

Oxygen Saturation in Primary Teeth of Individuals With Sick Cell Disease and Sick Cell Trait

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Purpose: To determine oxygen saturation in the pulp of primary teeth in children with sickle cell disease (SCD) and sickle cell trait (SCT) for establishing the usefulness of pulse oximetry in screening and monitoring of SCD or therapy.

Materials and Methods: A cross-sectional study among 30–60 months children with sickle cell disease (SCD) and sickle cell trait (SCT) compared with healthy children (HbAA). A pulse oximeter (BCI 3301) recorded oxygen saturation on six anterior primary maxillary teeth and on index fingers. Data were analyzed using SPSS version 20.0. Mean oxygen saturation for teeth and fingers was calculated. Comparison of Mean across groups was done using post hoc analysis in one-way ANOVA (Bonferroni test). Pearson correlation coefficient was calculated for mean oxygen saturation on fingers and teeth. Level of significance was set at 0.05.

Results: Altogether 360, 102, and 96 teeth were examined from children with SCD, SCT, and HbAA respectively. 53% of participants were girls. The mean age of participants was 46.3 months $\pm$ 9.4 SD. Low mean oxygen saturation (77.5%) was recorded from teeth of children with SCD relative to those with SCT and HbAA ($>86\%$; $P = 0.00$). There was no statistically significant difference in oxygen saturation on teeth between children with SCT and HbAA. The mean oxygen saturation on fingers was found to be above 97.2% regardless of sickle cell status. There was no correlation between oxygen saturation on teeth and fingers.

Conclusion: Pulse oximeter detected a lower oxygen saturation in dental pulp of primary teeth of participants with SCD (HbSS) relative to those with SCT (HbAS) and HbAA. Oxygen saturation on fingers remained unaffected regardless of sickle cell disease status. Although more studies are needed, our study shows that when other conditions affecting peripheral tissue oxygen delivery are ruled out, the low pulse oximetry in primary teeth may be indicative of SCD. The oximeter may also be useful in monitoring response to SCD therapy targeted at improving oxygen carrying capacity and delivery.

Keywords: pulse oximeter, dental pulp, microcirculation, oximetry

Introduction

Sickle cell disease (SCD) is a genetic disorder due to the inheritance of mutant hemoglobin when glutamic acid at position six in the beta-globin chain is substituted by valine.¹ Erythrocytes with mutant hemoglobin become distorted, rigid, and more adherent to vascular endothelium following polymerization during low oxygen tension.² Sickled erythrocytes block capillaries and restrict blood flow to various organs and systems causing ischemia and infarction leading to multiple tissue and organ damage.³ Sickled erythrocytes are also inefficient in oxygen transportation through microcirculation resulting in low peripheral tissue oxygen saturation.⁴ Tissue oxygen saturation of 90–100% in healthy (HbAA) individuals is considered to be within the normal range.⁵

Pulse oximetry is a well-accepted and widely used non-invasive technique for monitoring oxygen saturation and real-time pulsation. A pulse oximeter utilizes red and infrared light at the wavelengths of 660 nm and 900–940 nm, respectively, to measure the differential level of blood oxygenation. In dentistry the tool is known for its use in assessing

dental pulp vascularity and vitality;^{6–9} it is relatively inexpensive, readily available and highly accepted, especially for pediatric patients compared with traditional tests such as electric and thermal pulp tests which are associated with discomfort and/or pain. To date, there is no commercially available pulse oximeter for dental use, so small-sized probes with or without modifications have been successfully adopted for the same.^{8,10,11} The device has been employed in assessing oxygen saturation in teeth of healthy individuals (HbAA) but has been used less in individuals with SCD, mostly in permanent teeth. The mean oxygen saturation in permanent teeth in HbAA in most reports is comparably lower than general body saturation recorded from fingers, but above 85% (Bruno et al, 2014; Pozzobon et al, 2011; Calil et al, 2008). Contrary to most studies, Kong and co-workers report as high as 97–100% pulpal oxygen saturation in HbAA which is similar to general body oxygen saturation.¹³ Immature permanent teeth with the open apex on the other hand have been shown to register a higher mean pulpal oxygen saturation than mature permanent teeth, suggesting a decrease in pulp blood flow with dental maturity in HbAA.¹⁴

Though there are limited data in subjects with SCD, Souza et al report an even lower (78%) mean pulpal oxygen saturation in individuals with SCD (HbSS) than HbAA counterparts.¹⁵ Low pulpal oxygen saturation on teeth is partly attributed to morphological barriers of teeth to red and infrared light of the oximeter, while the even lower saturation in SCD may be contributed to by the disease itself.

Although most reports are on permanent teeth, primary teeth, on the other hand, are less mineralized, have a wider pulp chamber, thinner and porous enamel, a thinner dentine layer, and a more pronounced cervical constriction,^{16,17} thus light from a pulse oximeter would easily be absorbed and less diffracted allowing better oximeter readings.

This study investigated the oxygen saturation in primary teeth of children with SCD, SCT, and HbAA using a pulse oximeter to establish its usefulness in screening and monitoring SCD therapy as an affordable, non-invasive and readily available addition to the available diagnostic and screening tests for SCD such as hemoglobin electrophoresis and DNA testing which are invasive, expensive, and not readily available.

Materials and Methods

This was a cross-sectional study that investigated 558 primary maxillary anterior teeth from 93 children aged 30–60 months. Participants were enrolled into three groups namely SCD, SCT, and HbAA based on hemoglobin electrophoresis. Participants with SCD were recruited from sickle cell clinics in Dar es Salaam whereas those with SCT and HbAA were recalled by age from Muhimbili sickle cell program database. Data collection was done using a questionnaire and a hand-held pulse oximeter (BCI 3301) with a finger probe and a universal (Y) sensor for measuring oxygen saturation. A small universal probe (BCI 3043) was selected for its design that enables close adaptation to the tooth surface. The BCI 3301 hand-held pulse oximeter ensures an accuracy in its measurements of upto 99% with readings range of 0–99% indicating a functioning device, whereas 0% reading is for non-vital teeth. The oximeter was tested on 60 teeth among 10 subjects before the actual data collection for functionality and accuracy. A dental surgeon was trained in positioning the patient and the sensor on the tooth during data collection. An assistant nurse was present for recording the readings.

Questionnaire

A questionnaire was used to record age, sex, level of hemoglobin, hemoglobin phenotype, and genotype, and if the participant is taking any medication including hydroxyurea, folic acids, and penicillin. Participants with a hemoglobin level less than 6 g/dl, those with dental caries, deep restorations, severe periodontal disease, tooth mobility, developmental defects, severe sickle cell disease symptoms, chronic pulmonary illness (asthma and bronchitis), and heart disease were excluded from the study.

Clinical Examination

A handheld pulse oximeter (BCI 3301) was used to measure oxygen saturation from the index finger and primary (deciduous) maxillary anterior teeth. Before measurements, teeth were cleaned and dried with sterile gauze. For easy attachment of the probe on teeth, participants were supine positioned and the back supported at 45 degrees. The light-emitting diode of the sensor was placed palatally and the photoreceptor on the labial surface parallel to each other at the centre of the tooth crown. The sensor and receptor were held in place and stabilized by an incisal and buccal/palatal

finger rest until stable readings were detected on the oximeter display before recording the data. Six teeth (right and left central incisors (FDI teeth 51 and 61), right and left lateral incisors (FDI teeth number 52 and 62) and right and left canines (FDI teeth number 53, 63)) were serially investigated from each participant.

After examining the teeth, the participant's index finger was inserted into a finger probe and the oximeter used to take stable oxygen saturation; in both teeth and index finger readings, measurements without changing for a minute or more were considered stable and recorded. The finger probe and the universal sensor were disinfected with an alcohol-based disinfectant between participants. Handwashing and gloving for examiners were ensured.

Data Analysis

Data were analyzed using Statistical Package for Social Sciences (IBM SPSS Statistics for Windows, version 20.0 Armonk, NY: IBM Corp.). Age, sex, hemoglobin level, hemoglobin genotype, and medications were considered independent variables whereas oxygen saturation from teeth and index finger as dependent variables. Age and hemoglobin levels were summarized as mean, sex as the frequency distribution of boys and girls, and hemoglobin genotype as HbSS, HbAS, HbAA. Oxygen saturation on teeth was summarized as a mean percentage for groups of teeth (central incisors, lateral incisors, and canines) based on sickle cell genotype and as mean oxygen saturation for each study group [SCD (HbSS), SCT (HbAS), and HbAA] and oxygen saturation on fingers as a mean percentage based on a study group. Comparison of mean was done using post hoc analysis in one-way ANOVA (Bonferroni test calculated). The Pearson's correlation coefficient was calculated for mean oxygen saturation on teeth and index fingers for both groups. The level of statistical significance was set at $P < 0.05$.

Ethical Consideration

Ethical approval for this study (MUHAS-REC-07-2020-317) was provided by the Research and Ethics Committee of the Muhimbili University of Health and Allied Sciences (MUHAS). Written informed consent to participate in the study was obtained from parents before participation. Tailored oral health information, advice, and oral hygiene instructions were provided to escorts and children after an examination. All activities done in this research comply with the Declaration of Helsinki.

Results

We investigated 558 primary maxillary anterior teeth, comprising 360, 102, and 96 teeth from children with SCD, SCT, and HbAA respectively. A total of 93 children (30–60 months) were studied, 53% of which were girls. The participants' mean age was $46.3 \text{ months} \pm 9.4 \text{ SD}$. Only 3% of participants with SCD were on hydroxyurea and 88.3% of them were on either folic acid or penicillin or both.

We found a low (75.2–80.4%) mean oxygen saturation for a group of teeth from children with SCD compared with SCT and HbAA. Canines recorded slightly higher oxygen saturation in both study groups. A mild difference in mean oxygen saturation for teeth between children with SCT and HbAA was observed but the difference was not statistically significant (Figure 1).

When pulled together, the overall mean oxygen saturation on teeth was found to be 77.5% for children with SCD compared with 88.2% for SCT and HbAA. The observed difference between mean oxygen saturation on teeth from children with SCD and the other groups are statistically significant ($P = 0.00$). For index fingers, the mean oxygen saturation was found to be above 97% with no statistically significant difference across the study groups (Table 1).

There was no correlation between teeth and finger oxygen saturation regardless of sickle cell status. Although there were more participants with SCD than the rest, it was found that the majority of participants in both groups had oxygen saturation above 80%, and there was a weak positive correlation of oxygen saturation to hemoglobin levels (Figure 2A and B).

Discussion

The current study found a low oxygen saturation from the dental pulp in primary teeth of children with SCD, findings which agree with another similar study in permanent teeth.¹⁵ Other studies^{11,12,18,19} have reported low mean oxygen saturation from teeth in HbAA; our study recorded an even lower oxygen saturation from primary teeth in individuals

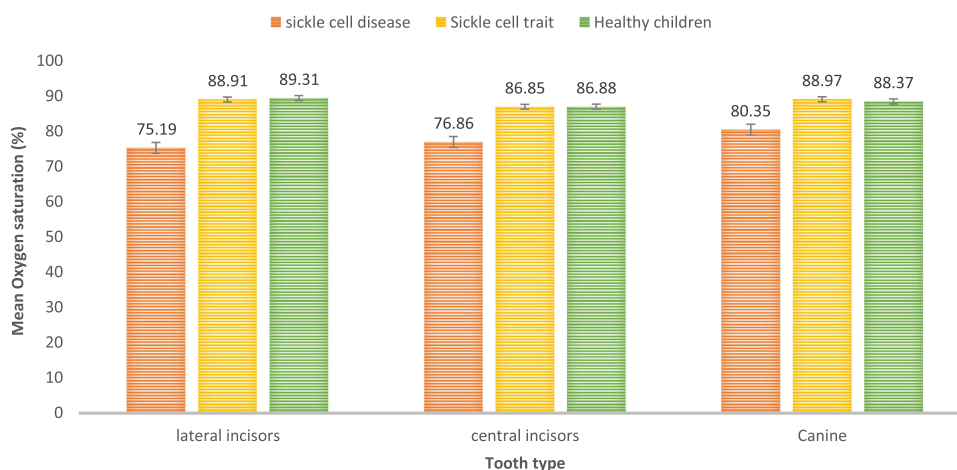


Figure 1 Summary of mean oxygen saturation per tooth type based on sickle cell status.

with SCD. These findings could be attributed to the fact that in addition to diffraction of red and infrared light from the pulse oximeter by enamel and dentine surrounding the dental pulp,³ SCD reduces resilience and oxygen-carrying capacity of erythrocytes and ultimately oxygen delivery through the microvasculature. Analysis of grouped teeth consistently showed low mean oxygen saturation in SCD with canines displaying a slight high oxygen saturation. The slightly high saturation in canines may be explained by a relatively wider pulp space with comparably bulk pulp tissue to central and lateral incisors. There was no statistically significant difference in oxygen saturation for teeth between participants with SCT and HbAA, signifying that there is a less clinical manifestation of structural and functional changes in SCT at optimal oxygen condition as reported in other studies elsewhere.^{20,21} Although, a pulse oximeter is shown from a previous study by Karayılmaz and Kırzio to be ineffective in assessing the effect of physiological root resorption on oxygen saturation, laser Doppler flowmetry in the same study reports an increase in oxygen saturation with increase in level of resorption.²² In our study the age for inclusion was 30–60 months, at which the physiological root resorption for anterior teeth is still minimal and the fact that presence of tooth mobility which usually in absence of trauma or periodontal disease is indicative of a high level resorption was an exclusion criteria, narrows down the effect of resorption in our findings. Low oxygen saturation is also reported in irreversibly damaged but vital pulp in HbAA;⁹ our study investigated otherwise healthy teeth from both groups of subjects.

However, oxygen saturation on fingers was found to remain unaffected regardless of sickle cell status. The possible explanation of these findings could be the presence of collateral blood supply on fingers contrary to teeth, whereby, in addition to diffraction of red and infrared light from a pulse oximeter, the vascular tissue (pulp) is confined within

Table 1 Comparison of Mean Oxygen Saturation on Teeth and Fingers Based on Sickle Cell Status (Bonferroni Test)

SCD (Mean % ± SD)	Comparison Sickle Cell Status	(Mean % ± SD)	P-value
Oxygen saturation in dental pulp			
77.5±7.5	SCT	88.2±3.9	0.000 ^a
	HbAA	88.2±3.8	0.000 ^a
Oxygen saturation in index fingers			
97.4±3.4	SCT	97.2±3.1	0.831
	HbAA	98.3±0.8	0.283

Note: ^aStatistically significant (P<0.05).

Abbreviations: SD, standard deviation; SCD, Sickle Cell Disease; SCT, Sickle Cell Trait; HbAA, Hemoglobin AA.

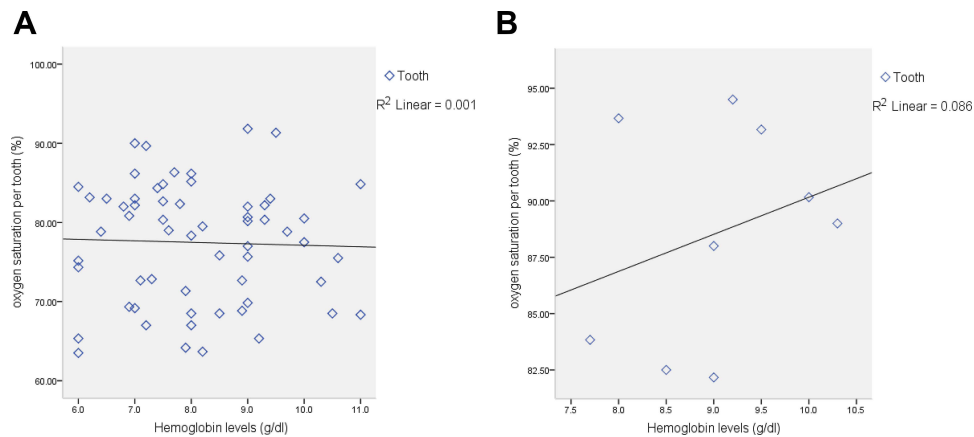


Figure 2 (A) Scatter plot showing mean oxygen saturation to hemoglobin levels for teeth among participants with SCD. **(B)** Scatter plot showing mean oxygen saturation to hemoglobin levels for teeth among participants with SCT.

surrounding hard tissue (the enamel, and dentine) which does not allow sufficient vascular elasticity, which when coupled with the lack of collateral blood supply²³ may lead to poor oxygen delivery and more sensitivity of teeth to oximetry.

A recent review showed only a limited number of other studies on primary teeth.¹¹ Our study has been able to shed light that the dental pulp which is known to lack collateral blood supply and is encased within less mineralized hard tissue of primary teeth is readily affected by disorders that affect peripheral tissue oxygen delivery such as SCD and the pulp is more sensitive to pulse oximetry, such that it can be useful in detecting such disorders before further confirmatory tests can be done.

We recommend further exploration with more advanced tools such as Doppler flowmetry studies to benchmark and validate our findings for the possible use of an oximeter as a screening tool and/or for monitoring improvement in oxygen saturation during SCD therapy. Further studies on oxygen saturation at other than optimal sickle cell disease status are needed to assess the reliability of oxygen saturation on monitoring SCD conditions and therapy.

Conclusion

Our study shows that children with SCD register a low oxygen saturation from their primary teeth relative to those with SCT and those with HbAA. A pulse oximeter detected no difference in oxygen saturation on fingers regardless of sickle cell disease status. The confined nature of the dental pulp and the lack of collateral blood supply may have made the tooth more sensitive to vascular conditions affecting tissue oxygen delivery such as SCD. Although more studies are needed, the current findings show that the low oxygen saturation on teeth measured with a pulse oximeter may be indicative of SCD, thus a pulse oximeter may be a useful adjunct tool for screening conditions that affect oxygen delivery to the peripheral tissues such as SCD and for monitoring therapy that targets improvement in tissue oxygenation such as hydroxyurea in SCD.

Acknowledgments

The authors would like to thank the parents/guardians and children for their participation, members of staff at sickle cell clinics at Muhimbili National Hospital, Temeke and Amana Regional Referral Hospitals for their support, Prof. Lewis Hsu for constructive inputs during proposal development and manuscript writing, Dr. Candida Moshiri, Dr. Karpal Singh and Dr. Kasusu Klint for assisting in data analysis.

Funding

Research reported in this publication was supported by the National Heart, Lung, and Blood Institute of the National Institutes of Health under Award Number U24 HL135881 (Sickle Pan-African Research Consortium - SPARCO) and U01 HL156853. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

Disclosure

The authors report no conflicts of interest in this work.

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