# The identification of tattoo designs under cover-up tattoos using digital infrared photography.

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## Abstract

This paper looks at the role that digital infrared photography has as technique for identifying primary tattoos even if they have been covered up with additional tattoos. The study's goal was to look at a sufficient number of cover-up tattoos using infrared photography to enable the technique to be used more widely and so that the reasons for successful and unsuccessful infrared photography of primary tattoos through cover-up tattoos could be elucidated. 36 tattoos were photographed in infrared along with colour control records. The results showed that primary tattoos could be visualized to some extent in 55.6 % of the cover-up tattoos and very well in 38.9%, this still left some 44.4% where the design of the primary tattoo could not be seen. The extent of visibility of underlying designs was found to depend on the ink colour, ink density and how the tattooist covering up the tattoo did or did not incorporate the existing tattoo into the new design.

## Introduction

For the purpose of this paper we refer to tattoos created over existing as "Cover-up tattoos", as in some instances there are not one but many revisions of existing tattoos and the initial tattoo as the "Primary tattoo".

The increasing trend in having a new tattoo placed over an existing tattoo, whether to update to a more fashionable design or to cover-up tattoos that were poorly executed or whose meaning has become inappropriate with change in personal directions and ideas, means the need to identify primary tattoos could become forensically significant. The ease and low cost of having further tattoos, compared to laser ablation or surgical removal, means that cover-up tattoos could be used by offenders with distinctive tattoos to change their appearance and so avoid identification.

Techniques using infrared photography were first used by Abney as early as 1880, then Vogel using dyes to sensitize emulsions which were further developed by Eastman Kodak and others into commercial products such that by 1933 'there were about a dozen well-known infra-red and extreme red sensitive materials on the market' [1]. In 1938 Jörg [2] looking at the use of infrared photography in criminalistics and medicine found that black and white film sensitized to infrared together with a Kodak Wratten 87 filter could be used to record tattoos following surgical removal which were not visible using Panchromatic film with a light red or orange filters. This was referred to regularly in later books on infrared photography but little further work on infrared photography and tattoos was undertaken until the 1990s and more recently using digital photography rather than silver-based black and white infrared films.

When looking at an infrared photographic record we are looking at whether the skin, dyes and substrates reflect, transmit or absorb infrared. Anything that absorbs infrared will appear dark anything that reflects or transmits infrared will appear lighter or transparent.

Recent research has looked at the ability of infrared to penetrate the darkened skin of mummified bodies in archaeology [3, 4] and at post-mortem Starkie 2011 [5] or through the skin following laser removal as in McKechnie's 2008 study using digital photography [6]. It can also be used to penetrate dyes to reveal other writing [7] or to enhance the contrast between writing and substrates which reflect more infrared than visible light [8,9].

## Materials and methodology

The research was undertaken using a Fuji S5 IS Pro camera, 70mm Sigma Macro lens and Metz 45 CL-4 flashgun. The Fuji S5 IS Pro is sensitive to light from 400nm – 900nm [10] and requires an ultraviolet/ infrared cut-off filter to take normal colour photographs. Research by Tetley and Young has shown that the Fuji IS Pro records infrared in all three channels Red, Green and Blue(RGB) [11]. For this project a Schneider Optics (B+W) 486 interference filter was used for the colour control photographs and for the infrared records a Kodak Wratten 87 filter, see Figure 1. The technique will also work with Kodak Wratten 89B, 88A as well as 87 and infrared filters made by other manufacturers.

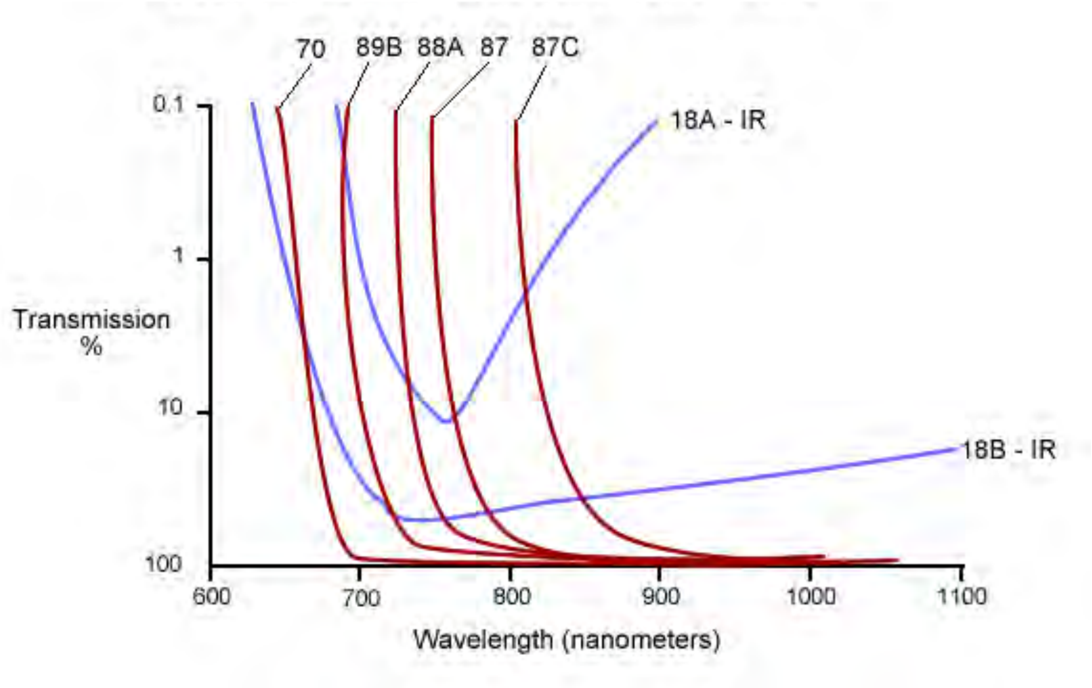



Figure 1 Kodak Wratten transmission of ultraviolet and infrared filters in the red to infrared region of the spectrum.

When working with near-infrared it is necessary to make a small adjustment in focus as these wavelengths are not focused to the same point as colours of the visible spectrum on the film plane [12, 13]. To provide sufficient depth of field and uniformity of illumination flash was used and the aperture set at f5.6 to f/8. As recommended by Fuji the cameras film speed was set with at ISO 200 and files were saved as RAW files (.RAF) before being converted to jpgs.

Photographs of tattoos were taken first with the UV/IR cut-off filter in place to give a colour control record and then with the infrared filter in place to give an infrared record. The infrared records were converted to black and white by discarding the colour data. These records included a Macbeth colour scale, grey scale and 'L' shaped scale for measurement, see Figure 2. The impact of infrared filtration can be seen on the Macbeth colour scale by comparing Figure 3a and 3b where the only colour that absorbs and doesn't transmit infrared is black and alongside it the 18% grey rectangle which is printed using black.

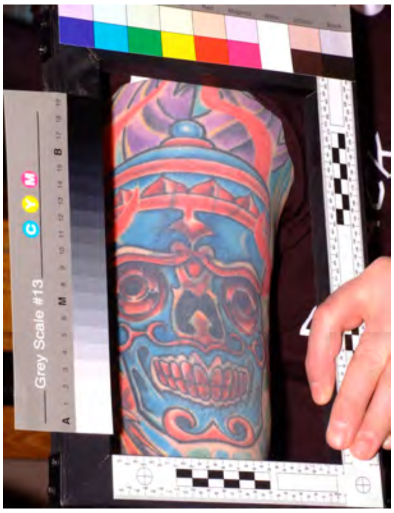


Figure 2 Record showing use of Greyscale (Left), Macbeth Chart (Upper) and Scale (Right and Lower).

Consent for photography was obtained from the participants along with anonymised personal data about their tattoos. The data recorded included the age of the first tattoo, age of the cover-up tattoo and any subsequent tattoos, the design of the first tattoo, cover-up tattoo and subsequent tattoos. This was kept separately from the photographic records but cross-referenced using simple codes for individual tattoos. A total of 36 cover-up tattoos were photographed on 33 individuals, 3 of these had 2 cover-up tattoos.

The colour and infrared photographs of the tattoos were analysed and the methodology further developed to include grading criteria to help determine the value of the infrared records compared to control records in visualizing designs under cover-up tattoos, see Figures 3, 4, 5 and 6 for examples of each of the grades and Table 1 for the grade descriptors. Each subject's tattoos were then assessed by examining what could be seen using the infrared photographs compared to the primary tattoo design.

| Grade | Description |
|---|---|
| 0 | None of the original tattoo could be seen, Figures 3a and b. |
| 1 | Design difficult to distinguish but some features partly visible, Figures 4 a and b. |
| 2 | Design visible but with some parts obscured by the cover-up tattoo, Figures 5 a and b. |
| 3 | Clear design not obscured by the cover-up tattoo, Figures 6 a and b. |

Table 1 Grading descriptors for visibility of primary tattoos under cover-up tattoos using infrared photography.

**Results**

In photographing single or multiple tattoos there are a number of different combinations that may occur:

- There is only one tattoo or part of a tattoo with no underlying tattoo, see Figures 7a and b
- There may be two or more layers of tattoos one on top of the other, see Figures 3-6.

The designs of primary tattoos were found to be visible to some extent, Grades 1, 2 and 3 in over half of the subjects (55.6%), with clear visualization, Grades 2 and 3, in 38.9%. This means that there were a large number 20 (44.4%) of tattoos where no underlying tattoo could be visualized, see Table 2.

In examining the colour and infrared photographs it was clear that there were a number of characteristics that helped or hindered identification of the underlying tattoo; the colour or colours of the dyes used in the cover-up tattoos and how the tattooist has or has not incorporated the design of the underlying tattoo into the cover-up tattoo, see Table 3. The age of the cover-up tattoos was also noted and it can be seen in Table 4 that there is a tendency for older cover-up tattoos to be unsuccessful.

Table 5 shows a summary of what was found through analyzing the infrared photographs and the features of cover-up tattoos and the characteristics that determine whether the underlying tattoo can be successfully visualized.

| Grade | No of tattoos |
|---|---|
| 0 | 16 (44.4%) |
| 1 | 6 (16.7%) |
| 2 | 11 (30.6%) |
| 3 | 3 (8.3%) |
| Total | 36 |

Table 2 Grading of infrared records for visibility of the tattoo under the cover-up tattoo.

| Reason for not seeing primary tattoo | No of tattoos |
|---|---|
| Black cover tattoo | 11 (68.5%) |
| Original tattoo design incorporated into cover design | 3 (18.75%) |
| Similar ink colours in both cover-up and primary tattoos | 1 (6.25) |
| Laser removal treatment before cover-up | 2 (12.5%) |
| | 16 |

Table 3 Reasons for unsuccessful tattoos

| Time since cover-up tattoo applied | Successful | Unsuccessful |
|---|---|---|
| <1 year | 8 | 4 |
| 1 to <5 Years | 3 | 8 |

| | | |
|---|---|---|
| 5 to <10 Years | 2 | 3 |
| 10 – 20 Years | 0 | 1 |

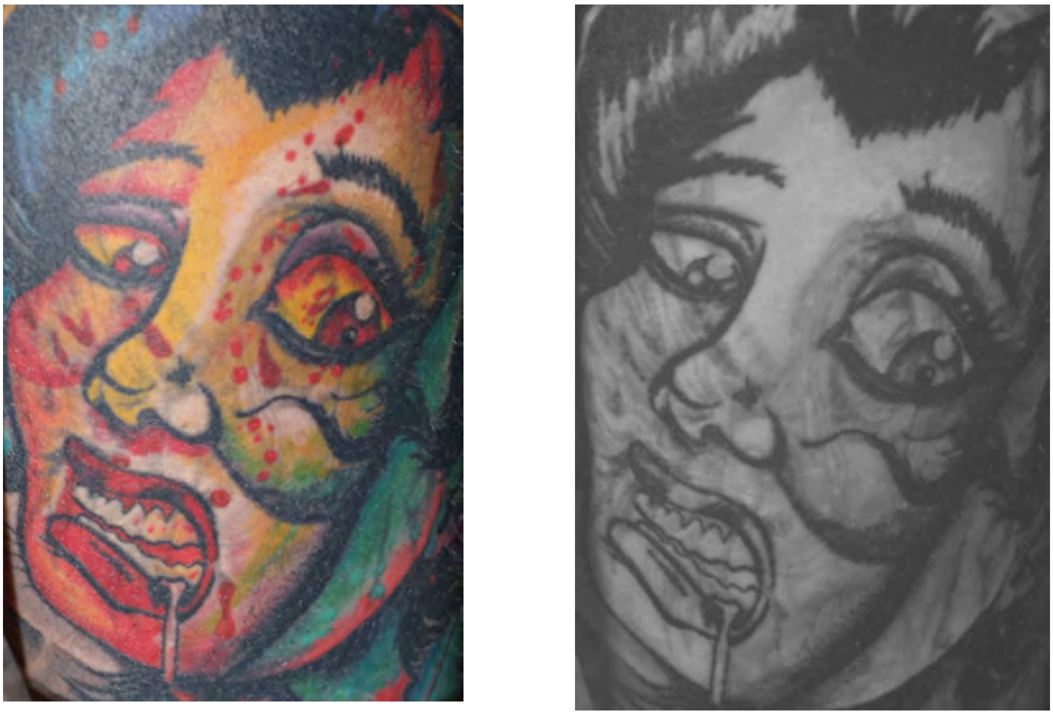
Table 4 Time since cover-up tattoo

| **Feature** | **Criteria for successful visualization** | **Criteria for unsuccessful visualization** |
|---|---|---|
| Dye colour | Yellow, Red, Green, Blue, Light purple | Dark purple, black cover tattoo |
| Dye density | Light / Pale tattoos | Colour inks combined different amounts of black the more black the less visible. |
| Cover design | Separate designs | Original design integrated into cover design. |

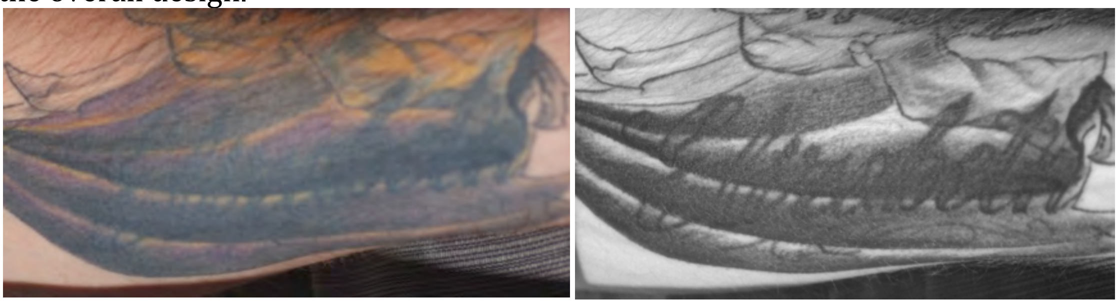
Table 5 Summary of features of cover-up tattoos and the characteristics that determine whether the underlying tattoo can be successfully visualized.

**Control colour record** **Infrared record**

Figures 3 a) Colour control and b) Infrared record – Grade 0. Case 8 None of the primary tattoo was visible through the cover-up tattoo.



Figures 4 a) Colour control and b) Infrared record - Grade 1. Case 32 Some of the features of the primary tattoo are visible but not enough to be able to determine the overall design.



Figures 5 a) Colour control and b) Infrared record - Grade 2. Case 3 Some of the writing was visible with the colour record but more can be seen with the infrared record despite the realtively dense cover-up tattoo so the word 'Elizabeth' can be seen.

Figures 6 a) Colour control and b) Infrared record - Grade 3. Case 26 The primary tattoo can be seen slightly in the colour record but is completely visible using infrared photography as the cover-up tattoo is transparent to infrared. On detailed examination some depigmentation can be seen, similar to Figure 7b over parts of where the butterfly is tattooed.

**Discussion**

Jörg [3] and McKechnie [6] were concerned with the ability of infrared to penetrate the skin so that any remaining pigmentation, in the papillary layer of the epidermis or the dermis itself, could be visualized. In contrast we are looking at the ability of infrared to penetrate the dyes of the cover-up tattoo so that the primary tattoo can be visualized. This ability of infrared to penetrate or "see through" the cover-up tattoo has been found to depend on the comparative absorption and transmission characteristics of the dyes used in the cover-up tattoo. This is similar to the use of infrared to examine inks [7, 14], powder burn patterns on clothing and textiles [15] and the ability to visualize blood on dark textiles [16].

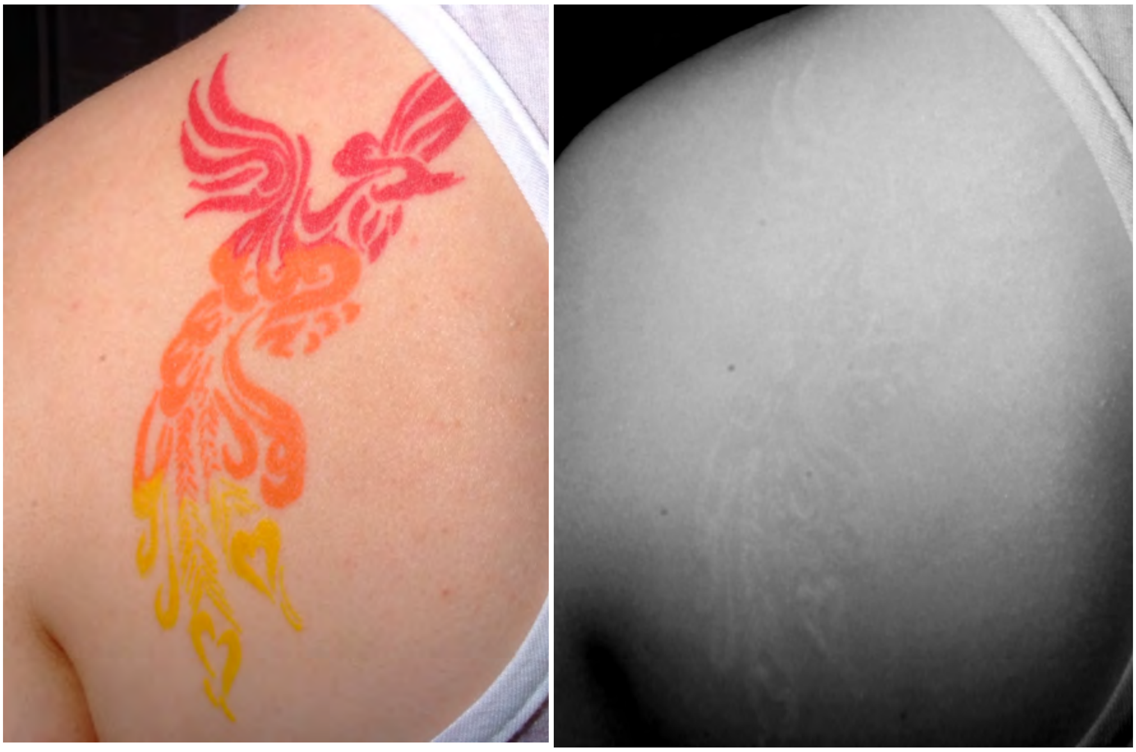


Figure 7 a) Colour record of red, orange and yellow tattoo, b) Infrared record seeing through the dyes but also showing depigmentation of the skin following healing of the tattoo.

If a particular dye does not absorb infrared but instead transmits it then we will not see that dye but the absorption or reflection of the underlying dye or skin. For example in Figures 7a and 7b the difference between the colour record where the red, orange and yellow of the tattoo can be seen compared to the infrared record where the tattoo dyes transmit the infrared so we see the underlying skin, in this instance we can also see the depigmentation of the skin following healing of the skin after the tattoo. Similarly in Figure 6a the cover-up tattoo can be seen in the colour record, with slight visibility of the underlying tattoo, but only the underlying tattoo is visible in the infrared record Figure 6b, so we are looking through the cover-up tattoo as the dyes used in the cover-up tattoo transmit infrared.

The other feature that affects infrared transmission through a tattoo was found to be the density of the dye. In terms of visual appearance this means the colours appear more saturated but from looking at the infrared records the greater the density, added black, the less transparency even with a colour that when lighter lets infrared through. For example in Figure 3 where although the tattoo ink is green, normally a dye that can be seen through, the quantity of black mixed with the dye means that the infrared is absorbed rather than transmitted through the tattoo so the primary tattoo cannot be seen.

The finding that older cover-up tattoos are less likely to be transparent to infrared is due not to the age of the tattoo but the change from tattoos being monochrome, usually black only including cover-up tattoos, to the more recent fashion trends of using coloured tattoos and many of these fairly pale rather than heavy in colour. So as more recent cover-up tattoos use coloured dyes the primary tattoo is more likely to be visualized using infrared photography.

In analyzing the colour control and the infrared records we found that as well as the infrared transmission characteristics of the dyes used for the cover-up tattoos a key feature was how the cover-up tattoo was designed whether the tattoo was literally just a cover-up or the new design incorporated part or all of the old design into the new design, see Table 3.

## Conclusion

The use of digital infrared photography provides an easy mechanism to look at the tattoos underneath cover-up tattoos or to show whether the individual has had more than one tattoo on the same part of the body. However, it is clear that this technique does not work with every cover-up tattoo especially where the ink is dense, there is a significant amount of black in a dye or the designs blend too well into each other so are indistinguishable one from the other.

In preliminary investigations it was found that tattooists often mix their own inks, to go with their particular style, and that these mixes are very much part of their intellectual property and are trade secrets. So examining the infrared absorption/transmission characteristics of different tattooist's dyes, along with looking at the significance of identification of tattoo designs by experts compared to non-experts and to what extent when a cover-up design is incorporated into the original design this affects identification of a primary tattoo will be useful directions for future research.

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