

# **An Evaluation to Identify Best Printing Process and Substrate for Newly Developed Color Vision Deficiency Diagnosing Tool**

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## **Abstract**

Color vision deficiency (also known as color-blindness) is a defect in ‘color perception’ by the eyes. The Ishihara pseudo isochromatic plates is widely used to detect color vision deficiency by Optometrists and Ophthalmologists in India & other developing countries. This testing tool is expensive and its print quality & paper durability gets deteriorated due to exposure to various atmospheric conditions and temperatures while using them in vision screening camps. Due to this limitation, millions of children in India are left undiagnosed for color-blindness in their school. The aim of our paper is to make an affordable, highly reliable and extremely durable color vision deficiency testing tool (Dalton’s PIP) which has the capacity to test mass population in a minimal time.

This paper presents results from an experimental analysis of various printing substrates and printing processes and finding the best substrate and process to make newly designed Dalton’s PIP color vision deficiency testing tool. The analysis involved experimenting various substrates and processes for durability, reliability, low impact scratch resistance test, repeatability and cost effectiveness. Experimental results showed that color vision deficiency testing tool (Dalton’s PIP) designed could be best printed under dry electro photography printing process on synthetic polyester (PET) film 200 microns substrate. This study would be highly beneficial for future researches on the printing requirements for medical grade tests.

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## Introduction

Color vision deficiency is a defect in ‘color perception’ by the eyes. Color vision deficiency is also commonly known as color-blindness. It is more common in men compared to women. Color vision deficiency is prevalent in as many as 8% males and 0.4% females globally [1]. Although there are many types of color vision deficiency, the red-green type is the most common and highly prevalent type. Color vision deficiency does not cause complete blindness and there is no available therapeutics that can treat or cure color vision deficiency. However, color vision is crucial to an individual’s understanding of their visual world, and those with color vision defects can experience difficulties in everyday life [2]. People with color deficiency can only see a limited range of colors and mistakes can be made in color identification.

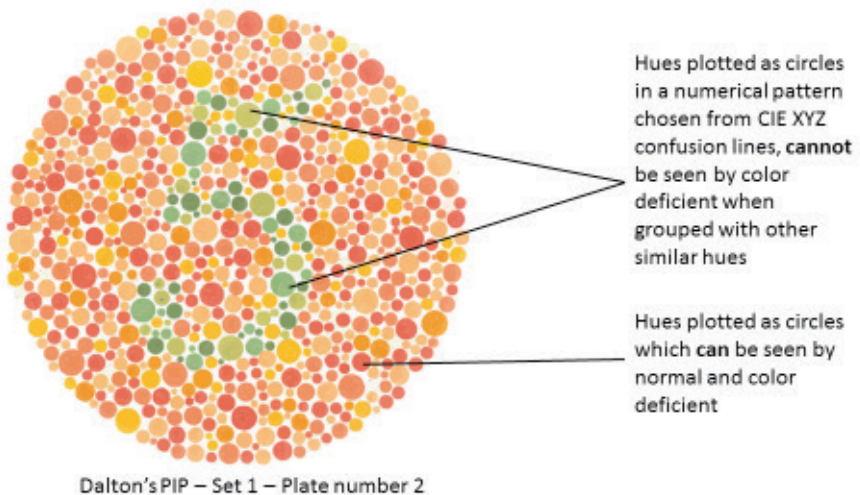
The need for color vision testing as a routine optometric/ophthalmologic examination is well emphasized as color vision deficiency has an impact in the choice of career/growth in the career for a person [3]. Those who have color vision deficiency will be better able to adapt and make more informed career choices, if they know about their color vision status. However, a high proportion of school children are unaware of their color vision status and undiagnosed color deficiency could pose a handicap to the scholarly performance of an affected student. Moreover, early detection of color vision deficiency in children allows parents and teachers to make necessary adjustments to the teaching methods for appropriate learning. Indian judiciary department also noticed increased legal cases of color vision deficiency and career rejections among the young population of India.

The Ishihara pseudo isochromatic plates (a paper based printed testing tool) is widely used to detect color vision deficiency by Optometrists and Ophthalmologists in India & other developing countries. This testing tool is expensive and its print quality & paper durability gets deteriorated due to exposure to various atmospheric conditions and temperatures while using them in vision screening camps. The Ishihara pseudo isochromatic plates have also been reported to lose its print solidity earlier than the estimated time with noticeable shifts in the colorimetric values [4]. This affects the reliability of the color vision deficiency testing and has led to limited research data.

Thus, we identified the need for more affordable, highly reliable and extremely durable color vision deficiency testing tool which has the capacity to test mass population in a minimal time. Henceforth, we have done extensive research, designed and developed Daltons Pseudo isochromatic plates (Dalton’s PIP). We developed this new testing tool focusing on the properties and characteristics of different printing materials and printing methods to find the best durable material and printing method which can withstand different atmospheric and usage conditions in developing countries.

## Methods

The design and the construction of the testing tool (Dalton's Pseudo Isochromatic Plates) was done through Corel Draw X7 designing software under the preview of Optometrists from the Elite school of Optometry, Chennai (India). The construction of Dalton's Pseudo isochromatic plates is based upon the pseudo-isochromatic principles proposed by Stilling. The principle of the pseudo-isochromatism is that the color of a target (digit or letter) embedded in a background of another color appears "falsely of same color" to a color deficient individual. The designing of the tool involved selectively picking the hues from the confusion lines of CIE XYZ color space [5] and converting them to CIE LAB values. The hue values are then plotted in small circles with dimension ranging from 0.1 to 0.4 cms. These circles of hues derived from the confusion lines of CIE xyz color space are made into numerical patterns and are surrounded by the hue circles of similar dimensions which appear normal to both the color deficient and color normal person. Figure 1 shows the design pattern of Dalton's PIP with the numerical pattern built based upon the confusion lines. This design pattern thus makes the color deficient person not to appreciate any numeral in the plate, whereas a person with normal color vision can appreciate the numeral present in the plate.



*Figure 1. Dalton's PIP: Design*

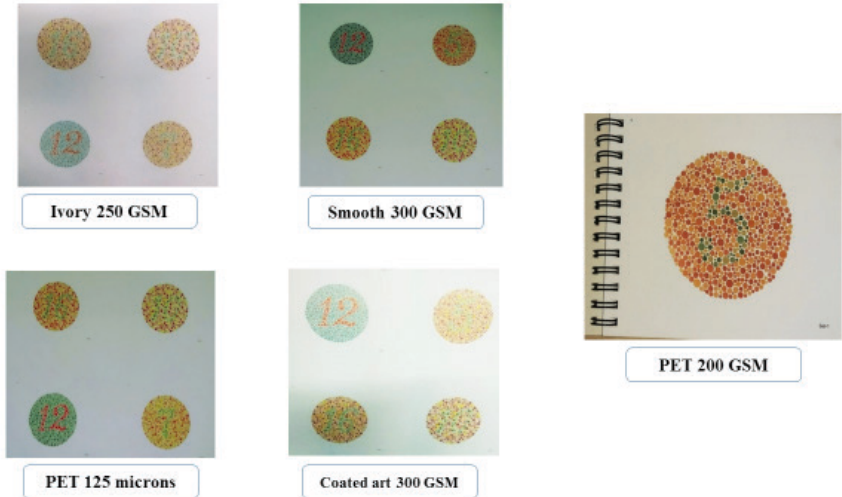
Post designing the plates, the key aspects of our study was carried out, which was to find the best substrate and printing process to make the newly designed Dalton's color vision deficiency testing tool. The study was carried out on different printing technologies like liquid electro photography (HP Indigo), dry electrophotography (Heidelberg Versafire) and UV inkjet (KM Accuriojet) focusing on their print quality & cost effectiveness. Five different types of substrates (coated art board 300 GSM, uncoated smooth board 300 GSM, uncoated ivory texture board 250 GSM,

synthetic polyester film 125 microns and synthetic polyester film 200 microns) for printing were selected based on their durability properties. Ishihara’s PIP was made on paper based material. The exact material used for Ishihara is unknown, because of various editions and usage of inconsistent paper materials from time to time by various publishers across the globe. Thereby we choose the best substrate from the list of substrates (mentioned above) which were considered good for print durability.

Each substrate was printed with newly designed Dalton’s PIP under three printing processes which were Dry electrophotography, Liquid electrophotography and UV inkjet. Each substrate which was printed in these three printing processes was evaluated for consistency in color, print surface quality and cost effectiveness. The print surface quality and color consistency was evaluated visually and through spectrophotometer. The cost effectiveness was evaluated based on the price of substrate and printing. After all these evaluations, ‘Dry electrophotography’ was found to be the best printing technology for printing ‘Dalton’s PIP’. Figure 2 shows you the different substrate printed under ‘Dry electrophotography printing process’. Table 1 shows you the assessment results of various printing processes.

PRINTING TECHNOLOGY	PRINT SURFACE QUALITY	COST EFFECTIVENESS	REPEATABILITY (Color consistency)
Dry Electrophotography	Good	Good	Good
Liquid Electrophotography	Good	Poor	Good
UV Inkjet	Poor	Poor	Good

*Table 1. Analysing different types of printing processes*



*Figure 2. Pictures of various substrate Materials printed under dry electro photography process*

After determining the proper printing process (Dry electrophotography), the substrates which were printed using Dry electrophotography were evaluated for durability, low impact scratch resistance, print surface quality and assessment with color deficient individuals. For testing the durability and low impact scratch resistance, substrates printed under dry electrophotography process were immersed into a beaker containing distilled water and were left for 48 hours. Figure 3 shows you a substrate undergoing water durability test.



**Figure 3.** Water durability test (Substrate is immersed in distilled water for 48 hours).  
Substrate shown in this figure is PET 200 microns

After 48 hours the substrates were taken from the beaker and left dry for a minute. Then a cotton swab is taken and rubbed forcefully on the printed substrates, this is called as low impact scratch resistance test. The substrates for which the print stays after the test, is determined to be durable. Figure 4 shows a substrate undergoing low impact scratch resistance test. For uncoated smooth board, during water durability test, there was a minor dispersion of print from the print surface of the substrate after 36 hours. Other substrates except for synthetic polyester (PET) film 200 microns failed the durability test and all substrates except for synthetic polyester(PET) film 125 microns and synthetic polyester (PET) film 200 microns failed the low impact scratch resistance test.



**Figure 4.** Low impact scratch resistance test (cotton swab is rubbed continuously over the printed substrate for a minute) Substrate shown in this figure is PET 200 microns

SUBSTRATE NAME	DURABILITY	PRINT SURFACE QUALITY	LOW IMPACT SCRATCH RESISTANCE	ASSESSMENT OVER COLORVISION DEFICIENT SUBJECTS
coated art board 300 GSM	Poor	Good	Poor	Good
uncoated smooth board 300 GSM	Poor	Good	Poor	Good
uncoated ivory texture board 250 GSM	Poor	Good	Poor	Good
synthetic poly-ester(PET) film 125 microns	Poor	Good	Good	Good
synthetic poly-ester(PET) film 200 microns	Good	Good	Good	Good

**Table 2.** Analysing various substrate materials under different testing parameters

## Results and discussion

Based on our evaluations, we found ‘dry electro photography’ printing technology as the best method to print Dalton’s Pseudo isochromatic plates. And the best substrate on which Dalton’s PIP has to be printed is determined to be ‘synthetic polyester (PET) film 200 microns’. Optometrists from Elite school of Optometry, Chennai have further validated the newly printed Dalton’s pseudo isochromatic plates by comparing with Ishihara pseudo isochromatic plates among 1000 school children in their school vision screening programme. The sensitivity and the specificity of the Dalton’s PIP was found to be 98.40% and 94.12% respectively and the positive and negative predictive values were 99.90% and 100% respectively. The design and clinical validation of Dalton’s pseudo isochromatic plates were done by the Optometrists from Elite School of Optometry, Chennai, India. For a printed medical examination tool, in order to serve the purpose must be printed in the best substrate and with the best printing process. Our assessment methods and results ensure that the newly developed Dalton’s Pseudo isochromatic plates will be very durable, highly reliable and cost effective against the existing tools.

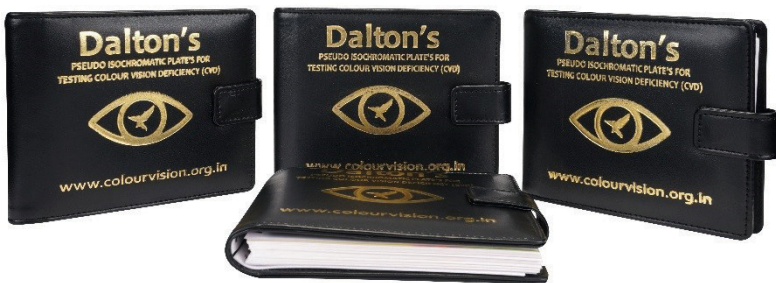


Figure 5(a)

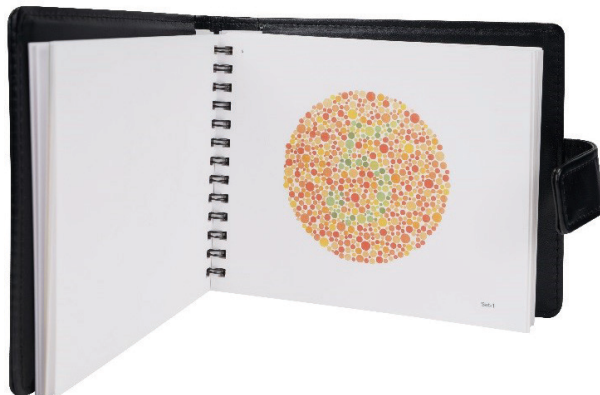


Figure 5 (b)

Figure 5 (a), (b). Dalton's PIP's (Final finished tool)

The outcomes of newly developed Dalton's pseudo isochromatic plates were really encouraging among the Optometrists & Ophthalmologists of India as this tool will be highly beneficial in detecting color vision deficiency for large populations in minimal time. Also, they will be able to pre screen school childrens for color vision deficiency and provide remedies accordingly.

### **Conclusions**

This study presents the results that the newly developed 'Dalton's pseudo isochromatic plates' the color vision deficiency testing tool could be best printed under dry electro photography printing process on synthetic polyester(PET) film 200 microns substrate. Further, this study would be highly beneficial for future researches on the printing requirements for medical grade tests.

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