

Analysing and Differentiating Original Documents from their Colored Copies Produced by Inkjet and Laser Printers

Skanda Priya Ganti¹, Komal Saini², Gagandeep Kaur³ and Vinayak Gupta^{4*}

¹M.Sc. Department of Forensic Science, Lovely Professional University, Phagwara – 144411, Punjab, India

²M.Sc. Department of Forensic Science, Punjabi University, Patiala-147002, Punjab, India

³Ph.D. Department of Forensic Science, Punjabi University, Patiala-147002, Punjab, India

⁴Ph.D. Department of Forensic Science, Lovely Professional University, Phagwara – 144411, Punjab, India

***Corresponding Author:** Vinayak Gupta, Ph.D. Department of Forensic Science, Punjabi University, Patiala 147002, Punjab, India, Email id: vinayakgupta224@gmail.com

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Abstract

The increase in the application of printers for producing official as well as other documents has intensified their use in various types of crimes such as counterfeiting documents of legal importance. A detailed knowledge about the identifying characteristics of all conventional and modern printing methods is required in order to be capable of examining and differentiating the printouts of different printers. Hence, this study has been carried out to analyse the differences between characteristics of original documents and their scanned colored copies produced by inkjet printers and laser printers using a stereomicroscope. The results were satisfying. Sufficient peculiar characteristics were recorded easily, reliably and non-destructively with the aid of a stereomicroscope. Stereomicroscope proved to be an effective tool for analysing and comparing various characteristics of original documents with their colored copies in order to differentiate them.

Keywords: Forensic Science; Forgery; Laser Printer; Inkjet Printer; Scanned Document; Stereomicroscope

List of Abbreviations: **B.Sc.** - Bachelors of Science; **CBSE** - Central Board of Secondary Education; **CMYK** - Cyan, Magenta, Yellow, Key (Black); **DMC**- Detailed Marks Certificate; **M.Sc.** - Masters of Science; **PSEB** – Punjab State Education Board; **DMC**- Detailed Marks Certificate



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Introduction

The concept of document examination is constantly changing due to the ongoing advancements in digital technology associated with printers. Text or images existing in a document can be digitally manipulated easily and multiple copies can be prepared. The authenticity and integrity of such documents is an important aspect in forensic document analysis, which cannot be ignored. Thus, it is essential to have detailed knowledge about the class and individual characteristics of printed and copied documents. This may help a forensic document examiner to prove whether a document is original or just a colored copy [1-3]. This knowledge may also help to link two or more documents and to conclude whether these two documents originated from a single printer or multiple printers were used for their preparation [4-6]. Documents can also be differentiated on the basis of the physical characteristics of printer used to print them [7-9].

Thus, this study has been carried out to determine the differences between the characteristics of original documents and their scanned colored copies. Original documents were scanned and their colored copies were produced using inkjet printers and laser printers. A stereomicroscope (Nikon SMZ800N) was used for analysing and comparing various physical characteristics.

Materials and Methods

Sample Preparation

Different types of original documents were collected on request and are listed in Table 1 along with their sample ID. Each original document was scanned and printed using five laser printers and four inkjet printers. Table 1 also indicates the specifications of various printers used for sample preparation. The phrase "FOR EXPERIMENTAL PURPOSE" was super-scribed on each scanned document before printing it. The dimensions of some documents were adjusted by printer settings to make them fit on the sheets on which they were printed. The prints were obtained on plain A4 size sheets in case of inkjet printers and glossy sheets were used for laser printers. The samples were collected in two phases over the course of two months. However, in first

phase, one document (MSD) was not printed by an inkjet printer (E380) due to its large size as compared to the scanner. This reduced the sample size to 71 ($8 \times 9 - 1$). In second phase, two printers (DC2020 and CN3010) were not in a working condition, further limiting the number of samples to 55 ($8 \times 7 - 1$). Hence, in total 134 samples (126 copies + 8 original) were examined.

A separate 9 samples were prepared in similar manner for a blind test of the method. Out of these nine samples, five were printed using a laser printer. While the rest four samples were printed using inkjet printer. The samples were randomly presented to the lead author for evaluation and the identity of the samples was kept confidential until the evaluation was complete.

Analysis

All documents were rigorously analysed in two steps. The first step included a visual examination of document and the second step included a stereomicroscopic examination. The results were tabulated.

Visual Examination

All original documents and their respective copies were initially examined and compared on the basis of visual characteristics and irregularities present in the smooth surface of paper, followed by recording their pictures under oblique light to obtain maximum depth. Change in the dimensions, change in color, and indentation and embossment were analysed in the visual examination.

Stereomicroscopic Examination

The original documents and their respective colored copies were examined and compared under a Nikon (Tokyo, Japan) SMZ800N stereomicroscope with a maximum magnification of $2 \times 10 \times 8 \times$, and Nikon C-FLED2 LED light source was used at different angles with respect to the paper, in order to observe minute details present in the document. For analysis, images were captured using a Nikon DIGITAL SIGHT DS-U3 camera head and camera model DS-Fi2. The NIS-Element software (Nikon, Tokyo, Japan) was used to capture images. Analysis was done with extreme care at different magnifications. Various observations witnessed with the help of stereomicroscope under

oblique lighting are as follows.

- Printing method and ink type
- Security features

- Printing characteristics and defects

Similarly, blind samples were analyzed for the aforementioned features, by following similar procedure. The outcomes were noted down and compared.

Table 1: List of materials used for sample preparation

S. No.	Type of Documents	Sample ID	Type of Printers		Sample ID
1	Matriculation DMC (PSEB)	MDP	Laser Printer	DOCUCENTRE SC2020	DC2020
2	Matriculation DMC (CBSE)	MDC		KONICA MINOLTA BIZHUB E452	KMB452
3	Intermediate DMC (CBSE)	IDC		WORKCENTRE 7425	WC7425
4	B. Sc. DMC	BSD		CANON 650	CN650
5	M. Sc. DMC	MSD		DOCUCOLOR 252	DC252
6	Library card	LC	Inkjet Printer	BROTHER MFC-J3520	BM3520
7	Aadhaar card	AC		HP DESKJET GT 5811	HP5811
8	B.Sc. Degree	BD		EPSON L380	E380
9	-	-		CANON G3010	CN3010

Results

Visual Examination

Following observations were made after visual examination of the original documents and their colored copies and tabulated in table 2 – table 7.

Change in Dimensions

On scanning and printing the original document, any of the three major changes were observed in the copied document, that is, the size of the copied document reduced, the size of the copied document remained same as the original document, or the size of the copied document increased. In case, the size of the copied document reduced or increased from the size of the original document, it was clearly observable in the visual examination and comparison. In addition to this, incomplete information such as cropped signatures, text and edges were also observed in all the three samples.

Changes in Color

Printing inks are broadly distinguished by the printing method in which they are utilized. The dyes and pigments present in the ink determine the color of the ink, its hue, strength, and transparency. On juxtapose comparison of original and copied documents, difference in colors was observed. Also, different printing methods used in copying resulted in different characteristic colors.

Indentation and Embossment

Indentation and embossment was present on various original documents, all of which disappeared in their respective copies. Embossment was observed mostly on the back side of the indented text or logo.

Stereomicroscopic Examination

Following observations were made after stereomicroscopic examination of the original documents and their colored copies and tabulated in table 2 – table 7.

Table 2: Comparison of characteristics B.Sc. Degree of original with its colored copies from inkjet and laser printouts

Sr. no.	Features to be observed	Observations observed in original document	Features observed in inkjet printed documents	Features observed in laser printed documents
1	Number and types of printing methods	Two(a) letter press or relief printing(b) laser printing	One(a) Inkjet printing	One(a) Laser printing
2	Ink	Blue ball pen ink	CYMK colors	CYMK colors
3	Gap	Between letters of Gurumukhi	May or may not be present	May or may not be present

Table 3: Comparison of characteristics of original M.Sc. DMC, original CBSE Intermediate DMC with its colored copies from inkjet and laser printouts

Sr. no.	Feature to be observed	Features observed in original document	Features observed in Inkjet printed documents	Features observed in Laser printed documents
1	Watermark on front and back side	Orange dotted pattern in background	No dotted pattern (different colors in its background)	No dotted pattern (mixture of colored toners in background)
2	Backside text	Shading is present along with text	Different colored droplets	Different colored toner particles
4	Gap between Gurumukhi letters	Present	Rarely present	May or may not be present
5	Inks on back side	Three inks at different positions	Three inks at different positions	Three inks at different positions
5 (a)	Ball pen	Gooping, paste like appearance	Different colors are present. Instead gooping, more black colored drops	Different colors are present. Instead gooping, more black colored toner particles
5 (b)	Gel pen	Totally absorbed into fibers	Different colored drops with majority of cyan color.	Different colored drops with majority of cyan color is observed
6	Color of serial number	Orange alone	Red with colored drops	Red with color toner particles
7	Number and type of printing methods used	Two(a) Dot matrix printing(b) Inkjet printing	One(a) Inkjet printing	One(a) Laser printing

Table 4: Comparison of characteristics of original B.Sc. CBSE DMC with its colored photocopies from inkjet and laser print-outs

Sr. no.	Features to be observed	Features observed in original document	Features observed in Inkjet printed documents	Features observed in Laser printed documents
1	Micro-printing in seven straight lines at back side	Naked eye- Straight line Microscopically- Micro-printing present (PUNJAB UNIVERSITY)	Naked eye- Straight line Microscopically- Micro-printing absent	Naked eye- Straight line Microscopically- Micro-printing absent
2	Watermark	Green color dotted pattern resulted in the formation of PUNJAB UNIVERSITY	Colored droplets	Colored toner particles
3	Ink in signatures	Blue ball pen (Gooping, paste like appearance, skipping)	Colored droplets present. In place of gooping, extra deposition of ink droplets present.	Colored toner particles are present in their specific toner deposition pattern
4	Intersection	Intersection of two printing methods	No intersection	No intersection
5	Micro-printing around serial number	Present (PUNJAB UNIVERSITY)	Micro-printing absent	Micro-printing absent except KMB452 (few letters were readable)
6	Copy printed on bottom	Naked eye- Not visible Microscopically- copy clearly visible	Not visible	Not visible
7	Number of printing methods used	Two	One	One
8	Ink used for Signature	Black ink	Black ink droplets	Black toner particles

Table 5: Comparison of characteristics of original Matriculation PSEB DMC, PSEB Intermediate DMC with its colored photocopies from inkjet and laser printouts

Sr. no.	Feature to be observed	Features observed in original document	Features observed in inkjet printed documents	Features observed in laser printed documents
1	Color and pattern of printing	Letters of Punjabi in particular color dotted pattern in background.	Different mixture of colors in letters were present, no fine dot pattern in background.	Different mixture of colors of toner particles in letters were observed, no fine dot pattern in background.
2	Word COPY (invisible with naked eye)	Present in a specific pattern of one color larger than background pattern	Microscopically- present in CYMK colored droplets and can be easily observed	Microscopically- present in CYMK colored toner particles but Sometimes mixed with background
3	Boundary pattern	Boundary pattern of dark blue color is present.	CYMK with dark blue and green color (maximum dark blue color)	CYMK colors are present in background pattern
4	Picture background	Fine dot pattern in particular inclined direction.	CYMK with green color randomly scattered	CYMK colored toner particles in its specific toner deposition pattern
5	Indentation of stamp	Present at front side	Absent	Absent
6	Embossment at back side	Present	Absent	Absent
7	Ink	Blue ball pen (Gooping, paste like appearance, groove)	CYMK color, in place of Gooping, in place of Gooping more black ink is observed	CYMK colored toner particles, rarely more black toner particle deposition at the place of Gooping
8	No. of printing methods	Two	One	One
9	Micro-printing in straight line	Full form of PSEB	No letter, CYMK with green color	No letter CYMK with green colored toner particles
10	Stray toner particles	Present	Absent	Present

Table 6: Comparison of characteristics of original Aadhaar card with its colored photocopies from inkjet and laser printouts

Sr. no.	Features to be observed	Features observed in original	Features observed in inkjet printouts	Features observed in laser printouts
1	Quality of printing in Letters of Hindi below logo	Clearly present	No letter is in readable form, Liquid droplets mixed into each other	In some cases, letters are clear but sometimes toner particles scattered and letters are not visible
2	Picture	Specific toner deposition pattern along with clusters	Absent	Present
3	Picture background	CYMK colored toner particles	CYMK color droplets absorbed in paper fibers	CYMK color toner particles on the surface of paper
4	Specific toner deposition pattern	Present in two colors where lines of toner particles are inclined in specific direction	Absent	Present
4 (a)	Green	Pattern of green and yellow color	No pattern	In some cases, pattern of yellow and green with inclined lines, otherwise clusters of toner particles without any pattern.
4 (b)	Red	Pattern of red and yellow color	No pattern	In some cases, pattern of yellow and green with inclined lines, otherwise clusters of toner particles without any pattern.
5	Stray toner particles	Present in CYMK color	Absent	Present
6	Toner particles in text	Present	Absent	Present

Table 7: Comparison of characteristics of original library card with its colored photocopies from inkjet and laser printouts

Sr. no.	Features to be observed	Features observed in original document	Features observed in inkjet printouts	Features observed in laser printouts
1	Picture and it's background	CYM colored droplets	CYMK with green and dark blue droplets	CYMK colored toner particles
2	Pen ink	Three types	-	-
2 (a)	Ball pen ink characteristics	Gooping, paste like appearance, skipping of ink	CYMK with green and dark blue droplets	CYMK colored toner particles. In some cases, maximum cyan color is present
2 (b)	Gel pen ink characteristics	Ink absorbed in paper fibers, tracking of ink	Maximum cyan color (very small amount of other colors)	CYMK colored toner particles. In some cases, maximum cyan color is present
2 (c)	Stamp ink characteristics	Purple color ink	Maximum magenta and cyan color are present along with other colors	Maximum magenta and cyan color toner particles are present along with other colors
3	Number of printing method used	Two	One	One
4	Intersection	Small part of one side of picture is present behind the laminated part	Present on same surface	Present on same surface

Printing Method and Ink Type

Printing methods - In some of the original documents, printing characteristics of more than one printing method were observed. However, their respective colored copies indicated the use of only one printing method in the whole document.

Pen inks - In case of original documents, signatures were observed to be made up of a ball point pen ink or gel pen ink. However, the pen inks of signatures were printed in accordance with the printer used in the respective colored copies when observed under stereomicroscope.

Intersections - In original documents, where more than one printing method was utilized for printing, clear intersecting strokes were observed. Intersections were observed between printed text, images, handwritten signatures, etc. In contrast, intersections were absent in the colored copies and at certain places it blurred.

Security Features

Micro-printing - Micro-printing was the most common security feature observed in various original documents under stereomicroscope. It was absent in their respective colored copies as the scanner and printer could not replicate the micro-printing.

Watermark - In some of the original documents, printed watermarks were observed in the background. Under stereomicroscope it appeared as a pattern of fine dots or text of a particular color. However, the respective copies of original documents did not show such patterns or these were tampered.

Printing not visible to naked eye at the bottom - A specific pattern of dots (whose dot size was larger than the size of dots present in the background pattern) found in the words 'COPY', 'ORIGINAL', made of single color that was only visible under the stereomicroscope in original documents. Either it disappeared or changed microscopically in

aspects of color configuration in the forged documents.

Indentation and embossment - Indentation and embossment of logo was observed under stereomicroscope on various original documents when observed with light at grazing angle. However, these disappeared in their respective copies.

Printing Characteristics and Defects

Sheen - In few original documents, when observed under oblique light, sheen was observed on the surface of text and logo. This may be due to raised printing of text or due to coating material. However, sheen was not observed in their respective colored copies.

Spacing between texts - When observed under stereomicroscope, a minute space was observed between some Gurumukhi letters in original documents of MDP. However, this space was not observed in their respective colored copies. The text appeared to be continuous.

Printing defects - A number of printing defects depending on the scanner and type of printer used to print the documents, such as spur marks, extra deposition of ink droplets or toner particles, poor quality printing, mechanical defect, and glass platen defects were observed in the copied documents. However, no such defects were present in their respective original documents. Apart from this, individual features of inkjet printing (Table 8) and laser printing (Table 9) were observed. These defects were helpful to individualise and identify the make and model of the printer used for the production of the forged document.

Blind Test

The blind test samples were also examined using the same methodology. After careful examination of all the blind samples, correct interpretation was made for 100% samples. Hence, the results of blind test were similar to the results in this study. This validated the methodology and the results obtained in the study.

Table 8: Individual characteristics observed in inkjet printouts

Sr. no.	Type of printer	Features to be observed	Features observed
1	BM3520(BROTHER)	1.Satellites2.Colored droplets 3.Defect	1.Satellites Absent2.Colored droplets randomly scattered all over the document3.(a) Spur marks (in Aadhaar card only)(b) Extra deposition of ink in small size text printing
2	HP5811(HP)	1.Satellites 2. Deposition of colors 3.Defects	1.Satellites present on both sides of the printed strokes2. Black color droplets in black colored text, CYMK with green color in colored text.3.(a)Lining(b)Dragging effect
3	E380(EPSON)	1.Satellites2.Colored droplets	1.Satellites absent2.Present around and near the printed letters
4	CN3010(CANON)	1.Satellites2.CYMK colored droplets3.Defects	1.Satellites present on left side of strokes2.Present opposite to direction of satellites 3.(a)Lining(b) Feathering

Table 9: Individual characteristics observed in laser printouts

Sr. no.	Type of printer	Features to be observed	Features observed
1	DC2020(XEROX)	1.Deposition of toner particles2.Gap3.Micro-printing in straight line4.Clusters5.CPC code	1.Colored clustered toner particles 2.Gap always present3. Some letters readable 4.Clusters present all over the document5.Present in the form of yellow dots
2	KMB452(KONICA MINOLTA)	1.Clarity2.CPC code3.Defects	1.Affected in small printed letters2. Present 3.Only Some letters are readable in Micro-printing, Absence of somewhat black toner particles
3	WC7425(XEROX)	1.Specific toner deposition Pattern 2.Clusters 3.CPC code	1.Naked eye- same observationsMicroscopically-clusters of toner particles of CYMK color having clusters of CYM color in the background, very rarely black color clusters present.2.Stray toner particles in the form of clusters3.Present
4	CN650(CANON)	1.Specific toner deposition pattern 2.Stray toner particles3.CPC code	1.Naked eye- same observationsMicroscopically—lines of toner particles inclined in specific direction (each color had different direction) having toner particles in the background.2.Present in CYMK color3.Present

Discussion

A number of physical characteristics were considered which proved extremely useful for the comparison of original documents with their copies. From the results, it is evident that the changes in dimensions are enforced while copying an original document, which can be clearly observed in the copied document. In addition to this, it came out to be apparent that it is very difficult to copy the exact color, indentations, embossments and micro-printing present on the original documents. Although, the copied document may look similar on viewing with naked eyes, but a

clear picture can be formed with the help of a stereomicroscope and juxtapose comparison. Previously, [1, 2, 5, 16] reported various defect marks, physical features, spur marks, and satellite droplets in their individual studies for the purpose of classification and identification of inkjet printouts. Referring to the above studies, the study has also utilized features such as satellites, spur marks, lining, and feathering for the identification and comparison of inkjet printouts. Further, [4, 5, 7, 9, 14, 15, 17] Arbouine *et al.* (1994), determined the source of electrostatically photocopied and laser printed documents on the basis of various physical characteristics and defect marks present on the printouts. In addi-

tion, [4] reported the use of image processing tools for examination of computer manipulated documents. All such general and individual characteristics like counterfeit protection system (CPS) code, toner particles, specific deposition pattern, and defects marks have been utilized for the examination and comparison of original documents and their respective copies.

Conclusion

The study demonstrated the competency of stereomicroscope in the analysis of physical characteristics of original documents as well as their colored copies. Characteristics including change in dimensions, change in color,

embossment, indentations, pen ink, number of printing methods used, micro-printing, background details, defects, intersections, sheen, spacing, and individual features of printing method(s) were examined using Nikon SMZ800N stereomicroscope. The examination and comparison was performed between original documents and scanned copies of original documents. This study helped in determining sufficient physical characteristics of documents for proving their authenticity by utilising stereomicroscope. A stereomicroscope was used because this microscope is mostly used by document examiners in forensic science laboratories in India. It proved to be an easy, reliable and non-destructive method for analysis and comparison of documents.

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