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REVIEW ARTICLE

Do Gel Manicures Affect SpO_2 Readings? A Clinical Investigation

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ABSTRACT

Background: Pulse oximetry is a vital non-invasive method for monitoring oxygen saturation (SpO_2). However, factors such as nail polish and artificial nails can potentially affect accuracy. Gel-based manicures, widely used for their durability, may interfere with SpO_2 readings. This study evaluates the impact of gel manicures on pulse oximetry accuracy.

Methods: A prospective observational study was conducted in Akash institutes of Medical Sciences, including 25 healthy volunteers with and without gel manicures. SpO_2 was measured on gel-painted and unpainted nails using a standard pulse oximeter. A comparison was made between the two readings using paired t-tests.

Results: A statistically significant difference ($p < 0.05$) was observed in SpO_2 readings between gel-painted and unpainted nails. The mean SpO_2 recorded from gel-painted nails was lower than that from unpainted nails.

Conclusion: Gel-based manicures significantly impact pulse oximetry readings, potentially leading to false hypoxia alarms. Clinicians should consider alternative measurement sites (earlobe, forehead) in patients with gel manicures.

KEYWORDS

• Pulse oximetry • SpO_2 • Gel nail polish • Artificial nails • Hypoxia detection

INTRODUCTION

Pulse oximetry, generally known as the fifth vital sign, is a rapid, non-invasive monitoring method utilised to assess oxygen saturation in the bloodstream.[1] This technique involves the transmission of light at specific wavelengths

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through tissue, typically the fingernail bed providing heart rate measurements and tissue perfusion based on pulse amplitude.[2] It is an accepted practice in most non-critical care areas.[3] Normal arterial blood oxygen saturation (SpO2) level at room temperature ranges between 96% and 100%.[4]

However, it is important to understand how the technology functions as well as its limitations because erroneous readings can lead to unnecessary testing and wrong management. Multiple factors can affect the SpO_2 reading. Endogenous factors such as low perfusion (secondary to hypothermia, low cardiac output, increased systemic vascular resistance, profound anaemia, etc) and dyshaemoglobinaemias (e.g. carboxyhemoglobinemia and methaemoglobinaemia) can compromise the SpO_2 readings.[2]

Exogenous factors such as excessive ambient light or motion, intravenous dyes and nail polish may cause artefactual readings.[3] As the use of fingernail polish can potentially alter the SpO2 readings in normal subjects, removal of the polish is commonly recommended prior to measurement.[5]

Gel nail polishes represent an advanced class of acrylic based nail polishes, with the ability to cure under ultraviolet (UV) radiation, and consequently demonstrate improved properties and greater durability compared to conventional nail polishes and hence has gained popularity recently.[6] However, removal of such nail polish is difficult and requires special assistance, also patients are often resistant to removal because of its elaborate and costly designs.[5] The thickness and opacity of the gel, as well as the presence of colours and additives, could potentially interfere with the light absorption and emission process.[7]

To our knowledge, only one study has been conducted by Jia Lin Jacklyn Yek et al. in 2019 in Singapore where black colour gel nail polish has found to significantly lower the SpO2 readings and orange and light blue colours to significantly increase it.

When conducted on normal Nail Polish, Studies by Coté et al described the effects of black, blue and green fingernail polish to significantly lower SpO2 readings by 3%–6%, postulating that it could be due to the differing spectrophotometric absorption abilities of the colours.

Hence, we evaluated the effects of the gel-based manicure on pulse oximetry by two common oximeters (Mindray and Accuro), which are using different technology and wavelength combinations.

METHODOLOGY

Study Design and Location

This investigation was a randomized, single-blind, self-controlled study conducted at Akash Institute of Medical Sciences and Research Centre, Devanahalli, Bangalore. Ethical approval was granted by the institution ethics committee.

Participants

Twenty-five healthy adult female volunteers aged 21–40 years, classified as American Society of Anesthesiologists Class 1 and of Asian descent, were enrolled after providing written informed consent.

Exclusion criteria included a history of anaemia or hemoglobinopathy, hypothermia (T < 34°C), systolic blood pressure < 90 mmHg, diastolic blood pressure < 50 mmHg, poor plethysmographic waveform, or any nail pathology.

A normal plethysmographic waveform was visually identified by equally spaced, consistently wide waves of uniform amplitude over 10 seconds, whereas a poor waveform displayed an inconsistent or irregular pattern with varying amplitude and wavelength.

Baseline Measurements

Baseline SpO_2 readings were taken on each finger at 30-second intervals.

Randomization and Nail Polish Application

Subjects were randomly assigned a number from 1 to 10 using an online random number generator. Ten pre-selected nail polish colours were numbered as follows:

1. Yellow
2. Brown
3. Pink
4. Red
5. Green
6. Lilac

7. Blue
8. Black
9. Skin colour
10. White

Fingernails were painted sequentially from the left little finger to the right little finger, starting with the finger corresponding to the randomly assigned number.

Figure 1: Demonstration of Gel Nail Polish Color Application

Each fingernail was painted with a different gel nail polish color to assess the impact of various shades on pulse oximetry readings. Colors applied (from left to right): Yellow, Brown, Maroon, Red, Green, Blue, Dark Blue, Black, Skin Color, and White. SpO_2 readings were recorded using two pulse oximeters (Mindray and Accuro) at defined time intervals from each finger.

Pulse Oximetry Measurements

SpO_2 measurements were obtained using two devices: the Mindray Pulse Oximeter on a Drager Vista 120 Monitor and the Accuro tabletop Pulse Oximeter.

The Mindray sensor emits light at wavelengths of 660 nm and 940 nm, while the Accuro device uses wavelengths of 660 nm and 905 nm. These models were chosen due to their frequent use in our clinical setting and to demonstrate the effects of varying wavelengths and technologies.

Nail Polish Application Procedure

GLAM gel nail polish (Diamond House, Bandra, India) was applied by a professional nail technician. Each nail was coated with a base coat, two layers of gel polish, and a top coat, with an LED light used to cure the polish between applications.

Measurement Procedure

All SpO_2 readings were taken in room air with subjects seated to minimise motion artefacts and ambient light interference. Measurements were recorded before and after nail polish application, using the subject's unpainted finger as a control. A blinded observer, unaware of the subject and nail polish colour, recorded the measurements.

The pulse oximetry probe was placed directly on the nail bed, and readings were taken at initial stabilisation, then at 30 seconds, 60 seconds, 1 minute, and 2 minutes.

Data Dropout

Data dropout was defined as instances where a poor pulsatile SpO_2 waveform was observed after two minutes of probe repositioning and manual stabilisation, as documented by the independent observer.

For the Mindray pulse oximeter, no readings could be obtained in 15 instances, for eight green, five blue and two black nails, and these were treated as missing values in the data analysis.

Along with that, readings were missing at 10 seconds interval for 5 subjects, one for yellow, one for brown, one for pink, one for red and one for lilac and were also treated as missing values. For the Accuro pulse oximeter, waveform was lost in 2 subjects at 10 seconds, one for brown and one for black, a delay in the initial reading was noticed in one subject with white colour nail polish and not considered for statistical analysis.

Statistical Analysis

Data was entered into Microsoft excel data sheet and was analyzed using SPSS 22 version software. Categorical data was represented in the form of Frequencies and proportions. Normality of the continuous data, was tested by

Kolmogorov–Smirnov test and the Shapiro–Wilk test.

ANOVA (Analysis of Variance) was the test of significance to identify the mean difference between more than two groups for quantitative data.

Graphical representation of data: MS Excel and MS word was used to obtain various types of graphs such as Line diagram, bar diagram.

p value (Probability that the result is true) of <0.05 was considered as statistically significant after assuming all the rules of statistical tests.

Statistical software: MS Excel**,** SPSS version 22 **(**IBM SPSS Statistics, Somers NY, USA) was used to analyze data.

RESULTS

Table 1: Profile of subjects

Age (Years)		Mean	SD	Median
		28.76	4.31	28
HR		82.61	9.55	80
Right	SBP	115.91	6.54	116
	DBP	78.78	6.92	78
Left	SBP	116.61	4.41	118
	DBP	79.30	6.28	80

- The study included subjects with a mean age of 28.76 ± 4.31 years, with a median age of 28 years. The mean heart rate (HR) was 82.61 ± 9.55 bpm, with a median of 80 bpm.
- Blood pressure measurements showed a right-sided systolic blood pressure (SBP) of 115.91 ± 6.54 mmHg and a diastolic blood pressure (DBP) of 78.78 ± 6.92 mmHg, while the left-sided SBP was 116.61 ± 4.41 mmHg and DBP was 79.30 ± 6.28 mmHg.

Table 2: Time taken to read Pulse oximetry

			Mean	SD	P value
Time taken to read	Time taken to read Accuro	234	6.37	4.128	0.279
	Time taken to read Mindray	234	6.70	2.740	

The time taken to read pulse oximetry values using Accuro device was 234 ± 6.37 seconds, compared to 234 ± 2.74 seconds for Mindray device. The difference in reading times between the two methods was not statistically significant (P = 0.279).

Comparison of mean SpO_2 readings recorded over six time intervals using Mindray and Accuro pulse oximeters. Mindray consistently shows higher values.

Table 3: Comparison of Pulse oximetry readings between ACCURO and MINDRAY methods at different time intervals

	ACCURO			MINDRAY			P value
	Mean	SD	Median	Mean	SD	Median	
BASELINE	96.43	1.63	97	97.37	1.33	97	<0001*
10s	97.00	1.91	97	98.00	1.38	98	<0001*
30s	96.66	1.64	97	97.97	1.31	98	<0001*
60s	96.63	1.57	97	97.93	1.33	98	<0001*
90s	96.66	1.47	97	97.92	1.27	98	<0001*
120s	96.69	1.40	97	97.93	1.28	98	<0001*

The comparison of pulse oximetry readings between the Accuro and Mindray devices at various time intervals revealed significant differences. At baseline, the mean pulse oximetry reading for the Accuro device was 96.43 ± 1.63, whereas for the Mindray device, it was higher at 97.37 ± 1.33, with a statistically significant difference (P < 0.0001). At 10 seconds, the mean reading for the Accuro device increased slightly to 97.00 ± 1.91, while the Mindray device showed a mean of 98.00 ± 1.38, maintaining a significant difference (P < 0.0001). This trend continued at subsequent intervals, with the Accuro device showing mean readings of 96.66 ± 1.64 at 30 seconds, 96.63 ± 1.57 at 60 seconds, 96.66 ± 1.47 at 90 seconds, and 96.69 ± 1.40 at 120 seconds. In contrast, the Mindray device consistently had higher mean readings of 97.97 ± 1.31 at 30 seconds, 97.93 ± 1.33 at 60 seconds, 97.92 ± 1.27 at 90 seconds, and 97.93 ± 1.28 at 120 seconds. Each comparison between the two methods at these intervals showed highly significant differences (P < 0.0001). These results indicate that the Mindray device consistently produces higher pulse oximetry readings compared to the Accuro device across all measured time intervals.

Mean SpO_2 values (in %) obtained using the Accuro pulse oximeter for Yellow, Brown, and Pink gel-based manicures over multiple intervals.

Table 4: Pulse Oximetry Findings at Different Intervals and Comparison with Baseline for Accuro Device

	Yellow			Brown			Pink		
	Mean	**SD**	**P value**	**Mean**	**SD**	**P value**	**Mean**	**SD**	**P value**
Baseline	97.28	1.67		96.76	1.74		96.50	1.25	
10s	97.16	2.08	0.843	97.21	1.82	0.388	96.71	1.60	0.564
30s	97.16	1.65	0.827	96.60	1.26	0.733	96.17	1.66	0.370
60s	97.08	1.55	0.710	96.56	1.61	0.695	96.50	1.47	1.000
90s	97.08	1.44	0.704	96.76	1.59	1.000	96.29	1.40	0.553
120s	96.88	1.30	0.395	96.48	1.42	0.577	96.42	1.28	0.784

Mean SpO_2 values (in %) recorded using the Accuro pulse oximeter for subjects with Red, Green, Light Blue, Dark Blue, Black, Skin Colour, and White manicures.

Table 5: Pulse Oximetry for Different Colours at Specific Time Intervals

	Red			Green			Light Blue		
	Mean	**SD**	**P value**	**Mean**	**SD**	**P value**	**Mean**	**SD**	**P value**
Baseline	96.00	1.08		96.13	1.19		96.28	2.87	
10s	96.36	1.38	0.288	96.52	1.58	0.295	96.80	2.72	0.494
30s	96.56	1.36	0.115	96.44	1.78	0.480	96.44	2.04	0.790
60s	96.12	1.48	0.730	96.12	1.42	0.906	96.52	1.56	0.685
90s	96.32	1.38	0.382	96.12	1.48	0.806	96.36	1.60	0.899
120s	96.52	1.48	0.163	96.04	1.21	0.684	96.72	1.34	0.403

	Dark Blue			Black		
	Mean	**SD**	**P value**	**Mean**	**SD**	**P value**
Baseline	96.08	1.38		96.28	1.17	
10s	97.40	1.63	0.002*	96.67	1.79	0.324
30s	96.28	2.11	0.645	96.46	1.53	0.543
60s	96.36	2.20	0.545	96.64	1.47	0.356
90s	96.64	1.66	0.143	96.60	1.29	0.319
120s	96.52	1.85	0.240	96.64	1.44	0.327

	Skin Colour			White		
	Mean	**SD**	**P value**	**Mean**	**SD**	**P value**
Baseline	96.56	1.36		96.44	1.69	
10s	97.28	2.37	0.214	97.88	1.54	0.002*
30s	97.28	1.28	0.056	97.16	1.37	0.089
60s	97.32	1.44	0.034*	97.08	1.08	0.158
90s	97.28	1.24	0.026*	97.16	1.28	0.113
120s	97.32	1.22	0.021*	97.32	1.07	0.038*

Accuro Device

Yellow Group: The baseline mean pulse oximetry value for the Yellow group was 97.28 ± 1.67. Across different intervals (10s, 30s, 60s, 90s, and 120s), there were no significant changes in mean values when compared to baseline, with P values all above 0.05.

Brown Group: The baseline mean was 96.76 ± 1.74. Similar to the Yellow group, no significant changes were observed at different time intervals, with P values indicating no statistical significance (all $P > 0.05$).

Pink Group: The baseline mean was 96.50 ± 1.25. At 10s, 30s, 60s, 90s, and 120s, there were no significant changes from baseline (P > 0.05).

Red Group: Starting at a baseline mean of 96.00 ± 1.08, there were no significant changes at subsequent intervals (10s, 30s, 60s, 90s, and 120s), as all P values exceeded 0.05.

Green Group: The baseline mean was 96.13 ± 1.19. Throughout the intervals, no significant changes from baseline were noted (all P > 0.05).

Light Blue Group: Starting at a baseline mean of 96.28 ± 2.87, there were no significant changes at the subsequent time points (all P > 0.05).

Dark Blue Group: The baseline mean was 96.08 ± 1.38. At 10 seconds, a significant increase was observed (P = 0.002). No other significant changes were noted at later intervals (P > 0.05).

Black Group: The baseline mean was 96.28 ± 1.17. No significant changes were observed at different time points (all P > 0.05).

Skin Colour Group: The baseline mean was 96.56 ± 1.36. Significant increases were observed at 60s (P = 0.034), 90s (P = 0.026), and 120s (P = 0.021).

White Group: The baseline mean was 96.44 ± 1.69. Significant increases were observed at 10s (P = 0.002), and 120s (P = 0.038).

Mean SpO_2 values (in %) from the Mindray pulse oximeter for Yellow, Brown, and Pink gel-based manicure groups.

Table 6: Pulse Oximetry Findings at Different Intervals and Comparison with Baseline for Mindray Method

	Yellow			Brown			Pink		
	Mean	**SD**	**P value**	**Mean**	**SD**	**P value**	**Mean**	**SD**	**P value**
Baseline	97.92	1.04		97.40	1.19		97.13	1.42	
10s	98.33	1.24	0.106	98.08	1.18	0.057	98.22	.95	0.01*
30s	98.28	1.10	0.153	97.96	1.21	0.110	98.13	.80	0.007*
60s	98.36	.91	0.031*	98.00	1.00	0.053	98.04	.86	0.02*
90s	98.20	1.00	0.230	98.04	1.24	0.069	98.00	.83	0.023*
120s	98.00	.96	0.679	97.76	1.13	0.257	98.04	1.00	0.021*

	Red			Green			Light Blue		
	Mean	**SD**	**P value**	**Mean**	**SD**	**P value**	**Mean**	**SD**	**P value**
Baseline	97.44	1.16		97.36	1.11		97.48	1.19	
10s	98.00	1.29	0.124	97.47	2.10	0.557	97.60	1.47	0.714
30s	98.00	1.22	0.075	97.94	1.70	0.095	97.33	1.76	0.730
60s	98.04	1.31	0.066	98.06	1.76	0.053	97.13	1.70	0.350
90s	97.88	1.01	0.126	98.17	1.47	0.015*	97.38	1.53	0.824
120s	98.04	1.24	0.096	97.88	1.69	0.165	97.46	1.64	1.000

	Dark Blue			Black		
	Mean	**SD**	**P value**	**Mean**	**SD**	**P value**
Baseline	97.56	1.23		97.52	1.29	
10s	98.15	1.39	0.054	97.43	1.67	0.686
30s	97.95	1.39	0.144	97.70	1.52	0.843
60s	98.05	1.57	0.076	97.43	1.62	0.717
90s	98.25	1.16	0.009*	97.65	1.56	0.929
120s	98.20	1.32	0.028*	97.73	1.52	0.842

	Skin Colour			White		
	Mean	SD	P value	Mean	SD	P value
Baseline	97.08	1.66		96.80	1.71	
10s	98.08	1.26	0.024*	98.52	.96	0.001*
30s	98.04	1.27	0.023*	98.32	.90	<0.001*
60s	98.04	1.21	0.027*	98.12	1.01	0.001*
90s	97.96	1.24	0.033*	97.80	1.50	0.014*
120s	98.00	1.19	0.023*	98.16	1.11	0.001*

MINDRAY DEVICE

Yellow Group: The baseline mean was 97.92 ± 1.04. A significant increase was noted at 60 seconds (P = 0.031), but not at other intervals (P > 0.05).

Brown Group: The baseline mean was 97.40 ± 1.19. A significant increase was observed at 10 seconds (P = 0.057), but not at other intervals (P > 0.05).

Pink Group: The baseline mean was 97.13 ± 1.42. Significant increases were noted at 10s (P = 0.01), 30s (P = 0.007), 60s (P = 0.02), 90s (P = 0.023), and 120s (P = 0.021).

Red Group: The baseline mean was 97.44 ± 1.16. No significant changes were noted at any time intervals (P > 0.05).

Green Group: The baseline mean was 97.36 ± 1.11. A significant increase was observed at 90 seconds (P = 0.015), but not at other intervals (P > 0.05).

Light Blue Group: The baseline mean was 97.48 ± 1.19. No significant changes were noted at any time intervals (P > 0.05).

Dark Blue Group: The baseline mean was 97.56 ± 1.23. Significant increases were observed at 90 seconds (P = 0.009) and 120 seconds (P = 0.028).

Black Group: The baseline mean was 97.52 ± 1.29. No significant changes were observed at any time intervals (P > 0.05).

Skin Colour Group: The baseline mean was 97.08 ± 1.66. Significant increases were noted at 10s (P = 0.024), 30s (P = 0.023), 60s (P = 0.027), 90s (P = 0.033), and 120s (P = 0.023).

White Group: The baseline mean was 96.80 ± 1.71. Significant increases were observed at 10s (P = 0.001), 30s (P < 0.001), 60s (P = 0.001), 90s (P = 0.014), and 120s (P = 0.001).

DISCUSSION

This study aimed to explore the impact of gel-based manicures on pulse oximetry readings using two distinct devices: ACCURO and MINDRAY. Our findings provide valuable insights into how these devices and the gel-based manicure interact, potentially affecting pulse oximetric accuracy.

Our study, with a mean age of 28.76 ± 4.31 years and a median age of 28 years, exhibited baseline cardiovascular parameters within normal ranges, including a mean heart rate of 82.61 ± 9.55 beats per minute. Both devices recorded oxygen saturation levels at baseline, with the Mindray device consistently showing higher readings compared to the Accuro device (97.37 ± 1.33% vs. 96.43 ± 1.63%, respectively; P < 0.0001). This discrepancy persisted across all measurement intervals, indicating a systematic divergence between the devices, likely due to differences in calibration or technology.

The time required to obtain pulse oximetry readings did not significantly differ between the Accuro (234 ± 6.37 seconds) and Mindray (234 ± 2.74 seconds) devices (P = 0.279), suggesting that differences in measurement duration do not account for the observed discrepancies.

Gel-based manicures influenced pulse oximetry readings both transiently and persistently. The Dark Blue Group showed a significant initial increase in readings at 10 seconds (P = 0.002), potentially due to initial gel application effects on sensor sensitivity or signal transmission. In contrast, the Skin Colour Group displayed significant increases at 60 seconds (P = 0.034), 90 seconds (P = 0.026), and 120 seconds (P = 0.021) for both devices, indicating a cumulative effect over time. The White Group also showed significant increases at 10 seconds (P = 0.002) and 120 seconds (P =

0.038), suggesting intermittent influence. The Pink Group demonstrated consistent increases across all time intervals with the Mindray device, with P-values ranging from 0.01 to 0.021, indicating a persistent impact of gel-based manicures on pulse oximetry readings, potentially through alterations in peripheral circulation or sensor performance.

The consistently higher readings from the Mindray device could be attributed to technological differences or calibration variances. This highlights the need for standardization and calibration to ensure accurate and comparable measurements across different devices.

Our findings align with Jia Lin Jacklyn Yek et al. (2019), who observed that black nail polish impaired SpO2 precision on Philips and Masimo devices, while orange and light blue gel nails increased SpO2 readings on the Masimo device. Yamamoto et al. suggested that the specific light-absorption characteristics of nail polish affect SpO2 readings, a hypothesis supported by Rodden et al.'s spectrophotometric studies.[16]

This study has limitations. It exclusively involved healthy subjects, which may limit the generalizability of findings to patients with significant cardiac or respiratory conditions and lower baseline SpO2 levels. The absence of hypoxic subjects prevented assessment of desaturation effects on pulse oximetry accuracy. Future research involving hypoxic individuals could provide crucial insights, as inaccurate SpO2 readings could delay or miss hypoxemia detection, leading to adverse outcomes. Additionally, co-oximetry was not used for validation, and spectral analysis of nail colors was not performed. Single imputation methods for SpO2 dropout values might have reduced variability associated with nail color. Variations in gel nail polish brands and thicknesses were minimized by using a consistent brand and standardized application.

In conclusion, nail color and gel-based manicures can significantly influence pulse oximetry readings, particularly over longer intervals. Understanding these variations is crucial for improving measurement accuracy and refining diagnostic protocols in clinical practice. Further investigation into the underlying mechanisms is warranted to enhance the reliability of pulse oximetry in diverse clinical settings.

CONCLUSION

This study provides valuable insights into the interaction between gel-based manicures and pulse oximetry readings. While the MINDRAY method consistently yielded higher readings, the impact of the gel-based manicure varied among different colour groups, suggesting both transient and cumulative effects. These findings emphasize the importance of considering such factors in clinical practice and underscore the need for further research into the mechanisms underlying these observations.

Future investigations should focus on exploring the specific physiological and technological mechanisms that contribute to these variations, aiming to develop standardized guidelines for pulse oximetry in the presence of gel-based manicures. Ensuring accuracy and reliability in pulse oximetric measurements is crucial for effective clinical decision-making and patient care.

Conflict of Interest: None

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