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# Comparative Study between Variable Computer Printed Documents to Identify the Type of the Producing Output Devices

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## Abstract

**Background:** Within the last years, forgery has markedly increased and expanded to encompass computers and printers' usage, their wide evolution facilitated the production of fraudulent printed documents by even non-experts. The printers and photocopiers leave their imprints on the produced documents. Examination of printed output of a questioned document is essential as it provides information about the producing device.

This study aims to compare the characteristics of different computer printed documents to identify the type of the producing output devices (photocopier, inkjet, and laser printers).

**Methods:** 132 documents were typed and printed using different models of inkjet, laser printers and photocopiers. The produced documents were examined with direct light digital microscope and ultraviolet light and the printed markings were compared.

**Conclusion:** Our results revealed that each class of the studied printing devices induced specific criteria on the examined printed documents. These criteria are class characteristics but differ from one type of device to another.

**Keywords:** *Forgery, inkjet printers, laser printers, photocopiers, questioned printed document.*

## Introduction

Documents are any material containing marks or signs that convey message to someone. Therefore,

adding, deleting information on it or replacing an entire page is considered forgery<sup>(1)</sup>. Forensic examination of these questioned documents to determine their genuineness is considered a critical and legal issue<sup>(6)</sup>.

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The examination of the printed matter in questioned documents can provide information about its authenticity and genuineness. It also provides clues for several criminal cases and sources of secure documents leak age<sup>(3)</sup>.

The examination of photocopied, laser and inkjet-printed documents provides unique characteristics corresponding to their operating mechanisms. These imprints produced by these devices are the main evidence in examining printed document<sup>(14)</sup>.

The present study aims to compare the characteristics of different computer-printed documents to identify the type of the producing output devices (photocopier, inkjet, and laser printers).

## Materials and Methods

### Study design and setting:

This is a comparative cross-sectional study conducted at Forensic Medicine and Clinical Toxicology Department, Faculty of Medicine, Ain Shams University.

### Materials:

§ Printing medium: white blank paper (80 GSM, Allam Premium, size A4, 210 X 297mm)

§ Documents were typed using the same computer (Toshiba, Microsoft Office version 2007).

§ Four models of inkjet printers (IJ) were used and labeled:

(i) IJ1: HP Deskjet, ink advantage 2135.

(ii) IJ2: Brother T300.

(iii) IJ3: HP Officejet 4500.

(iv) IJ4: Brother 1100.

§ Four models of laser printers (L) were used and labeled:

(i) L1: Xerox, 5024.

(ii) L2: Ricoh, Aficio, SP C430DN.

(iii) L3: HP 5000N.

(iv) L4: Samsung, ML-1865W.

§ Four models of photocopiers (PC) were used and labelled:

(i) PC1: Xerox 5645.

(ii) PC2: Ricoh, Pro907EX.

(iii) PC3: Ricoh, Pro1107EX.

(iv) PC4: Gestetner, Aficio, MP1100.

§ All printed documents were examined with:

- Paper Thickness Measuring Device, Mitutoyo 7360 Dial Thickness 0-10mm, Japan.

- USB Powered 50-500X Digital Microscope, China.

- Ultraviolet (UV) lamp 365 Mila T5 Electronic Fixture, China.

Samples:

· 132 sample documents were typed on Arabic language. Font used is "Black Simplified Arabic", size "16".

· *The samples were subdivided into 3 subgroups: Subgroup (IJ), (L) and (PC):* 44 samples were collected from every group, 11 samples were collected from each of the chosen models.

· The printed markings were examined and compared with that produced by their same group or other groups.

· **Exclusion criteria:**

- Paper of different type than the selected.

- Documents typed in fonts, sizes, colors, or languages different from the selected.

- Different devices' models other than the selected.

**Methods:**

1) Documents were examined by the Paper Thickness Measuring Device to get the mean thickness of letters as follows:

(i) Measuring the thickness of the studied document at 4 unprinted areas, and 4 printed areas then their mean thickness (in  $\mu\text{m}$ ) was calculated.

(ii) Difference between the mean thickness of printed and unprinted areas was calculated to get the mean thickness of letters (in  $\mu\text{m}$ ).

2) Documents and printed markings were magnified and examined by digital microscope and ultraviolet rays to compare between their characteristic features: brightness, homogeneity, and edges of the printed markings. Scattering of ink or toner, effect of folding and scratching of the paper over the printed markings.

Statistical analysis:

The data was collected, tabulated, and statistically analyzed where:

- Qualitative variables were expressed as percentages.
- Excel computer program was used to tabulate the results of paper thickness and calculate their means.
- Mean and standard deviation were used for description of the variables.
- Analysis of variance (ANOVA) was used to detect and confirm the significant difference between the quantitative variables (mean thickness of papers) for the tested groups.

**Ethical consideration:** This study was conducted after getting approval of the ethical committee of Faculty of Medicine, Ain Shams University, code

number (FWA000017585).

**Results and Discussion**

The current study showed that documents produced by different models of the same type of printing devices either (inkjet, laser, or photocopier) displayed no significant difference when the studied printed markings' characteristic were compared. On the other hand, this research suggested that each class of the chosen printing devices induced specific criteria that can be identified over the examined documents as class characteristics which differ from one type of device to the other.

*The general criteria induced by different types of the studied printers (Inkjet, laser, and photocopier) over the documents examined by UV rays and direct light digital microscope* revealed that inkjet-printed markings were dull, not homogenous, with hairy-like, ill-defined edges as shown in figures (1) and (4). Laser-printed markings were bright, homogenous, with sharp and well-defined edges as shown in figure (2). Photocopied markings were moderately bright, moderately homogenous, with slightly sharp edges as shown in figure (3). These results are shown in table (1).

**The dullness of the inkjet-printed marking** can be attributed to the chemical composition of the inkjet's ink which is composed of coloring substances dissolved in solvents<sup>(10)</sup>. According to *Shang et al.*<sup>(14)</sup>, the inkjet-printed markings were dull and non-glossy.

**The bright glossy appearance of laser-printed markings** can be related to the chemical composition of the laser's toner which contains different components like polymers, dyes, surfactants, and wax<sup>(15)</sup>. The toner particles become permanently fixed onto the paper surface when it travels between a fuser and a pressure roller. The polymers and wax are melted by pressure and heat then sprayed on the paper producing images with a shiny surface<sup>(7)</sup>. The

studies of *Noronha et al.*<sup>(8)</sup> reported that laser-printed markings are glossy, homogenous, with well-defined edges.

**The non-homogeneity of the inkjet-printed markings** can be referred to the mechanism operating inkjet printers as well as ink's liquid nature. Upon computer instructions the ink is jetted in the form of tiny liquid dots from the printer's nozzles over the paper<sup>(17)</sup>. Both viscosity and surface tension of the liquid ink determine drop's behavior on the paper substrate. Viscosity in all cases reduces dot area, liquid penetration, and dot surface coverage; leading to breaking of the ink stream into droplets with tiny spaces between<sup>(4)</sup>. *Noronha et al.*<sup>(8)</sup> found lack of uniformity of inkjet-printed markings and the ink was not consistent throughout the letter.

**The hairy like ill-defined edges of the inkjet-printed markings with scattered ink around them** could be referred to the printing-head that emit tiny ink droplets onto the printing paper. As the paper is drawn through the printer, the print-head moves back and forth horizontally and sprays the ink directly, leading to irregularities of the markings' edges with scattering of ink around them<sup>(13)</sup>. At the same time there was scattered ink around these inkjet-printed markings. *Shang et al.*<sup>(14)</sup> found tails or satellites of dropped ink near the inkjet-printed markings, and their contours were rough with ups and downs. *Noronha et al.*<sup>(8)</sup> observed that letters' edges in inkjet-printed documents were rough and looked degraded upon magnification, with apparent smudging in the background. *Krainer et al.*<sup>(4)</sup> found that inkjet-printed markings were asymmetrical with unrealistic drop spreading.

**Concurrently, the homogenous, sharp, well-defined appearance of edges of laser-printed markings** can be explained by the processing technique of laser printers. The computer sends a vast stream of electronic data to the laser printer;

this data carries the figures to be printed. Then a laser beam scans the optical photoconductor drum inside the printer to draw the image of the page and discharges specific locations on the drum, which attract toner particles the toner will be attracted to specific locations on the paper carrying opposite charge. Next, the paper with the toner particles on it passes through the fuser to be fixed. This makes the electronic devices in a laser printer accurately transfer the image signal corresponding to the document. As a result, the printed characters will have clear contours with regular and well-defined edges<sup>(18)</sup>. *O'Connell*<sup>(9)</sup> related the regularity of edges to the physical state of the toner as it is a solid fine powder. The physical properties of solids, with closely packed molecules fixed in position, dominate the behavior of the toner leading to its regular definite shape. *Schulze et al.*<sup>(13)</sup> recorded that laser-printed letters typically show sharp contours, regular edges with homogeneity of markings. *Shang et al.*<sup>(14)</sup> confirmed that the laser-printed words have clear contour with regular edges and higher printing quality. Furthermore, *Noronha et al.*<sup>(8)</sup> observed that letters' boundaries in laser-printed samples are sharp and significantly refined. The toner deposition in the letters was uniform giving them smooth borders with a considerable thickness and higher resolution.

*Additionally, to the previous results, examination of photocopied markings* revealed that they were moderately bright and moderately homogenous with slightly sharp edges. *Schulze et al.*<sup>(13)</sup> confirmed that it is very challenging to distinguish between laser-printed and photocopied documents as both devices use indirect electrostatic digital imaging to transfer the printing substrate. However, the present study noticed deterioration in quality of photocopied characters in comparison to those printed by laser. This can be explained by two factors. **First**, is how the image is formed on a photosensitive drum: A copier uses a bright light and lens to focus the image of the

original document onto the drum. So, any dimness of light, scratch, or dirtiness over the lens causes reduction of the photocopied markings' brightness and haziness of their edges. While laser printer uses a low power sharply focused laser beam to scan one line on the drum resulting in sharp bright markings. **Second factor** is the developer material (powdered iron) which are attracted by a magnet, if it is of low-quality cheap material, it will produce less bright characters<sup>(15)</sup>. *Shang et al.*<sup>(14)</sup> observed that toner used in photocopied documents has glossy appearance and the letters had clearer contour than the inkjet-printed characters but had less clear contour than that printed by laser printer.

**Scattering of toner on the front of the paper despite its absence around laser-printed markings was due to the incomplete removal of the toner** that must be swept using an electrically neutral soft plastic blade that scrapes it off the photosensitive drum into a debris hopper. When this process is not completed, a small portion of the toner' particles remain on the drum surface and are transferred to the paper and form "trash marks" the next time that the printer is used<sup>(16)</sup>.

**Scattering of toner on the front and back of plain paper, and its absence around photocopied markings** may occur due to the lack of commercial, cheap machines to the 'drum blade' which scrapes residual used toner from the drum, resulting in its precipitation over the drum' surface that gave rise to impressions of residual toner scattered as spots over the paper<sup>(5)</sup>. *Saroa and Saini*<sup>(12)</sup> found that the toner of photocopiers was scattered around the photocopied markings.

Furthermore, folding and scratching had no effect on inkjet-printed markings as shown in figure (1), on opposite to photocopied and laser-printed markings which were broken, removed, and disrupted by folding and scratching, as shown in figures (2) and (3). These results are displayed in table (1). The

mean thickness of letters in documents produced by the different studied printing devices was compared using ANOVA one-way statistical analysis, it showed significant difference between the letters' thickness of computer-typed documents produced by different devices (printers and photocopiers) with a degree of probability of ( $P < 0.05$ ) as shown in table (2).

**The non-disruption of the inkjet-printed marking** scan be explained by the interrelation between the ink's liquid nature and the paper texture. The projected ink droplets over the paper surface spread and absorbed upon their impact. The complex arrangement of the paper fibers as a network of layers over each other forms a complex porous media with a 3D network of pores. When the ink is injected, it is entangled in between these pores then completely absorbed and stained the paper tissues. So, it cannot be removed either by folding or scratching<sup>(2)</sup>. Concurrently, the injected ink was embedded and absorbed by capillarity leading to slight displacement and separation of the fibers' molecules with slight increase in the intermolecular space which will give relative increase in the paper thickness<sup>(11)</sup>.

**Folding or scratching the paper over laser-printed and photocopied markings resulted into their breaking and disruption. Furthermore, their mean thickness was found to be significantly higher than the unprinted areas.** These phenomena resulted due to the physio-chemical properties of the toner used in these machines<sup>(15)</sup>. During the printing process, toner is bonded to the paper by the principle of attraction of opposite charges. Then, it is fused to it by the effect of heat and pressure forming a layer of blocks that increase the thickness of the printed areas<sup>(5)</sup>. This also facilitated the removal and disruption of the conjoined toner upon folding or scratching of the printed papers<sup>(18, 19)</sup>.

**Table (1): Comparison between the general criteria induced by different types of the studied printers (Inkjet, laser, and photocopier) on the produced computer typed documents Samples were examined by UV rays and direct light digital microscope(N= 132 samples).**

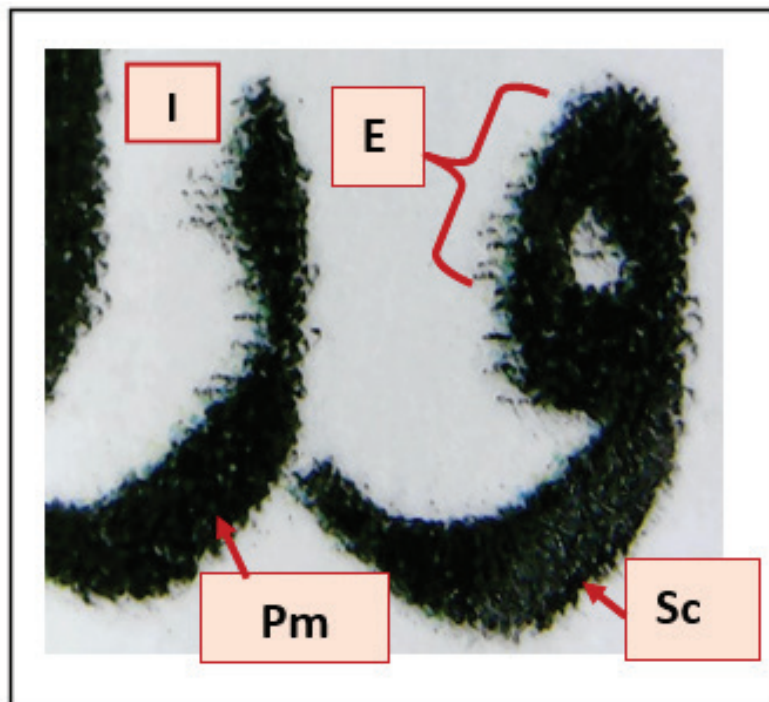
Examined criteria over the different printed markings	Inkjet printers		Laser printers		Photocopiers	
	Criteria	%	Criteria	%	Criteria	%
Brightness	dull	100	bright	100	moderately bright	100
Homogeneity	not homogenous	100	homogenous	100	moderately homogenous	100
Edges	hairy-like & ill defined	100	sharp & well defined	100	slightly sharp	100
Ink or toner scattered on the paper	absent	100	present on the front	100	present on the front& the back	100
Ink or toner scattered around printed markings	present	100	absent	100	absent	100
Effect of paper folding	no effect	100	printed markings broke	100	photocopied markingsbroke	100
Effect of scratching	no effect	100	printed markings removed & disrupted	100	photocopied markingsremoved & disrupted	100

**Table (2): ANOVA one-way statistical analysis for comparison of the measured mean thickness of letters of computer typed documents produced by the studied printers (Inkjet, laser, and photocopier) Samples were examined by the Paper Thickness Measuring Device(N= 132 samples).**

Mean thickness of letters in (µm)	Inkjet	Laser	Photocopier
Mean ± SD	4.926 ± 0.3811	17.14 ± 0.4124	10.82 ± 0.1852
P F	<0.0001 (S) 1280		

**SD= standard deviation S= Significant P = probabilityFc means calculated variance ratio**

The following figures show photomicrographs displaying the criteria induced by the printer devices on the computer-typed documents. Samples were examined by UV rays and direct illumination of digital microscope. (Mic.Mag 125X).



**Figure (1): photomicrograph of document produced from an inkjet printer showing:E: edges of inkjet-printed markings are hairy-like & ill-defined, Pm:inkjet-printed markings are dull and not homogenous, I:ink is scattered around the inkjet-printed markings and Sc:scratching or folding the paper over the inkjet-printed markingshadno effect on it.**

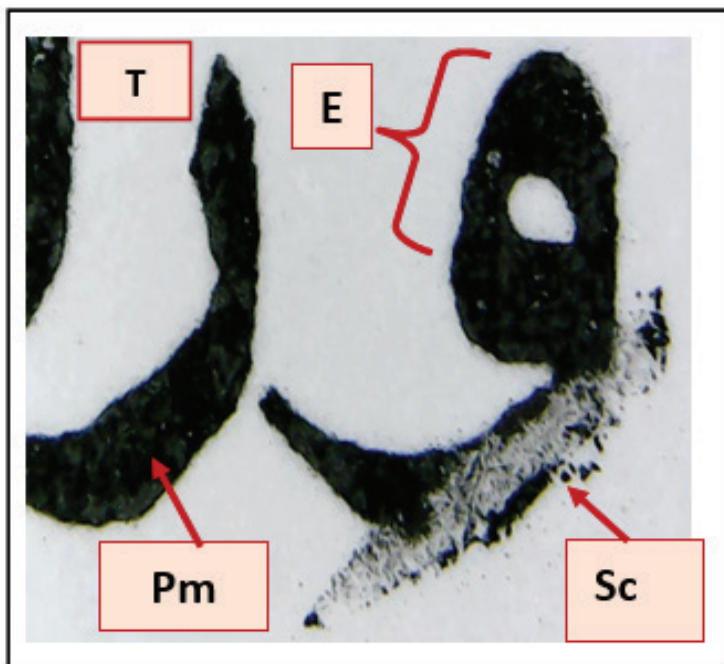


Figure (2): photomicrograph of document produced from a laser printer showing: E: edges of laser-printed markings are sharp and well-defined, Pm: laser-printed markings are bright and homogenous, T: toner is absent around laser-printed markings and Sc: scratching or folding the paper over the laser-printed markings induced its disruption.

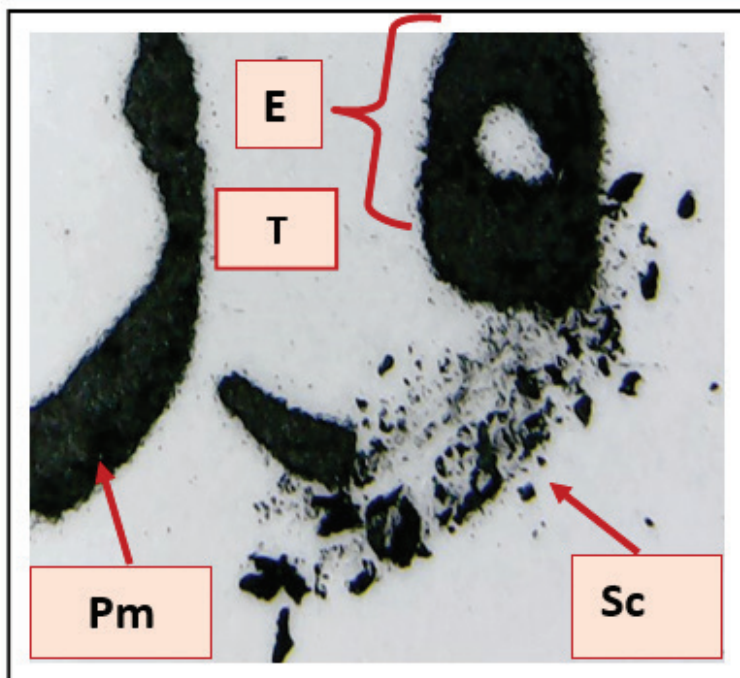
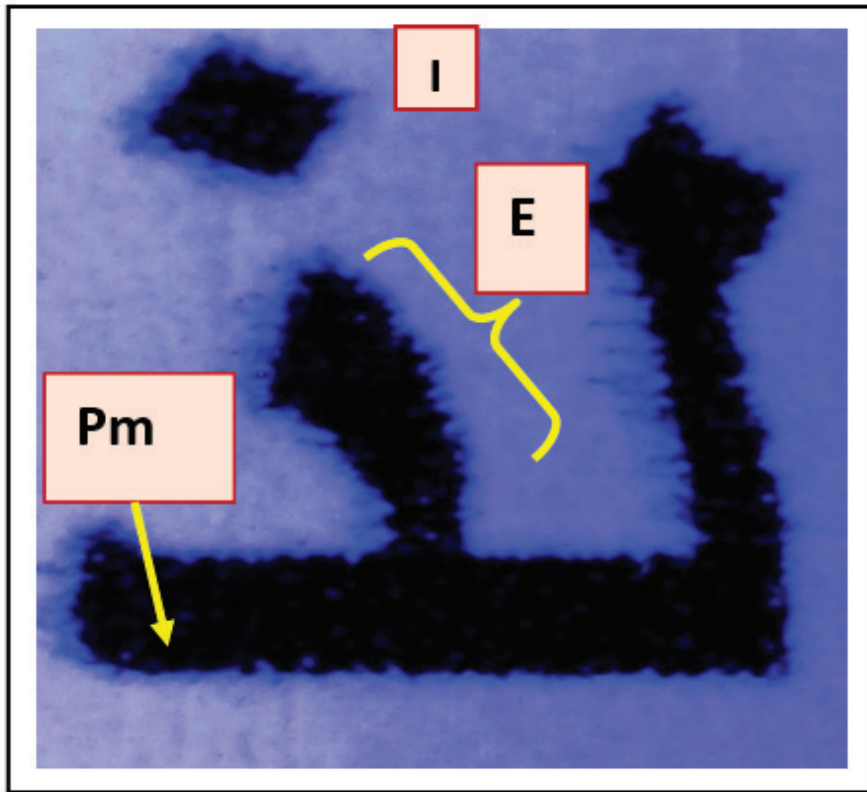


Figure (3): photomicrograph of document produced from a photocopier showing: E: edges of photocopied markings are slightly sharp, Pm: photocopied markings are moderately bright and moderately homogenous, T: toner is absent around photocopied markings and Sc: scratching or folding the paper over the photocopied markings induced its disruption.



**Figure (4): photomicrograph of document produced from an inkjet printer showing examined criteria by using UV light: E: edges of inkjet-printed markings are hairy-like & ill-defined, Pm: inkjet-printed markings are not homogenous and I: ink is scattered around the inkjet-printed markings.**

### Conclusions

In conclusion, the current study shows that the printed documents produced by different models of the same type of printer devices either (inkjet, laser, or photocopier) displayed no significant difference as regards the studied criteria which are class characteristics but differ from one type of the printing devices to another.

### Recommendations:

According to the findings of the present study the following suggestions could be recommended: application of the results of this research to a questioned printed document could help in identification of added word, or statement. Further studies on larger sample size to validate the findings, and more analysis of

the class and individual characteristics of printed documents using other sophisticated techniques.

**Conflict of Interest:** The authors declare that there is no conflict of interest.

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