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Digital Proofing of Spot Color Overprints for Flexography

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Abstract. *Due to the advancement in inkjet digital printing, it is possible to print spot color short run jobs with high quality and desired level of consistency in color at low cost. Mostly in the packaging industry, specific color is used for specific requirements of a customer, which is called a spot color. About 40 % of packaging jobs are printed by flexo, 30 % by offset lithography, 22 % by rotogravure, and 8 % by digital and other printing processes. The aim and purpose of this work was to investigate the proof color matching capability of two ink jet digital printers, differing in ink technology and prepress color matching software used, for spot color matching printed on a narrow web flexographic printing press. The results were produced by evaluating color differences between the colorimetric measurements from the flexographic printing press versus the digitally reproduced proofs from the two tested ink jet devices. © 2012 Society for Imaging Science and Technology.*
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INTRODUCTION

Printing is based on subtractive color theory where process color inks Cyan (C), Magenta (M), Yellow (Y), and Black (K) are transparent inks, and overprinting of yellow and magenta ink gives red, overprinting magenta and cyan gives blue, and overprinting yellow and cyan gives green.[1] On the other hand, spot colors are manufactured by premixing the colorants to attain certain color renditions. Generally, the spot color inks are more opaque as opposed to the process colors.[2] Overprint color is obtained when two or more colors overlap and the process of printing two or more colors overlap is called "overprinting" or "trapping" of colors. Overprinting could be of two or more process colors or spot colors. Use of spot colors gives advantages over process colors for brand building and specialty job printing.[3]

Due to an advancement in inkjet digital printing, it is possible to print high quality prints at low cost and less time. The unique properties of the ink jet printers to produce short run jobs in a simple way makes its use more versatile for pre-press proofing for commercial printing. The digital printer can create the prints, which can mimic the press, using color management workflow, ICC (International Color Consortium) profiles, or non-ICC Look-Up-Tables for different devices, such as printers, scanners, or monitors.[4] Use of color management allows ease of handling in digital color data processing, which can help to print digital proofs that mimic the printing press.[5,6]

Ink jet printers, substrates for printing, inks, and controlling software of color management systems are the main components of an ink jet proofing system. All these components affect accuracy of proof-press color matching in digital proofing systems.[4,7,8] There are ongoing efforts to develop new proofing systems that will meet the requirements, such as simulation of color of paper, effect of gloss, spot color reproduction, and remote proofing.[9]

Print media properties are important from the point of view of ink and paper interaction and achieving desirable color matching quality, and reproducibility. Color gamut and color stability of proofing systems are completely dependent on the combination of ink and media, and predetermine color gamut and color stability of proofing systems.[9–11] In order to control the ink jet printer, two kinds of software are used: one is the ink jet printer driver, which is provided by the printer manufacturer, and the second is the third party raster imaging processor software, i.e. RIP (Raster image processor) software. Which kind of workflow is to be used is dependent on the end application, whether RGB (Red Green and Blue) or CMYK (Cyan Magenta Yellow and Black) workflow will be employed.[5,10,12]

The aim and purpose of this work are as follows:

1. To understand and clarify the abilities of various proofing solutions to digitally reproduce spot colors and their overprints for a flexo press printing technique, proofing substrate, and ink system.

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2. To study the color reproduction abilities of three different proofing substrates.

EXPERIMENTAL

The inks used for the flexo trial were solvent based spot color inks: orange, green, blue, and pink. The substrate used on press was one side coated solid bleached sulfite (CIS-SBS) board.

The research work was divided into different tasks, which are as follows:

- Multicolor test charts creation with spot color overprints.
- Analytical: CIELAB color measurement, ΔE calculation, measuring the printed ink film opacity.
- Flexo press run of spot color test charts with different order of spot colors.
- Proofing charts on two digital printers using SMARTCOLOUR IVUE software, PHOTOSHOP CS-4, and RIP workflow.

CREATION OF TEST CHARTS WITH SPOT COLOR OVERPRINTS

In order to understand and clarify the abilities of various proofing software solutions to digitally reproduce spot colors and their overprints, a special test chart was created. This test chart had a total of 264 patches. Each spot color channel had a tone values from 0 to 100 %, i.e. tints in a 10 % increment for each color. These tone values for spot colors were used for determining the tone value increase of the press. Along with these tone values, it also contains different overprints of different intensity from highlights to shadows of two and three spot color inks. Out of the 264 color patches, each test chart also contained 76 of one-color patches, 65 of two color overprint patches, and 123 of three color overprint patches.

OPACITY CALCULATION OF SPOT COLOR INKS

Opacity is the optical property of ink and, for this research purpose, it was calculated as a ratio of reflectance measurements of respective X, Y, and Z values for a particular spot color ink from black and white patch of BYKO chart[13] and expressed in percentage.

Using a flexo head K-proofer which is shown in Figure 1, all four spot colors inks were printed over black and white patches of BYKO chart, as shown in Figure 2. In order to calculate the opacity of the ink, the reflectance data of each ink from black and white patch were measured by an Eye-One spectrophotometer (X-Rite). An average of ten readings were taken of respective X, Y, and Z values for a particular spot color ink from black and white area of BYKO chart and expressed in percentage. For example, only X values of reflectance were used for red and orange spot color inks, only Y values were used for green ink and only Z values for blue ink. For calculating final single opacity value based on selected X, Y, and Z for particular ink, Eq. (1) was used.

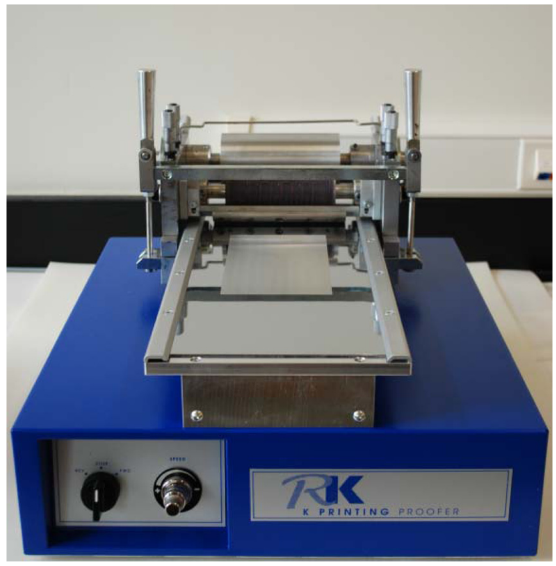

Figure 1. Gravure and Flexo K-proofer.

$$\text{Opacity of ink } (\%) = \frac{\text{Respective reflectance value from Black area}}{\text{Respective reflectance value from White area}} \times 100\ldots \quad (1)$$

FLEXO PRESS RUN

Figure 3 shows the flexographic photopolymer plates with various press and printing related symbols, including impression pressure marks, vignettes, and solid color patches. The substrate used was C1S-SBS board. The viscosity of the inks was kept constant at 22 s on a #2 Zahn cup over the period of the press run. The speed of the press was set to 50 feet/min.

PROOFING METHODOLOGY

The overprint test charts were sent to two different digital printers, i.e. Epson Stylus Pro 7900 and Epson Stylus Pro 9800. These two digital printers differed in their makeup of ink sets. Epson Stylus Pro 9800 has K3 UltraChrome technology with eight colors, whereas Epson Stylus Pro 7900 has additional inks of orange and green along with the eight color set. Through different proofing workflows, color managed ADOBE PHOTOSHOP, ADOBE PHOTOSHOP with SMARTCOLOUR IVUE plugin, and the CGS Publishing Technologies International GmbH RIP.

The SMARTCOLOUR IVUE plug-in can be installed as an option in ADOBE® PHOTOSHOP and ILLUSTRATOR software. The software is equipped with the SmartColour Color Picker, which enables using specific ink on a discrete substrate and predicts color appearance of an actual print, because it uses real ink on real paper proofs. The color picker allows individual selection of colors for any spot element either from brand-specific libraries or general libraries. Sun Chemical's Global Shade Library has various color shades, which were developed by previously proofed, printed, and measured inks for particular substrate, ink, and printing processes.

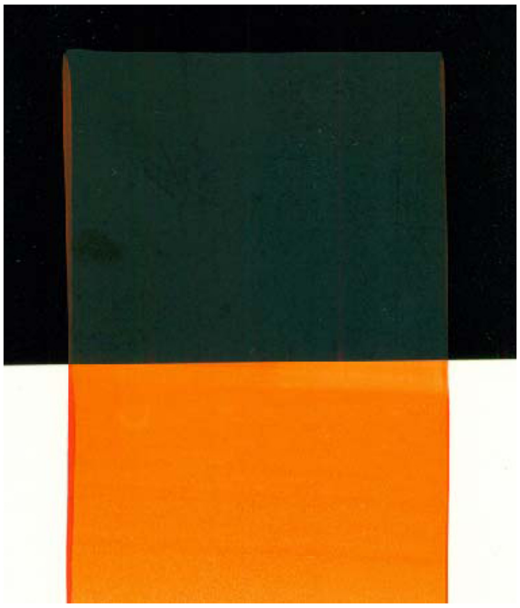

Figure 2. Ink drawdown on BYKO chart.

The RIP workflows are usually CMYK or CMYK and spot colors. In order to have predictable and repeatable results through the printer, most of the RIPS also have functions of device calibration and linearization processes. The use of built-in color management functions helps in defining the color space in software at pre-press and RIPing stage, which contributes to attaining the optimal end result. Some RIP workflows use color matching features that are based on integrating third-party ICC profiling techniques.

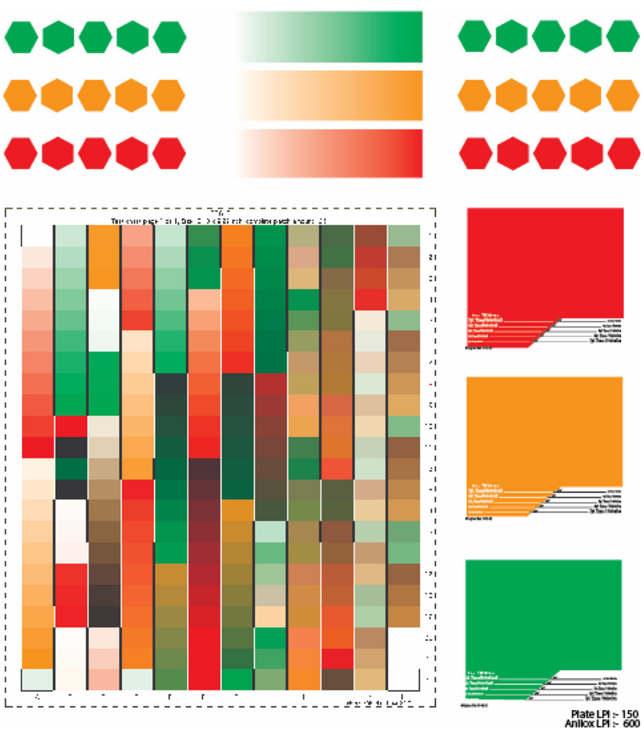

Figure 3. Plate design for flexo press trial.

Using different tools and available options for these software strategies, the effects of print properties, such as tone value increase or opacity, computed from the press results, were used for each of these three proofing software solutions. With the SMARTCOLOUR IVUE plugin, it is possible to set the tone value increase values per channel to achieve more accurate and consistent color reproduction. Similarly, the calculated opacity values from Table I were entered into PHOTOSHOP and in the RIP software. In the case of the RIP software, the printers were linearized and calibrated with the built-in tool provided by the software RIP. ICC profiles, both for RGB and CMYK workflow, were created for the printers, using ICC profiling test chart TC 9.18 RGB test target and ECI2002RCMYK test target.

CIELAB COLOR MEASUREMENT

The CIELAB values were measured for both the press printed sheets and proofed test charts on digital printers using MEASURETOOL software and an X-Rite i1-iO scanning spectrophotometer with 45°/0° geometry. The press sheet CIELAB values were considered as reference and all the ΔE calculations were done using formula $\Delta E_{CMC(2:1)}$. These reference press sheet CIELAB values are the average values of three different sheets printed on press for each individual patch. The standard deviation for all 264 patches measured for three press sheets was in the range of 0.05–0.15.

RESULTS AND DISCUSSION

Proofing Results for Overprints of Spot Colors

The overprint testcharts were produced with all four proofing solutions with two different printers and the CIELAB values from the proof results were compared to the values gathered from the flexo press sheets. In this case, the reference CIELAB values were set to be flexo press prints. The level of accuracy for overprints of spot colors was computed in terms of color difference ΔE calculations, using formula $\Delta E_{cmc(2:1)}$,[14] as this formula gives the color comparison more like visual analysis of color. The results were split into three categories for two different printers: one-color patches, which include solid colors and the tones steps, two color overprints of different levels of tone steps, and three color overprints of different levels of tone steps. All these computed results are for four different print combinations that were printed on press, i.e. BOP—Blue + Orange + Pink, BOG—Blue + Orange + Green, GBP—Green + Blue + Pink, and finally GOP—Green + Orange + Pink.

Figure 4 shows the $\Delta E_{cmc(2:1)}$ values for single color patches proofed by IVUE software solution were the lowest for all four print sequences. If the proofing solutions are compared then the results show the color reproduction in

Table I. Opacity values of the four spot color inks.

	Opacity (%)			
Spot color	Blue	Green	Orange	Pink
Solvent based ink	6	12	6	5

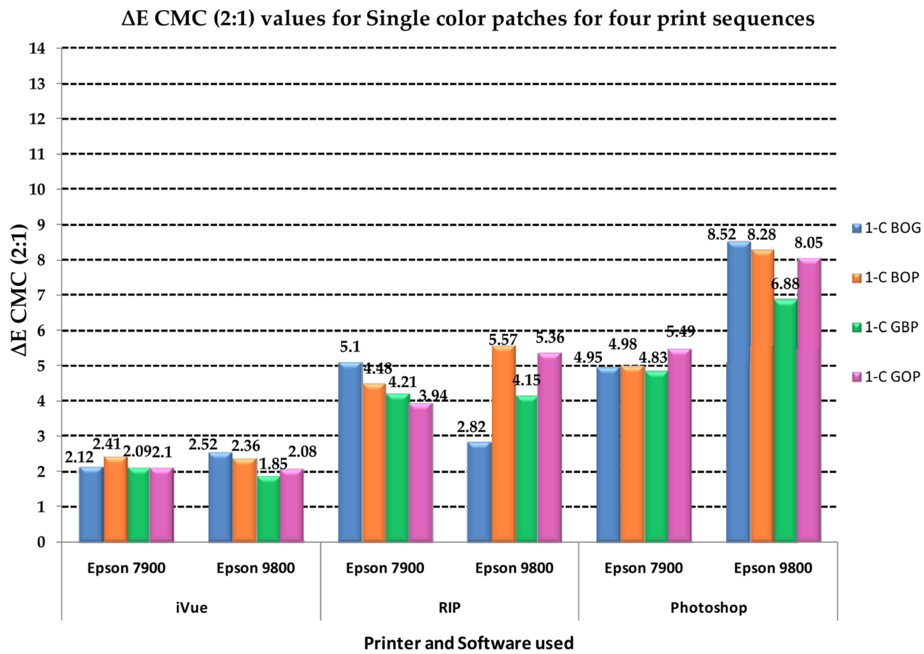

Figure 4. Graphical values of $\Delta E_{cmc\ (2:1)}$ color differences between flexo press and digital printers for single color patches.

terms of $\Delta E_{cmc\ (2:1)}$ by RIP and PHOTOSHOP software solutions was high, even for single color reproduction. Among the two digital printers, it was found that due to the high dynamic range (HDR)[15] ink technology, which has an extra orange and green color, the Epson Stylus Pro 7900 reproduced colors better than the Epson Stylus Pro 9800, irrespective of the substrate and proofing solutions.

If the proofing results for two color overlap patches for various software solutions are compared (Figure 5), it can be seen that the IVUE produced the best results followed by the RIP and then PHOTOSHOP. The ΔE values for all the software solutions increased as the number of overlap colors increased. If the proofing results for single color and two overlap patches for software solutions are compared, it can be seen that the IVUE produced the best results followed by the RIP and then PHOTOSHOP. It is also observed that almost all print combinations had similar trends for the $\Delta E_{cmc(2:1)}$ values, i.e. lowest ΔE values for

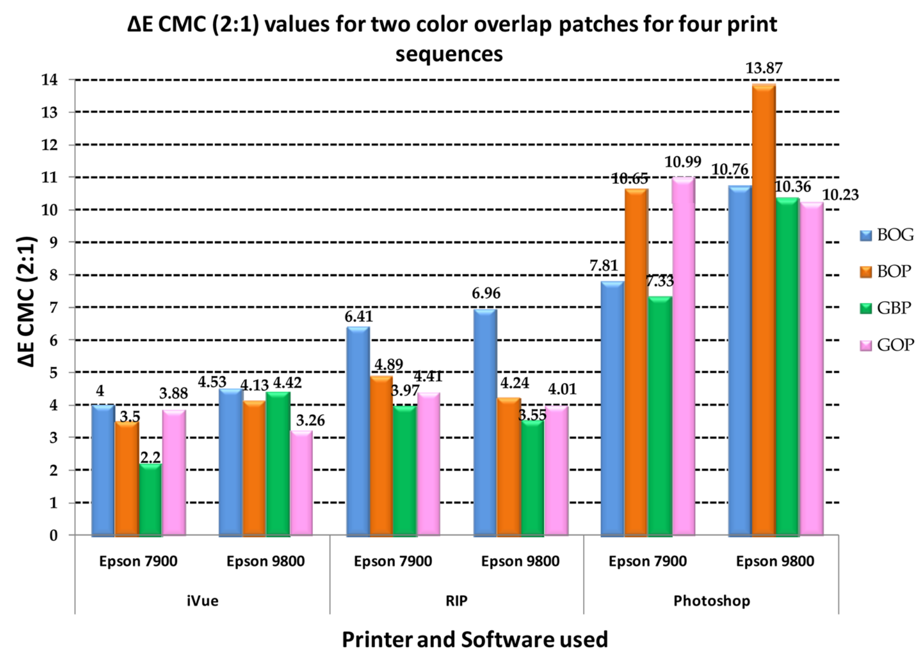

Figure 5. Graphical values of $\Delta E_{cmc\ (2:1)}$ color differences between flexo press and digital printers for two color overlap patches.

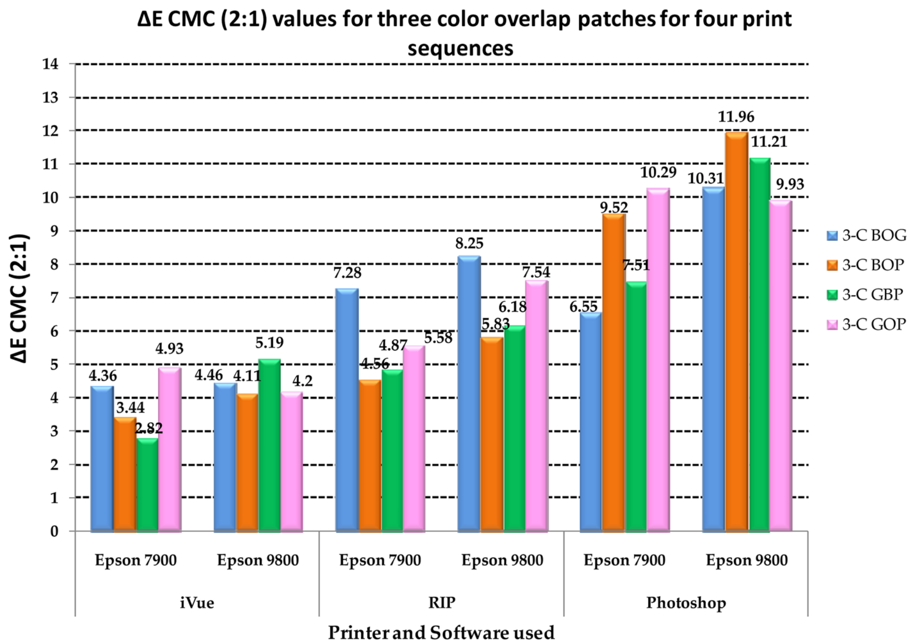

Figure 6. Graphical values of $\Delta E_{cmc\ (2:1)}$ color differences between flexo press and digital printers for three color overlap patches.

single color, slightly higher ΔE values for two color overlap, and highest ΔE values for three color overlap. This trend of higher $\Delta E_{cmc(2:1)}$ values was also observed for RIP and PHOTOSHOP solutions.

Figure 6 shows the proofing results for three color overlap patches against the press sheet. Color differences of proofs for all the software solutions were high, especially for PHOTOSHOP for all the four print sequences. It can be seen that the proofing of colors, i.e. the color reproduction by each software solution tends to be less and less accurate as the number of overlap colors increases (Fig. 6).

Proofing Results for Three Different Proofing Substrates

A few important things that must be considered when digital printers are used for proofing are the ink paper interactions, coating structure, and physical properties of substrate, such as roughness, porosity brightness, and opacity. The substrate should enable the digital printer to reproduce a good range of tone scales with fine details. Therefore, working with high quality proofing substrates can deliver a large color gamut, high color stability, high optical density, and image with good sharpness.[16] Table II shows the physical properties of three commercially available proofing substrates- Epson Glossy, Epson Semimatte, and ORIS Super glossy.

These commercially available proofing substrates were tested in order to see the possible effect of different proofing substrates on the color reproduction and accuracy for spot colors (Figure 7). Before proofing, the ICC profiles for all of those substrates were created. These substrates were proofed on the Epson Stylus Pro 9800 inkjet printer. Press sheets CIELAB values were considered as reference for $\Delta E_{cmc(2:1)}$ calculations.

Figure 7 shows the average $\Delta E_{cmc(2:1)}$ values for 264 patches of the test charts for each software solution on three different proofing substrates for the GOP print combination. The data show that there were minor differences in the ΔE values within the substrates and one software solution. The IVUE proofing solution produced slightly better results on the Epson Glossy substrate, the ORIS RIP yield similar result on all three substrates. The optical and physical properties are comparable for all the substrates, with rather lower roughness and higher opacity on the Epson Glossy paper. The Epson Glossy substrate with the Epson

Table II. Physical properties and color gamut volume of different substrates.

proofing substrates	Color gamut volume cCu	CIELAB values X-Rite.il-iO (with no UV filter)	PPS roughness microns	PPS Porosity ml/min	Opacity (%) Technidyne	Gloss @.75° MD Technidyne
Epson Glossy	753,433	93.96, – 0.43, – 1.11	1.89	1.12	96.4	68
Epson semimatte	714,086	94.54,.–0.41,.-2.11	2.35	1.3	94.78	64.68
ORIS Super glossy	716,984	95.55,.–0.47,.-0.93	2.11	1.16	94.98	71.06

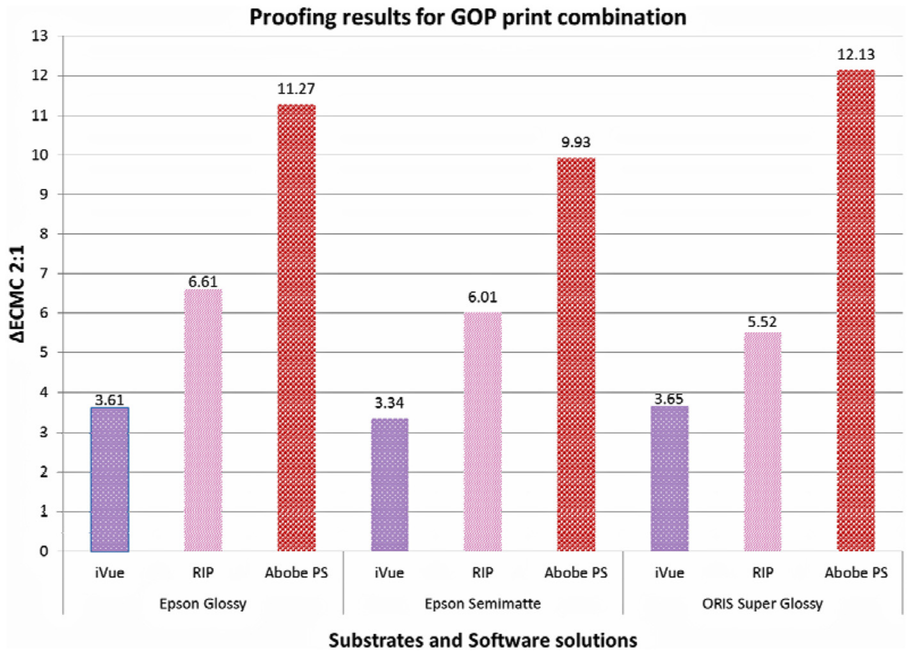

Figure 7. Graphical representation of ΔE values for GOP print combination for different software and substrates.

9800 printer combination also provides the largest color gamut volume.

CONCLUSIONS

The SMARTCOLOUR IVUE plugin from Sun Chemical was able to digitally reproduce the spot colors and its overprints with lower ΔE for all the four sequences of three ink combinations. The proofing ΔE values by the SMARTCOLOUR IVUE plugin for 76 single colors, 65 two color overlap, and 123 three color overlap patches for all the sequences were low compared to the RIP and ADOBE PHOTOSHOP.

The three-color overprints irrespective proofing software solution yield the worst color agreement between the real press print and the digital proof, the ΔE values were very high. This was expected, considering the complexity of the process and the differences in color compounding between the analog and digital color production.

Though color gamut was used as a measure of color reproduction capability of a device,[11] but if we consider the color gamut for three tested proofing substrates, it was observed that different proofing solution behave different ways when using various substrates.

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