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## Short Research Report

# Latent fingerprint development and accuracy using monochrome toner powder in Ibadan, Nigeria.

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**Abstract** - Dermatoglyphics is an essential component of physical anthropology. It has a wide range of applications such as criminology, population studies, phenotypic genetic studies and plays a crucial role in forensic science. This study aimed to assess the matching accuracy of latent fingerprints on a non-porous surface, with a pre-recorded database of patent fingerprints of a given population. Fingerprints were obtained using Dermalog LF10 fingerprint scanner. One hundred and forty-six (95 patent and 52 latent) medical and dental students of College of Medicine, University of Ibadan were recruited using convenience sampling method. The fingerprints were made up of 650 male and 290 female patent fingerprints and 520 latent prints. Monochrome toner powder was used as a developer of latent fingerprints deposited on glass slides. Four hundred and twenty-two latent prints were well developed and admitted for qualitative and quantitative analysis based on set criteria: pattern recognition and minimum of ten minutiae within pattern area were used as the prerequisites for matching between patent and latent fingerprints. GraphPad Prism 7.0 was used for the test of mean of variables. Ulnar and radial loops pattern were the most common types in both patent and latent prints among males and females. The calculation of matching accuracy, precision, specificity, and sensitivity showed 87.4%, 86.7%, 62.4% and 96.5% respectively. The results of matching demonstrate the reliability and the efficacy of monochrome toner powder as a tool for latent fingerprint development and is thus recommended for latent print development in forensic investigations.

***Key words***: Latent fingerprint development, Monochrome toner powder, Matching Accuracy, Forensic science.

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## Introduction

Dermatoglyphics is an essential component of Physical anthropology and has a wide range of applications in science, including criminology, cytogenetic studies, and dentistry. It plays a crucial role in forensic science and medicine. It is also a very useful tool for personal identification and paternity determination (Igbigbi and Ng'ambi *et al.* 2004).

Forensic science, particularly the analysis of latent fingerprints, is a critical component in modern crime investigation and criminal justice systems (Arslan 2019). Forensic science has evolved significantly, and fingerprint analysis remains one of the most reliable methods for individual identification. The unique ridge patterns and minutiae points on fingerprints provide a basis for accurate identification and have been instrumental in solving countless criminal cases globally (Bose and Kabir 2017).

Characteristically, fingerprint features can be divided into three levels: level-1 (patterns); level-2 (minutiae points); and level-3 (ridgeology) (Kryszczuk *et al.* 2004). There are different fingerprint patterns, including arch, loop (ulnar and radial) and whorl (Adetona 2023).

Fingerprint types are also divided into patent (visible), latent (invisible) and plastic (3D) prints (Sari *et al.* 2018). Several anthropological research have been carried out using patent prints to elucidate unique dermatoglyphic variations, features and characteristics of diverse populations in different countries (for review see Namouchi 2011). Adetona and Shokunbi (2019) provided ethnohistorical insights into dermatoglyphic and phenotypic characteristics across the 3 major ethnic groups (Yoruba, Igbo, Hausa) in Nigeria, using patent prints. Taylor (2020) illuminated the works of anthropologist Kent Fowler and colleagues who discovered the spread of age and sex across ancient antiques through the analysis of fingerprints' ridge and density, further espousing the veracity of patent prints in the study of sexual dimorphism.

According to Kaushal and Kaushal (2011) and Sangalad (2019), fingerprint classifications into patent, latent, and plastic impressions revealed that latent print was the one that typically requires lifting and development before analysis of the impressions, which may be from either porous or non-porous surfaces. Latent prints typically require forensic methods like alternate light sources, chemical methods, or fingerprint powders for visualization (Yamashita *et al.* 2010). However, there are cases where latent prints become visible naturally without any additional processing, known as patent prints, as described by Garg *et al.* (2011). Latent impressions are left unintentionally and often appear fragmented with different levels of clarity (Liu and Srihari 2009). A known sample can be documented through various conventional methods such as black printer's ink, inkless/chemical processes and Live scan.

Latent fingerprints, often invisible to the naked eye, present a challenge in forensic investigations (Friesen 2014). The development and analysis of latent prints are crucial for linking individuals to crime scenes, establishing identities, and providing valuable evidence in legal proceedings (Friesen 2014). Despite the global strides in forensic science, there is a need to evaluate and optimize latent fingerprint development techniques within specific contexts (Azman *et al.* 2019).

Latent fingerprint matching is a crucial process within the field of forensic science, encompassing the identification and comparison of fingerprints retrieved from crime scenes with those stored in databases or collected from individuals for verification purposes (Dhaneshwar *et al.* 2021). Unlike rolled or inked fingerprints obtained under controlled conditions, latent fingerprints are typically unintentionally left behind on surfaces by the natural oils and sweat present on human skin (Walker 2020). These latent prints are often partial or distorted, making their identification and matching a complex task (Kellman *et al.* 2014). Latent fingerprint matching involves two main stages: detection and comparison (Jain and Feng 2009). In the detection stage, latent prints are located, visualized, and enhanced using various techniques such as powdering, chemical treatment, or optical methods. Once detected, these prints are then lifted, developed and compared with known prints to determine if there is a match. This evaluation relies on the distinct ridge patterns, minutiae points and additional characteristics found within the fingerprints (Zaeri 2011). The accuracy of latent fingerprint matching is paramount in criminal investigations and legal proceedings, as it can significantly impact the outcome of cases (Ulery *et al.* 2011). Comprehending latent fingerprint matching is essential not only for forensic scientists and law enforcement professionals but also for researchers seeking to improve existing techniques and technologies (Koehler *et al.* 2023).

The University of Ibadan, with its unique environmental conditions, presents an ideal setting for assessment of latent fingerprint to study the effectiveness of current methods of development, and identify areas for improvement of development of latent prints to contribute to the overall enhancement of forensic capabilities.

The study seeks to suggest a reliable improvised non-conventional fingerprint developer, monochrome toner powder, as an alternative to conventional media while developing lifted latent fingerprint.

## Materials and Methods

**Study location:** Lecture theatres and laboratories of the Department of Anatomy, College of Medicine, University of Ibadan, Ibadan, Nigeria.

**Sampling technique:** This study was done through a convenience sampling method, with volunteers conveniently chosen among students in a class.

**Inclusion Criteria:** This included only 200 level preclinical students.

**Materials for Collection of Fingerprints in Database: -** Dermalog LF10 fingerprint scanner, - Laptop: HP Probook 11 (64-bit operating system with 4GB), - Tissue wipes, - Informed consent form

**Materials for Collection and Development of Latent Fingerprints: -** Glass slides, - Magnifying lens, - Lifting tape, - Latex gloves, - Monochrome toner powder, - Tiny brush, - Smartphone camera (Xiaomi Redmi Note 10 Pro), - Face mask

**Method of Patent Fingerprint Collection for Database:** The selection and collection of required parameters was based on participants' consent. Fingerprints were taken with a Dermalog LF10 fingerprint scanner, Hamburg, Germany. Before taking prints, participants' fingers were carefully cleaned using sterilized tissue wipes. This was done to clean the dirt off the fingertips. A small amount of pressure was applied to the fingers on the scanner to ensure appropriate contact between the fingers and the scanner, resulting in sharp prints of the fingers. The biodata of the volunteers was collected, according to their gender and stored on a personal computer to form the patent fingerprint database.

**Method of Latent Fingerprint Collection:** After 2 weeks of collecting patent fingerprints, the class was revisited for random collection of latent print without bias to gender or biodata. Glass slides were used for fingerprint deposition. Participants press their fingers onto a neat glass slide for the deposition of latent fingerprints. Afterwards, the glass slides were collated for development. The development of the latent print was done in a well-lit environment, where sunlight aided the sighting of the latent prints. The toner powder was gently applied in modest quantity on the area where the latent print was found. The glass slide was turned sharply and carefully to drop off the excess toner powder. The residue of the powder on the glass slide, and those surrounding the developed print was meticulously cleaned off to create clarity. Clear lifting tape is cut to size, and placed on the glass slide, pressed gently on the glass to adhere and subsequently lifted and pasted on a white A4 paper and labelled numerically. The next step involved capturing the latent prints with a Smartphone camera (Xiaomi Redmi Note 10 Pro). Thereafter, the images were numbered and uploaded to a designated folder on the laptop. The blurry background of the images was edited to create clarity before comparison was done with the pre-saved patent fingerprints in the database (**Fig. 1**).

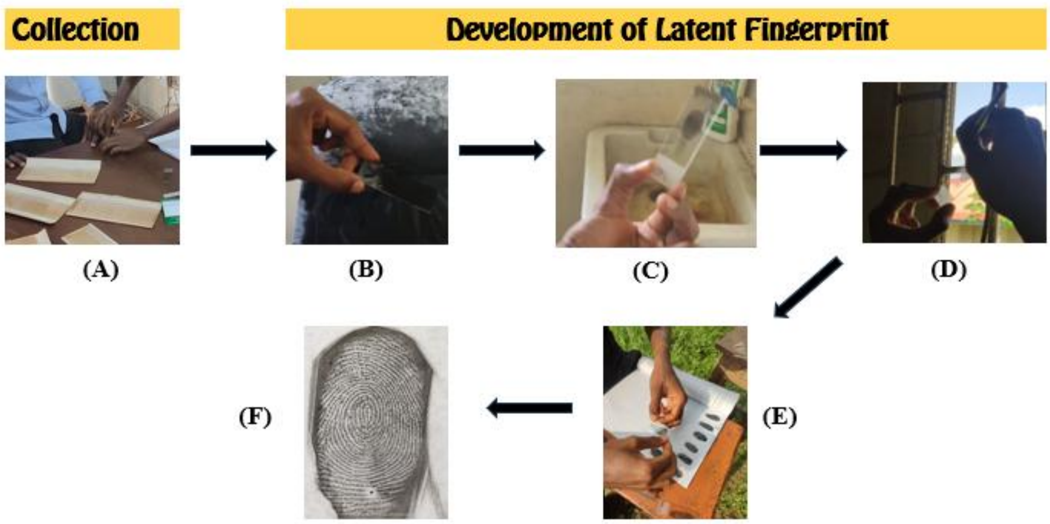


**Fig. 1:** Flowchart of latent fingerprint collection & development (a) Deposition of prints on glass slides (b) application of powder on latent prints (c-d) enhancement of prints (e-f) sorting and documentation of developed latent prints.

### Analysis of Matching of Latent Fingerprints:

The latent prints after development with the monochrome toner powder and storage were searched individually through the patent print database to find a match. Afterwards, the number of minutiae existing in the assumed matches were counted to find a substantial level of correlation between the latent and patent prints. The number of minutiae (minimum of 10 or above) served as a determinant of match. Thereafter, using the mathematical formula, the percentage of matching accuracy, as well as sensitivity, precision and specificity were decided for the latent fingerprints (**Fig. 2**).

**Statistical Analysis:** GraphPad Prism 7.0 was used for descriptive statistical analysis and the statistical significance was at $p \leq 0.005$.

**Ethical Consideration:** Ethical review guidelines of the University of Ibadan and University College Hospital (UI/UCH) relating to the use of human subjects for research were duly followed (UI/EC/24/0051). Informed consent was obtained from every volunteer before sampling.

**(a.)**

(**b.**)

**Fig. 2: (a.)** Patent fingerprint, (**b.**) Developed Latent Fingerprints

## Results

The total of fingerprints collected was 1460, of which 1362 were admissible for levels one and two details. This comprised of 940 patent prints from 65 males and 29 females and 520 latent prints from 30 males and 22 females.

### Qualitative Analysis of Patent Fingerprints

***Male Participants*****:** The predominant pattern type is radial loop (31.23%) as shown in Table 1. The pattern distribution of patent prints for the males was arch (9.70%), ulnar loop (28%), radial loop (31.23%) and Whorl (31.07%). Significant differences were found between the right and left hands for arches (p=0.0111), radial loops (p<0.0001), ulnar loops (p<0.0001), and whorls (p=0.0111). The study highlighted that loop patterns (radial and ulnar combined) were the most common among males, accounting for 59.23% of the patterns.

There was a significant difference in the patent prints of the arches of the right and left hand of the male subjects at (p=0.0111). A comparison between the radial loop between the right and left hand showed significance at (p<0.0001). A comparison between the ulnar loop between the right and left hand showed significance at (p<0.0001). A comparison between the whorl between the right and left hand showed significance at (p=0.0111).

Table 1. Distribution of Pattern Types in the Patent Prints for Males (n=650)

| PATTERN TYPES OF PATENT PRINTS FOR MALES (Right and left hands) | | | | | | |
|---|---|---|---|---|---|---|
| **Patterns** | **Right hand** | **Left hand** | **Total** | **Perc (%)** | **Mean ± S.D** | **p-value** |
| **Arch** | 22 | 41 | 63 | 9.70 | 31.5 ± 13.435 | p=0.0111 |
| **Ulnar loop** | 6 | 176 | 182 | 28.00 | 91 ± 120.208 | p=0.0001 |
| **Radial loop** | 188 | 15 | 203 | 31.23 | 101.5 ± 122.329 | p=0.0001 |
| **Whorl** | 109 | 93 | 202 | 31.07 | 101 ± 11.314 | p=0.0111 |

***Female Participants*****:** The female participants in the patent fingerprint collection (Table 2) showed predominant pattern of ulnar loop (31.72%). The pattern distribution was arch (10.69%), ulnar loop (31.72%), radial loop (30.69%), whorl (26.90%). Significant differences were noted between the right and left hands for radial loops (p<0.0001) and ulnar loops (p<0.0001). There were no significant differences for arches and whorls. Similar to males, loop patterns were the most common among females, constituting 62.41% of the patterns.

The predominant fingerprint revealed by the study in both hands for patent prints (Table 2) in females is the ulnar loop (31.23%). Among the females for patent prints, arch pattern constitutes 10.69% of the whole while radial loop makes up 30.69% of the patterns. Whorl pattern is the third occurring pattern among the females. The aggregate (62.41%) of the two subtypes of loop among the females indicates that loop pattern is the most common pattern type.

Table 2. Distribution of Pattern Types in the Patent Prints for Females (n=290)

| PATTERN TYPES OF PATENT PRINTS FOR FEMALES (Right and left hands) | | | | | | |
|---|---|---|---|---|---|---|
| **Patterns** | **Right hand** | **Left hand** | **Total** | **Perc (%)** | **Mean ± S.D** | **p-value** |
| **Arch** | 13 | 18 | 31 | 10.69 | 15.5 ± 3.536 | |
| **Ulnar loop** | 5 | 87 | 92 | 31.72 | 46.0 ± 36.062 | P<0.0001 |
| **Radial loop** | 85 | 4 | 89 | 30.69 | 44.5 ± 57.26 | P<0.0001 |
| **Whorl** | 42 | 36 | 78 | 26.90 | 67.5 ± 36.067 | |

## Qualitative Analysis of Latent Fingerprints

***Male Participants*****:** The predominant Pattern is Whorl (32.90%). The pattern distribution is Arch (12.28%), Ulnar loop (30.70%), Radial loop (24.12%), Whorl (32.90%). Significant differences were observed between the right and left hands for radial loops (p=0.0006) and ulnar loops (p<0.0001). No significant difference was found for arches and whorls. Despite the whorl pattern being predominant in latent prints, the combined loop patterns (ulnar and radial) remained highly common at 54.82% (Table 3).

Table 3. Distribution of Pattern Types in the Latent Prints for Males (n=228)

| PATTERN TYPES OF LATENT PRINTS FOR MALES (Right and left hands) | | | | | | |
|---|---|---|---|---|---|---|
| **Patterns** | **Right hand** | **Left hand** | **Total** | **Perc (%)** | **Mean ± S.D** | **p-value** |
| **Arch** | 13 | 15 | 28 | 12.28 | 15.5 ± 1.414 | |
| **Ulnar loop** | 9 | 61 | 70 | 30.70 | 35.01 ± 36.77 | P<0.0001 |
| **Radial loop** | 42 | 13 | 55 | 24.12 | 27.5 ± 20.506 | P=0.0006 |
| **Whorl** | 36 | 39 | 75 | 32.90 | 37.52 ± 2.121 | |

There was no significant difference in the latent prints of the arches of the male subjects. A comparison between the radial loop between the right and left hand showed significance at (p=0.0006). A comparison between the ulnar loop between the right and left hand showed significance at (p<0.0001). A comparison of the whorl between the right and left hand showed no significant difference.

***Female Participants*****:** From table 4, the predominant pattern ulnar loop (31.44%). The pattern distribution among the females includes arch (13.40%), ulnar loop (31.44%), radial loop (25.77%), whorl (30.41%). Significant differences were found between the right and left hands for radial loops (p=0.0006) and ulnar loops (p<0.0001).

Table 4: Distribution of Pattern Types in the Latent Prints for Females (n=194)

| **PATTERN TYPES OF LATENT PRINTS FOR FEMALES (Right and left hands)** | | | | | | |
|---|---|---|---|---|---|---|
| **Patterns** | **Right hand** | **Left hand** | **Total** | **Per (%)** | **Mean ± S.D** | **P-value** |
| **Arch** | 10 | 16 | 26 | 13.40 | 15.5 ± 3.0 | |
| **Ulnar loop** | 4 | 57 | 61 | 31.44 | 46.0 ± 26.5 | P<0.0001 |
| **Radial loop** | 45 | 5 | 50 | 25.77 | 25.0 ± 20.0 | P=0.0006 |
| **Whorl** | 28 | 29 | 57 | 30.41 | 28.5 ± 0.5 | |

## Comparison of qualitative characteristics of patent and latent fingerprints

Figures 3 & 4 showed that there was correlation between the distribution of pattern types in both patent and latent prints with no significant difference.

## Criteria for matching

**True Positive:** Match, with 10 minutiae or above

**True Negative:** No match at all

**False Positive:** Pattern type match, but minutiae less than 10

**False Negative:** Pattern type match, but minutiae not meeting the set criteria.

## Calculation of Matching of Latent prints

The matching accuracy of the latent prints with the created database is 87.4% demonstrating reliability and efficacy of the choice of the powder, and the method of development. The result of the calculation for sensitivity was 96.5%. The result of the calculation for specificity was 62.4%. Precision reflects the ability to achieve consistent results across multiple measurements, and the result was 86.7%.

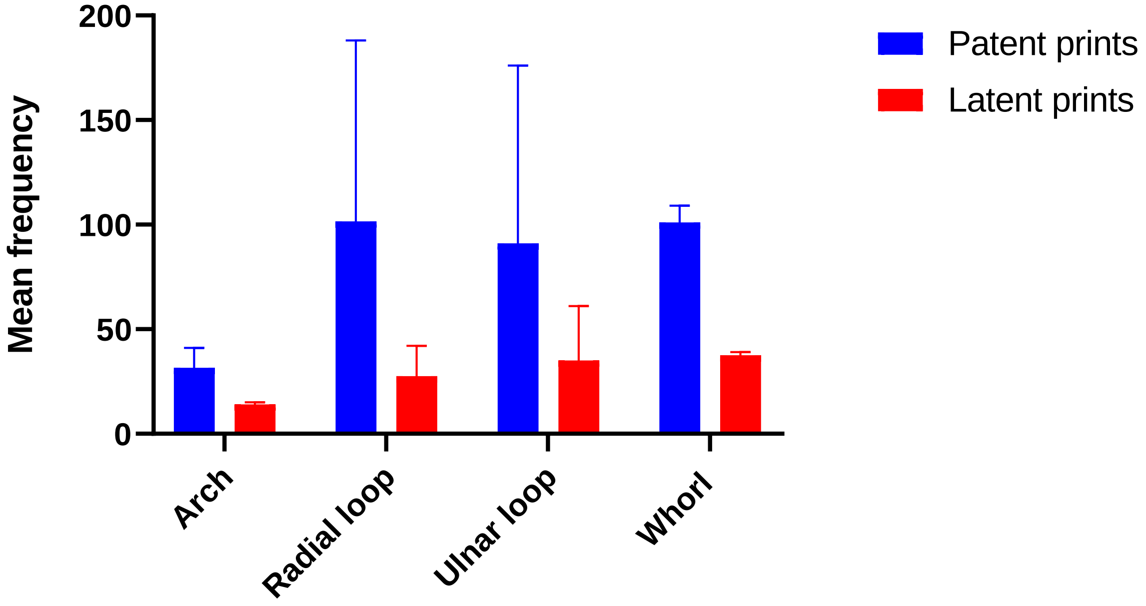


**Fig. 3:** Chart showing the Comparison of both latent and patent prints pattern types in males.

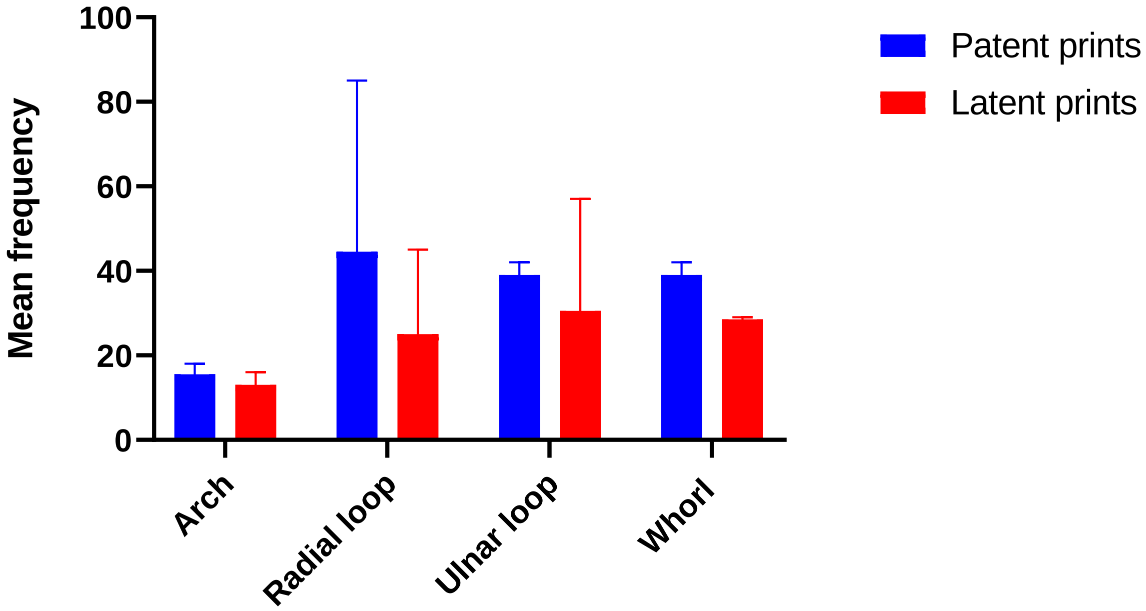


**Fig. 4**: Chart showing the comparison of both latent and patent prints in females

## Discussion

For both male and female subjects, no significant differences between the patent and latent prints, indicating consistency in fingerprint pattern distribution across different fingerprint types. Loop patterns are the most prevalent fingerprint types among both male and female participants, in both patent and latent prints (Adetona & Preyor 2023).

Several unconventional powders like orange and lemon peel, talcum, vermilion, turmeric, henna, coffee powders, etc., have been experimented for latent print development (Chauhan & Udayakumar 2015; Rana *et al.* 2021). Use of monochrome toner powder for latent prints development is first reported in this study. The strategies used in getting the toner powder to develop latent prints on glass slides are relatively new, and efficacious. The monochrome toner powder is a reliable tool for latent fingerprint development on glass slides.

The accuracy, precision, sensitivity and specificity employed in the use of monochrome toner powder was based on previous works done by Baratloo *et al.* (2015), who demonstrated the use of these parameters in the study of health crises experienced by different patients. Also, Taghizadieh (2015), Alavi-Moghaddam (2012) and Kariman *et al.* (2013) demonstrated the necessity and scope of calculating the accuracy of results and variables in a given case study.

The application of these formulae with the designed parameters in this study reveals the accuracy of latent fingerprint using monochrome toner powder at 87.4%, which demonstrates the reliability and efficacy of the choice of the powder, and the method of development. The result of the calculation for sensitivity was 96.5%. The result of the calculation for specificity was 62.4%. Precision reflects the ability to achieve consistent results across multiple measurements, and the result was 86.7%.

## Conclusion

The symmetry of distribution in certain pattern between patent and latent fingerprints is notable and may have implications for forensic science and identification processes. The matching accuracy, precision, sensitivity and specificity suggest that monochrome toner powder is a reliable tool for latent fingerprint development on non-porous surfaces. Comparison and analysis of both patent and latent prints are complementary in this study and previous forensic studies; hence, the results are relevant for forensic as well as anthropological studies.

***Conflicts of interest***: The authors declare no conflict of interest

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