molecules (Schriemer and L. L. 1996). It utilizes a matrix to aid in the ionization and desorption of laser desorption imaging which increases the yield of analyte ions. Thus, with increased ion yield better structural information about the object of interest could be identified. It has been widely used till now for the detection of endogenous lipids in sebaceous and eccrine prints thus demonstrating the sensitivity of the instrument in analyzing the object of interest in trace quantities (Wolstenholme 2009).

Wolstenholme R, et al. employed MALDI-MSI for the imaging of endogenous lipids obtained from ungroomed and groomed prints. Oleic acid was used as a part of the methodology and was detected along with its degraded products after a passage of 7 days, at different temperatures. The imaging of fingerprint samples was then performed. The fingerprint's pattern was confirmed by analyzing the m/z values of degraded products of oleic acid which enabled the distinction of the different fingerprints (Wolstenholme 2009).

Lauzon N, et al. investigated the use of MALDI and LDI IMS for detection of chemical constituents in the finger print. Polymeric substances such as polyethylene glycol and polypropylene glycol found in hand lotions were observed on the ungroomed fingerprint. For IMS analyses, the fingerprint motif was observed on paper after silver deposition, and numerous compounds of squalene, wax esters, fatty acids, DAGs, and TAGs were detected. The use of 2-MBT was found to be most suitable matrix for IMS of constituents from latent fingerprint (Lauzon et al. 2015).

Groeneveld G, et al. employed different variants of MALDI MS technique for the detection and mapping of drugs of abuse and their metabolites in fingerprints with and without prior development with cyanoacrylate fuming or by the technique of vacuum metal deposition. Seventeen compounds were selected from five different classes of drug: amphetamines, alkaloids, opioids, cannabinoids, and designer drugs. VMD treatment was found to be more capable than cyanoacrylate fuming and the quality of ridge pattern was found to be strongly molecule dependent (Groeneveld et al. 2015).

Time-of-flight secondary ion mass spectrometer

It is a surface sensitive analytical technique which utilizes a pulsed ion beam for the removal of molecules from the outermost shell of the sample. It is applied in forensic science for the visualization, characterization, and analysis of fingerprints left after their contamination by traces of drugs, cosmetics, and other such surface contaminants (Szynkowska et al. 2009).

Rowell F, et al. investigated the use of hydrophobic silica dusting agent containing carbon black as a matrix to detect illicit drugs and contact residues using SALDI-TOF-MS in positive ion reflectron mode. The dusting agent produced developed marks for visualizing the prints while acting as a SALDI-TOF MS enhancer that was equivalent to the standard matrix enhancer 2,3-dihydroxybenzoic acid (DHB). Analysis was performed by direct MS of the pre-dusted fingerprints on the surface of a target plate and, lifted using commercial tape. The presence of the parent drug and its metabolites was confirmed as characteristic and unique fragmentation patterns were observed in each case (Rowell et al., 2009).

Hinder J S and Watts F J demonstrated the use of ToF-SIMS in the analysis of latent fingerprints with a view of forensic and biomedical applications (Hinder and Watts 2010). Szynkowska, et al. demonstrated that SIMS could be employed to produce images of whole fingerprints on inorganic surfaces such as steel, brass and glass. The detection of various exogenous substances, i.e., industrial lubricants, personal care products and pharmaceuticals on different organic surfaces was confirmed. SIMS images, even at low resolution was able to differentiate regions of underlying substrate materials and that of latent fingerprint. Fingerprint images acquired by SIMS imaging were capable of visualizing the minutiae associated with fingerprints in high resolution (Szynkowska et al. 2010).

Vibrational spectroscopy imaging

Fourier transform infrared spectroscopy

The vibrational spectroscopic imaging is another important technique for the reconstruction of latent fingerprints by generating the chemical contrast using the spectroscopic signatures identified in the fingerprint deposits. The previous studies have successfully detected the presence of latent prints on various surfaces using the infrared technique, the reconstructed images of the print were of sebaceous and eccrine residues which could also be used as an evidence (Williams and S. R. 2004)(Crane and B. G. 2007)(Ricci and Bleay 2007).

Ricci C, et al. investigated the combination of ATR-FTIR imaging with tape-lifting for the examination of fingerprint of an individual after the handling of illicit drugs. The variation in the distribution of amino acids and lipids were also identified using this approach. Crane J N, et al. utilized FTIR technique to obtain the detailed image of unprocessed groomed latent fingerprint on various substrates. In addition, the trace components present on various substrates were also preserved (Crane et al. 2007).

Tantouh M, et al. employed the use of FTIR in imaging fingerprints on different surfaces. Separate methodologies were employed in each surface for obtaining better quality of final fingerprint image. It was detected that FTIR gave high-quality images of cyanoacrylate fumed fingerprints on various substrates (Tantouh et al. 2007). Chen T, et al. investigated the use of infrared chemical images which indicated the presence of explosive, RDX mixed with natural secretions even in overlapped fingerprints (Chen et al. 2009). Ng Ronnie Hei Ping, et al. investigated the combined application of FTIR and Raman for imaging latent fingerprints. Spectral searching algorithms were tested for the detection of targeted substances in fingerprint out of which Spectral Angle Mapper correlational algorithms gave the best results. A total of 42 inferior quality spectra were observed and later characterized from the images of latent prints uncontaminated in nature. Aspirin, diazepam, and explosives deposited on the contaminated fingerprints were also detected Ng Ronnie et al. 2009.

Antoine M K, et al. compared the groomed fingerprint samples of father and son pair over a passage of 4 week using FTIRM. At the end of study, significant compositional differences were obtained between the respective prints. Thus, the study confirmed the use of FTIR spectrum for the determination of age of person using compositional difference (Antoine et al. 2010). Banas A, et al. employed FTIR to determine the ability of adhesive tapes to transfer exogenous substances together with fingerprint marks. The contaminated fingerprints were prepared using explosives and non-controlled substances like sugar and aspirin on different substrates. The prints were treated with gray, white, and black powders and underwent FTIR analysis. It was concluded that the time taken to identify the exogenous substances in fingerprint was increased because of presence of other contaminants (Banas et al. 2014).

Raman spectroscopy

It is a non-destructive chemical technique used to obtain detailed information regarding the chemical structure, polymorphy, phase, crystallinity, and their molecular interactions. Raman spectroscopy is a useful technique in the analysis of latent fingerprints as it allows the non-destructive analysis of the print and the subsequent identification (Daya and H. G. 2004)

Widjaja E, investigated the integrated results of Raman spectral mapping, tape-lift, and multivariate BTEM, to derive chemical information of latent fingerprints along with trace materials. Three model cases were developed, i.e., sebum-rich fingerprint obtained after touching forehead, drug model consisting of L-arginine, ibuprofen, and sodium bicarbonate; and additive model comprising of sucrose and aspartame. By the employment of advanced multivariate data analysis technique, pure component spectra of both lifting media and trace materials were achieved. The quality of pure component spectral reconstructions of the three cases was very high (Widjaja 2009). The results were achieved by the integration of tape-lift method and Raman spectroscopic imaging with effective multivariate curve resolution method. Emmons, et al. demonstrated in his study that explosives could be detected in contaminated fingerprints using bright field Raman imaging and Pearson's cosine cross- correlation analysis of the specific region of range $550\,cm^{-1}$ to $1850\,cm^{-1}$ (Emmons et al. 2009).

Immunogenic and nucleic acid reagents

Aptamers can be termed as oligonucleotide or peptide molecules which bind to specific target molecule. Aptamers when form a specific and stable three dimensional structure can easily bind a large number of targets (Stoltenburg and R. C. 2007). The aptamers are said to highly specific shown by the aptamer-target binding complexes which have been found to be in higher quantities than antigen-antibody complex (Yang and Y. D. 2007).

Russel, et al. demonstrated that a smoker's fingerprint can be examined by the combination of gold nanoparticles with the antibodies which were specific to cotinine and secondary antibody tagged with a dye. Fluorescence images revealed the minute second and third level details indicating simultaneous detection of chemical composition along with the physical features (Leggett and Lee-Smith 2007). Later in the study, Russel et al. further documented that by utilizing magnetic particles tagged with anti-cotinine antibodies to image the cotinine present in the latent fingerprints of smokers and concluded that the probable identity of an individual could be established within 15 min (Hazarika and Jickells 2010).

In a study, the use of gold NPs in conjugation with anti-L-amino acid antibodies was demonstrated for the visualization of latent fingerprints, particularly aged and degraded ones on non-porous surfaces (Spindler et al. 2011). Xu L R, et al. demonstrated the presence of epidermal growth, lysozyme, and dermicidin in the print residue. Through this study not only the ridge patterns but also the chemical constituents of the fingerprints were obtained effectively. Xiang Rang, et al. investigated nucleic acid controlled AgNCs platform for the visualization of latent fingerprints. Multi-color images for visualization of fingerprint pattern and the chemical constituents of fingerprints were obtained. Emission modulating region and aptamers region provide a simultaneous identification of multiple components (Rang et al. 2015).

Conclusions

Although fingerprints have been in use as evidence in forensic science for more than hundred years, developments in its research continue. Further advancements in the identification of the chemical constituents are still in progress, as an interest is rapidly growing among researchers to discern the chemistry behind the fingerprints. The analysis of fingerprints in providing chemical information about the donor's age, ethnicity, gender, lifestyle, and occupation is an important aspect of fingerprint examination. Detailed information is required to study the effects of influence factors on the fingerprint's constituent in order to determine the reaction mechanism for the analytical techniques.

Through this article an attempt has been made to furnish updated review of the analytical techniques applied till date in the quantitative and qualitative examination of constituents in the fingerprint residues. Though, there are several analytical techniques employed till date to explicate the constituents of fingerprints, detailed information is still lacking. Therefore, advanced future research is need of the hour for identification of the fingerprints and determining their aging kinetics.

Abbreviations

MeOH/TMSCl: Methanol/trimethylsilyl chloride; RDX: Research Development Explosive; FTIRM: Fourier transform infrared spectroscopy microscopy; BTEM: Band target entropy minimization; UCNP: Upconversion nano particle; CBA: Cocaine binding aptamers.

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Authors' contributions

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