ORIGINAL ARTICLE

SMART Monitoring computer program for oral and skin lesions measurements: analysis through clinical photography

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Abstract:

Lesion evaluation through photographs is a common clinical practice and its performance using computational tools is encouraged. Objective: To assess the reliability of the computer program SMART Monitoring (SM) in giving adequate lesion measurements through clinical photography. Materials and methods: A cross-sectional study was conducted with 28 patients diagnosed with oral or skin flat lesions. Each lesion was measured twice: clinically and by photographic image. Photographs were taken using a 3D-printed scale as a reference for SM measurements of the total lesional area (mm^2) and the two longest axes (length and width) by two different operators. The agreement was evaluated between the axis's measurements of the two operators with the clinic measurements by the Bland-Altman plot. Results: Both operators revealed excellent agreement (ICC=0.98) regarding measurements of the lesion's axes and the total lesional area with no difference between operators. Comparison of the axes' values from SM to clinical measurements were also not different (p=0.82 and p=0.43). The Bland-Altman plot revealed that most mean differences were within the 95% confidence interval. Conclusion: SMART Monitoring proved to be a reliable tool for measuring oral or skin flat lesions on clinical photographs, regarding length, width, and total area measurements. The values obtained using SMART Monitoring presented an excellent agreement with the clinical measurements.

Keywords: Photography, Dental, Dimensional Measurement Accuracy, Software, Wounds and Injuries.

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1.0 INTRODUCTION

Primary diagnosis of lesions is mainly conducted through clinical observations and periodic examination is needed to identify possible alterations, such as: spreading, augmentation, and changes in the lesion's morphology, size, texture, and color[1,2]. Additional tools for lesion evaluation are important to allow the analysis and data registration of lesions regarding their clinical aspects, including lesional measurements[3]. Longitudinal evaluation, mostly related to monitoring treatment approaches and their efficacy, would benefit from the lesion's measurement results. The evaluation of clinical aspects of a lesion, including its measurements, is important not just in the clinical practice, but also for clinical trials, treatment trials, cohort studies, and others. In addition, lesional clinical evaluation is also helpful in improving medical data registration, communication among health professionals, and more[4,5].

Previous studies demonstrated that the use of computer programs in lesion measurements was crucial in retrieving data for comparison between groups. The treatment of vascular anomaly skin lesions evaluated with clinical photographs was performed by comparing alterations in lesion size and color by establishing a measurement score system. All measurement scores correlated with objective clinical data, including the ones from treated and non-treated (placebo) patients[6]. A computer-aided proved to be an important tool for the measurement of psoriatic lesion area, minimizing the consequence of biased rounding up and an overestimation of lesion area by a physician. A reproducible method could be achieved by quantitative data[7]. Besides measurements for comparison, other studies have emphasized the importance of clinical photographs to be used for Artificial Intelligence datasets and algorithm creation. De Abreu et al. (2023)[8] performed a study with the evaluation of oral leukoplakia by using clinical images and concluded that lesion measurements would be difficult to achieve considering the definition of the limits of the lesion and that this could be necessary to be included when improving algorithms for supervised machine learning methods.

There are numerous ways to evaluate clinical photographs obtained in different conditions; however, there is a lack in the literature concerning the photography of intraoral and skin lesions which consider the perspective correction before performing the lesional measurements. In this way, this study aimed to use the SMART Monitoring computer program to obtain the measurements of oral and skin lesion through clinical photography. In addition, to evaluate the agreement between the results obtained using the program with the clinical measurements.

2.0 MATERIAL AND METHODS

A cross-sectional and prospective study was conducted with twenty-eight patients, who were included by a convenience sampling following the inclusion criteria of having flat oral or skin lesions. Exclusion criteria included patients under 18 years of age and the ones diagnosed with not-flat lesions. The patients were examined in two services by a team of professors and internship students at the Hospital Dentistry Service and Stomatherapy Services. The project was approved by the Institutional Research Ethics Committee (Register number CAAE: 46527321.0.0000.0121, with approval number 4.798.415). Written informed consent was obtained from all participants for the current study.

The clinical measurements were taken with a perioprobe for oral lesions (Figure 1A) and the longest axes (length and width) were recorded in millimeters. For skin lesions (Figure 2A), a standard millimeter ruler or a measuring tape was used to the records. These measurements were performed right before the photographs. All photographs were performed by a single trained operator with a DSLR camera (Nikon D90 equiped with an AF-S Micro NIKKOR 60 mm lens). Also, a smartphone (iPhone 12) camera was used. The DSLR camera equipment was chosen to be considered the professional standard for macro images of lesions photographs, and the smartphone was chosen as an alternative for professionals non-trained in macro photography.

Several 3D printed scale devices with pre-established sizes were printed to be used as dimensional reference for digital measurements. The 3D printed scales were manufactured with a fused deposition modeling printer (FDM) with biocompatible materials [polylatic acid (PLA) or polyethylene terephthalate glycol (PET-G)]

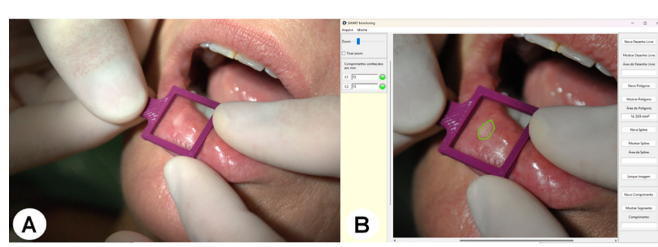

Figure 1. A - Oral lesion within the scale device. B - Total area (mm²) delimited by polygon draw measured on SMART Monitoring.

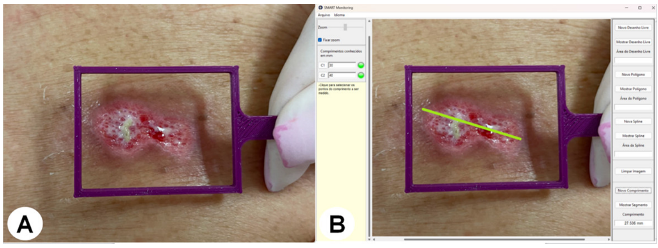

Figure 2. A - Skin lesion inserted inside the scale device positioned on the same lesion's plain around the lesion. B - Lenght measurement (mm) defined by a straight line (in yellow) measured with SMART Monitoring.

as described in smartmonitoring website (guidelines and instructions of the program creators available at: https://smartmonitoring.ufsc.br/index.php/dispositivo--de-escala/).

Briefly, following the orientations on the website of the SM program (https://smartmonitoring.ufsc.br), the scale device was positioned allowing the identification of at least two perpendicular inner edges of the scale within the image, and this device was positioned as most parallel as possible to the lesion plan. These guidelines for photographs are also available on the program's website. Special attention was taken at the moment of each measurement, avoiding the stretching or distortion of the mucosa for the oral lesion, as well as not making excessive pressure, which could negatively affect the real size of the flat lesion. The same procedure was followed during the skin lesions photographs.

To insert the images into the SM program, the photographs were converted to the JPG. format for standardization. All photographs were analyzed and measured twice by two different operators (first and second authors).

2.1 *SMART Monitoring* computer program

The SMART Monitoring (SM) (Florianópolis, Brazil) is a computer program that enables the measurement of the lesional area and linear measurements of flat lesions, using photographs captured by digital cameras. SM is a free-to-use program created by a research team from the Federal University of Santa Catarina. The program can be downloaded at the website domain https://smartmonitoring.ufsc.br.This program aims to assist health professionals and researchers in monitoring the dimensions of flat lesions, whether intraoral or extraoral. In the instructions, it is explained that to capture the images, it is necessary to use scale devices for calibration. The scale devices allow the conduction of measurements considering the distortion correction of the photography. The scale devices used in this study were produced in different sizes to better fit different lesions of different sizes. The scale is chosen by which better size fits the whole lesion within the device.

Photographs depicting clinical images of the lesions should be incorporated into the program, following a systematic procedure. Firstly, the two axes of the device used in the photograph must be precisely defined by positioning a line from one edge to another. Secondly, the dimensions of each axis of the device should be input into the program. Following this calibration, the third step involves manually outlining the lesion's boundaries for accurate measurement. Additionally, if required, a fourth step can be undertaken to measure the two longest axes of the lesions by drawing lines along the longitudinal and vertical axes, connecting points from one end to another.

For this study, two calibrated operators received previous orientation about the use of the SM program and about how to perform the manual drawing of the whole lesion (Figures 1B and 2B). Both operators conducted the interactive segmentation and measured the area of each lesion, followed by the measurement of both longest axes, length and width. The positioning of the lines for the axis measurements was defined in the calibration section with a supervisor (last author).

2.2 Statistical analysis

The data was inserted into Excel and analyzed using GraphPad Prism 9.0 (Boston, MA, USA). The Shapiro-Wilk normality test was performed for all variables. The comparisons were performed using the Mann--Whitney test. The concordance between operators was calculated with the intraclass correlation coefficient (ICC). The Bland-Altman analysis was performed to calculate agreement between the mean of both operator's measurements using the SMART Monitoring program and the clinical measurements. All lesional mean differences were displayed within the plot. A significance level of 5% was considered.

3.0 RESULTS

A total of twenty-eight patients were enrolled in the study, being 9 diagnosed with intraoral lesions and 19 with skin lesions. The higher number of patients included with skin lesions was representative of a higher number of plane lesions in this group. Of the 19 skin lesions, 10 were photographed with the camera and 9 with the smartphone. Regarding the intraoral lesions, 7 were photographed with the camera and 2 with the smartphone. Concerning the nature of the lesions using the elementary classification, there were: 19 ulcers, 8 plaques, and one macule.

Both operators revealed an excellent agreement related to the definition of the two longest axes of the lesion and the total lesional area (Table 1). The comparison of the measurements of the lesions regarding both longest axes and the total area between the two operators was revealed to be not different (Table 2). In addition, the comparison of the mean value obtained from both operators using the SMART Monitoring and the clinical measurements were no different (Table 2).

The Bland-Altman plot (Fig. 3) revealed that the mean differences between the 2 measurements ranged from -10.27 to 7.242 (bias -1.514) for the length measurement and from -10.61 to 6.186 (bias -2.212) for the width measurement, with most mean differences found to be within the 95% confidence interval (CI). This analysis plots the difference between the two values (obtained from the clinical perspective and by the photograph using the computer program) as a function of the mean of the two methods. The 95% CI is illustrated between the lower and upper dotted lines in the graphics. In sum, the agreement between the clinical measurements and the mean values obtained using the SMART Monitoring was considered acceptable with only one case out of the agreement limit for lenght and two for width measurement.

Table 1. Intraclass correlation coefficient between the two operators regarding the lesion's measurements.

Measurements	Coefficient	Classification	*p*
A1 (mm)	0.98	Excellent	<0.001
A2 (mm)	0.98	Excellent	<0.001
Lesional area (mm^2)	0.98	Excellent	<0.001

A1 Axis 1, A2 Axis 2. Significance $p<0.05$. Axis 1 corresponds to the length and Axis 2 corresponds to the width measurements.

Table 2. Comparison of lesional measurements between operators and between the measurements using the SMART Monitoring program and the clinical measurements.

Measurements	Operator 1	Operator 2	*p*
A1 (mm)	18.13 / 14.32 (6.97; 29.03)	17.27 / 14.31 (6.44; 27.27)	0.89
A2 (mm)	8.25 / 5.09 (3.77; 12.01)	8.46 / 5.58 (3.55; 13.13)	0.96
Lesional area (mm^2)	157.2 / 68.6 (15.48; 199.9)	151.3 / 71.73 (17.37; 238.9)	0.94
Measurements	**SMART Monitoring**	**Clinical**	***p***
A1 (mm)	17.7 / 14.23 (6.77 / 27.5)	19.21 / 15 (7.25; 29.75)	0.82
A2 (mm)	8.35 / 5.39 (3.23; 12.94)	10.57 / 5 (4.25; 18)	0.43

A1 Axis 1, A2 Axis 2. Mean / Median (25% Percentile; 75% Percentile). Significance $p<0.05$. Axis 1 corresponds to the length and Axis 2 corresponds to the width measurements.

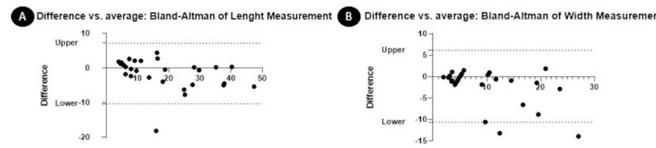

Figure 3. Bland-Altman plot of agreement between the clinical bi-dimensional measurement and the mean values obtained from the two operators using the SMART Monitoring program. The differences between the two methods are plotted against the mean values of the two methods. The upper and lower dotted lines represent the limits of agreement (average difference ± 1.96-times the standard deviation of the difference, meaning limits of agreement with 95% confidence intervals). The middle-dashed line represents the mean bias.

4.0 DISCUSSION

The SMART Monitoring computer program was created so researchers and health professionals, including the dentist, could obtain valuable measurements from the clinical images of lesions. Considering that bi-dimensional images could suffer from distortion, this program tends to correct this issue by adjusting the measurements using a calibrator. A 3D-printed device to be used during the photograph is the best option to be used as a scale device. In special for the oral cavity lesions, because of the oral cavity anatomy, rarely is it possible to take photographs in an orthogonal position, so perspective distortions can be observed, such as shortening or lengthening of part of the image. SM automatically considers and corrects the distortion effects arising from photo angulation, making measurement values of photographs truly reliable. Another way to correct the perspective is well described in the literature. Our results showed that SM is promising in allowing the obtention of trustable measurements from lesions in clinical images obtained from digital cameras and smartphones. The absence of significant differences comparing the results from the two operators shows that replicability is possible by using SM. In addition, the lack of significant differences comparing the results from the clinical measurements (a common practice in daily clinics and research) with the ones obtained using SM shows that trustable measurements can indeed be obtained from clinical images when using a computer program that considers the perspective correction.

The consolidated software ImageJ (National Institutes of Health, USA), through the plug-in Interactive Perspective it's possible to correct distortions by manual adjustment, but it is highly time-consuming and may suffer from subjective interpretation. On the other hand, SM facilitates this correction automatically, just by using the scale device, which will allow for two adjustments within the program before going to measurements. This problem is majorly related to oral lesions, because of the challenging situation to evaluate a lesion that is inserted into a cavity. Differently for skin lesions, ImageJ revealed a good performance throughout obtaining reliable results of surface measurements using the tools 'wand' and 'thresholding', proving to be reliable and trustable. A systematic review aiming to summarize, compare, and critically assess the measurement properties of digital and analog analysis systems for the surface calculation of vitiligo lesions revealed that the manual tracing on transparent sheets (contact planimetry) combined with a digital measurement or a point counting can be considered as the best-validated method for the evaluation of target lesions, taking into account the skin curvatures. Also, they concluded that two- dimensional digital imaging analysis on photographs also seemed robust[9]. We suppose that skin lesions frequently allow an orthogonal position of the câmera, so perspective correction adjustment is often not necessary. By those reasons, SM could an interesting tool for measurement of lesions, especially for oral flat lesions and for skin lesions in general.

The SM program should be considered a device capable of aiding healthcare professionals and health researchers, mostly by allowing monitoring of the alterations of the lesion's morphology. During different treatment modalities, the decreasing size of the lesion can be monitored if properly photographed. The evaluation of clinical aspects, including the lesions measurements would benefit most the clinical research, including clinical trials. Besides adequate data registration regarding the lesion's measurements, it is also good for better communication among healthcare professionals and allows the generation of substantial data for statistical analysis.

The results obtained in this study confirmed that there was an excellent agreement between the two longest axes of the lesions that were measured both clinically and using an image inserted into the SM computer program. Clinical measurements are done universally in clinical practice, although they are highly subjective. Facing this problem, the use of a photograph and a computer program to reduce this subjectivity should be encouraged. In addition, the total area was determined by SM, which cannot be clinically measured by conventional methods, since physician's measures tend to be overestimated. Kreft et al. (2006)[7] revealed that there is a great need for accurate and informative outcome measures in clinical trials, and that the therapeutic effect is usually assessed by physician's estimation of lesional area and other signs yet claiming that these measures were found to be un-reproducible. In their evaluation of psoriasis patients, the authors tested a method where the advantage of accurate computerized measurement of the area on the digital photograph was combined with physician's proficiency. The psoriatic area was manually outlined on the patient's photographs and the area was automatically measured by a computer, and the areas estimated by the physician and measured by computer were compared. Their study concluded that computer-aided measurement of psoriatic lesion area improved the power of the clinical trial, compared to the standard approach, where physician's estimations of the psoriatic lesion area tend to overestimate.

Concerning oral lesions, which seem to be the tricky ones, we observe that for the plain lesions, the use of SM can be easy to proceed, although considering the other difficulties regarding the photograph obtention. Inserting the 3D-printed device into the oral cavity so the lesion would be entirely included in the internal area of this device can be challenging and require expertise. One thing was to take more than one photograph so it could be tested when inserted within the SM program. Besides its inner difficulties, the results obtained in the image were good because did not reveal differences when conducted by different persons and were not different from the clinical measurements using a probe. Flanagan et al. (2016)[3] studied the standard bi-dimensional measurement of oral leukoplakia lesions and examined the feasibility of digital image analysis for automated measurements. Thirteen patients were evaluated by bi-dimensional measurement and were compared with both scalar digital measurements using a standardized measuring device within the photograph and by assessing the pixel number. The authors concluded that the digitized measures in photographs correlated with bi-dimensional measurements (r-squared=0.6661, $p=0.0007$), although revealing to be time consuming. The authors revealed that digital photography measurements, though highly correlative with the clinical analysis, are very cumbersome, what make us think about the use of computational tools as the SM program, which for sure facilitates the whole measurement process.

The excellent agreement by the first and second authors in the intraclass correlation coefficient was considered one of the major points of our study, especially due to challenges in the identification of the limits of some oral lesions. The difficulties encountered in this process can be explained by the characteristic of the lesion itself, but also due to light reflection caused by the combination of saliva and smooth surface of the oral mucosa. In addition, the anatomy of the oral cavity predisposes the incurrence of dark areas or shadows in photographs, making the identification of limits of some oral lesions not easy. Other factors such as the difficulty of settling the scale device in regions that aren't flat to avoid distortions and the operator experience may be an extra challenge to identify some oral lesion boundaries. Nevertheless, the replicability of the SM computer program was verified by different operators and no significant statistical difference was observed. These results prove a robust consistency in program execution regardless of the operator, and that suggests excellent replicability. The agreement in defining the two longest axes of the lesions may also reflect on the agreement of lesion limit for the correct calculation of the total area.

It should be emphasized that one of the advantages of digital photography is the possibility of immediate reappraisal of the photographs for alignment, brightness, positioning, and adjusting other photographic settings. Data storage and management - regarding clinical photographs - are crucial to clinical research[10,11]. Also, some limitations already mentioned are the difficulties in working with intraoral photography and the use of a scale device that should be positioned within the oral cavity. Future perspectives that will help to mitigate these limitations are related to the development of new tools based on Artificial Intelligence (AI) methods. AI methodologies will allow the identification of not just lesion boundaries automatically, but also the scale device limits and axes, making it necessary to make only a few adjustments by the operator, being less time-consuming.

5.0 CONCLUSION

In conclusion, SMART Monitoring proved to be a reliable tool for measuring oral or skin flat lesions on clinical photographs regarding length, width, and total area measurements. The values obtained using SMART Monitoring presented an excellent agreement with the clinical measurements and were consistent when executed by different operators.

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Compliance with Ethical Standards

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and the Declaration of Helsinki from 1964 and its later amendments or comparable ethical standards.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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