ESTEEM Academic Journal
Vol. 16, June 2020, 27-37

Utilization of 2D Photography for Acquisition of Facial Anthropometry

Sayfaldeen Kashmoola[1], Tengku Fazrina Tengku Mohd Ariff[2*] and Hazmyr Abdul Wahab[3]
[1, 2]*Centre of Restorative Dentistry Studies, Faculty of Dentistry, Universiti Teknologi MARA, Cawangan Selangor,47000 Sungai Buloh, Selangor, Malaysia*
[3]*Centre of Oral and Maxillofacial Surgery Studies, Faculty of Dentistry, Universiti Teknologi MARA Cawangan Selangor, 47000 Sungai Buloh, Selangor, Malaysia*
**corresponding author: fazrina@uitm.edu.my*

ARTICLE HISTORY

Received
10 April 2020

Accepted
29 May 2020

Available online
30 June 2020

ABSTRACT

Anthropometry is defined as the scientific study of the measurements and proportions of the human body. To date, the most used methods for the acquisition of facial anthropometric parameters are direct method employing calipers and protractors tools, which are time-consuming, or indirect methods employing three-dimensional (3D) imaging systems, which are expensive. Despite the possible advantages of two-dimensional (2D) photography, it is not widely explored due to complications such as resolution and distortion of digital photos. The objective of this study is to assess the accuracy of the Digital Single-Lens Reflector (DSLR) camera as an indirect method against direct method at different aperture and distance to subject. Adults aged 20-45 years were voluntarily recruited in this study (n=24). Twelve facial anthropometric parameters were measured for each participant using direct anthropometry (sliding caliper), and indirect anthropometry (DSLR camera). When placing the DSLR camera at 2.0 meters from subjects with f/6.3 aperture, nine facial anthropometric parameters were obtained accurately (p> .05). The findings suggested that the accuracy of the DSLR camera as an indirect method for the acquisition of facial anthropometric parameters was established at the aperture setting of f/6.3 and the object distance at 2.0 meters. Therefore, it can be recommended as a facial anthropometry acquisition technique.

Keywords: *Facial anthropometry; Indirect anthropometry; Direct anthropometry; Two-dimensional photography; Photogrammetry.*

1. INTRODUCTION

Facial anthropometry is defined as the study of measurements and proportions of the face. Several methods were used in facial anthropometry. They are categorized into two major groups, which are the direct anthropometry and indirect anthropometry. The direct anthropometry utilizes an accurate measuring tool, such as a sliding caliper, to obtain facial anthropometric data [1]. With the advancement in digital imaging systems, indirect anthropometry has remarkably developed [2].

Accuracy of any method in the acquisition of anthropometric data is of prime importance to scientists. An accurate tool will prevent errors and allow comparison to other anthropometric data obtained by other studies [3]. Direct anthropometry is an accurate, portable, and cost-effective method; however, it is time-consuming and uncomfortable to both operator and patient

p-ISSN 1675-7939; e-ISSN 2289-4934

[3–5]. Three Dimensional (3D) photogrammetric systems and laser scanning systems are commonly used for indirect anthropometry. Those systems tend to be time-saving and comfortable, making them suitable for children and patients who cannot stand still or sit for a long time. However, those systems tend to be extremely expensive and lack portability [3]. Two-Dimensional (2D) photography is an alternative to other sophisticated systems, but it is not widely explored in the literature.

The main disadvantages that can affect the accuracy of 2D photography in indirect anthropometry are resolution and distortion of the digital photos [6–7]. Resolution is defined as the details that a digital photo can record, while distortion is defined as the deviation from the rectilinear projection. It is characterized by variable magnification over the image [8]. Multiple factors can affect resolution and distortion of the digital image; this study focuses on the effect of distance between camera and subject (distance to subject) and lens aperture (f/number). Increasing lens aperture (reducing f/number) will increase the exposure value and reduce light diffraction, which will result in increasing digital photo resolution. However, this might result in a reduction in the depth of field, resulting in loss of some details in the image. Moreover, increasing the distance to subject will result in a reduction in distortion and an increase in depth of field producing detailed captured images with higher accuracy in dimensions [8 – 10].

The objective of this study is to assess the accuracy of the Digital Single-Lens Reflector (DSLR) camera as an indirect method against the direct method for the acquisition of facial anthropometry at different apertures and distances to subject.

2. METHODOLOGY

2.1 Study Population

A total of 24 participants of Malaysian Malay ethnicity with an age range of 20-45 years and equal gender distribution were voluntarily included in this study. The study sample size was calculated using G*Power application (3.1.9.4, Universität Düsseldorf, Germany). The effect size was 0.8, the significance level was 5%, with a power of 0.95, and a dropout rate was set at 5%. Prior to data collection, ethical approval was obtained from the Institute of Research and Management, Universiti Teknologi MARA (600-IRMI 5/1/6) and written consent were obtained from all participants.

For the inclusion and exclusion criteria, all participants included in this study are of Malaysian Malay ethnic group with no history of mixed racial parentage. Participants who had one of these conditions were excluded from this study:

1. Participants with a history of congenital disease in the facial region,
2. Participants with a history of trauma and/or surgical intervention in the facial region,
3. Participants who had orthodontic treatment,
4. Participants using complete dentures,
5. Partially dentate participants with loss of vertical dimension.

2.2 2D Photography System

The effects of distance to subject and lens aperture on distortion and resolution of the digital image were investigated in this study (Table 1). A DSLR camera (Nikon D3100, Japan) with a

p-ISSN 1675-7939; e-ISSN 2289-4934

zoom lens (Nikkor 18-55mm f/3.5-5.6G VR, Japan) and ring flash (Mecablitz 15 MS-1, Metz, Germany) were used. The camera settings are listed in Table 2. The camera was mounted on a tripod. The level of the camera was set horizontally at participants' eye level, which was calibrated for each participant individually.

Table 1: Camera Settings to Investigate

Distance to subject	Lens aperture	
	f/6.3	f/11
1.5 meters	P1	P2
2.0 meters	P3	P4

Table 2: Fixed Camera Settings

Camera level	**The camera was fixed at participants' eye level.**
ISO	ISO was fixed at 200
Shutter speed	Shutter speed was fixed at 1/60
Focal length	55 mm
Pixel count	4608*3072

2.3 Facial Anthropometric Landmarks and Parameters

The facial anthropometric landmarks and parameters included in this study were adopted from Farkas et al. 's international study [11]. Nine facial anthropometric landmarks and twelve facial anthropometric parameters were included in this study (Figure 1, Table 3 and 4).

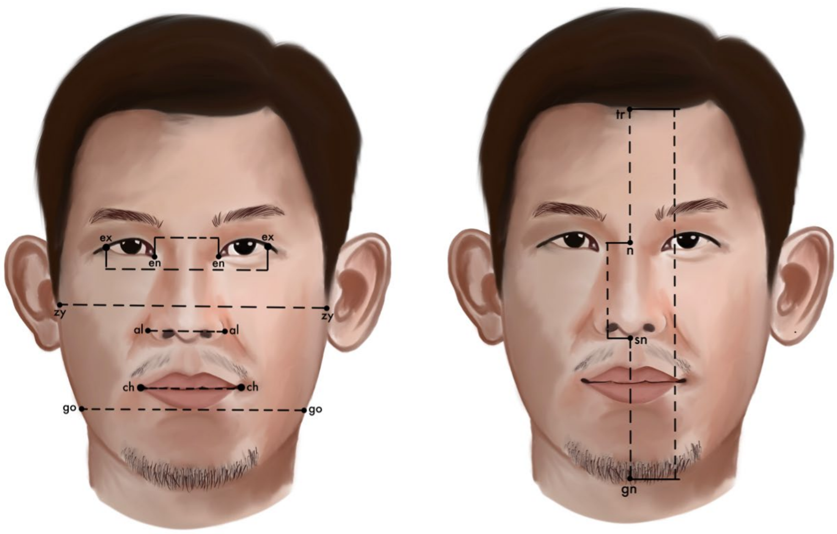

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Figure 1: Facial Anthropometric Landmark Markings (Adopted from Farkas et al., 2005[11])

Table 3: Facial Anthropometric Landmarks and Definitions

Landmark	**Name**	**Definition**
tr	Trichion	The point where the hairline meets the center of the forehead.
n	Nasion	The sagittal midline point of the nasal root at the nasofrontal suture
sn	Subnasale	The midpoint of the point of inflexion of the columellar base at the juncture of its lower border with the surface of the philtrum
gn	Gnathion	The lowest median landmark on the inferior aspect of the mandible
en	Endocanthion	The most medial point of the palpebral fissure, at the inner commissure of the eye
ex	Exocanthion	The most lateral point of the palpebral fissure, at the outer commissure of the eye
zy	Zygion	The most lateral extents of the zygomatic arches
al	Alare	The most lateral extents of the alar contours
ch	Cheilion	The most lateral points at the labial commissure
go	Gonion	The inferior aspect of the mandible at its most acute point (the mandibular angle)

Adopted from Deutsch et al., 2012 [1]

Table 4: Facial Anthropometric Parameters and Descriptions

Parameter	**Description**
tr-n	Upper facial height
tr-gn	Physiognomic facial height
n-gn	Morphologic facial height
sn-gn	Lower facial height
n-sn	Nasal height
en-en	Intercanthal width
ex-ex	Biocular width
en-exR	Right eye fissure length
en-exL	Left eye fissure length
zy-zy	Facial width
go-go	Mandible width
al-al	Morphological nasal width
ch-ch	Mouth width

Adopted from Farkas et al., 2005

p-ISSN 1675-7939; e-ISSN 2289-4934

2.4 Examiner Calibration

Prior to data collection, Interclass Correlation test was conducted to investigate the reliability of the examiner to locate the facial anthropometric landmarks and measure the facial anthropometric parameters. One examiner conducted the data collection under the supervision of an experienced maxillofacial surgeon. A total of 20 participants were voluntarily recruited at this preliminary stage. The examiner located all landmarks using a surgical marker and measured parameters of each. After one week, the same steps were repeated for the same participants. The average interclass correlation coefficient was ranging from 0.903-0.0996 (Lower band = 0.760, upper band = 0.998), indicating moderate to excellent reliability of the examiner to locate and measure the landmarks and parameters [12].

2.5 Data Collection

After the examiner's calibration, the study was conducted. All participants were asked to sit on a static chair at an upright position against a white background. The head was positioned with the Frankfort Plane parallel to the floor plane. All landmarks were located using a sterile surgical marker.

Facial anthropometric parameters were measured with direct anthropometry by using a digital sliding caliper with 0.01 millimeters resolution. All measurements were repeated three times, and the mean with the standard deviation) was calculated.

After data collection using direct anthropometry, four digitals images were captured using a tripod-mounted DSLR camera. A different set of distance to subject and lens aperture were used for each image (Figure 2) were captured. A reference circular sticker with known diameter was placed at the participants' forehead.

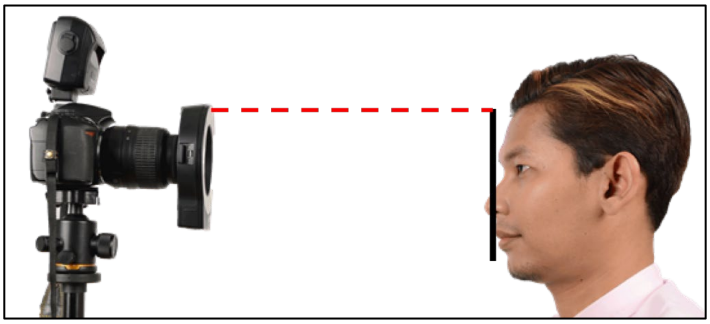

Figure 2: The distance measurement between camera and subject

The facial anthropometric parameters were extracted from the digital images in pixels using Photoshop software (CS6 13.0.1, Adobe Inc, USA) and then converted to millimeters using the following equation (Equation 1):

$$X=(Rmm*P)/Rp \quad (1)$$

p-ISSN 1675-7939; e-ISSN 2289-4934

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X is the parameter in millimeters. **Rmm** is the diameter of the reference circular sticker measured in millimeters. **P** is the parameter in pixels as obtained from the digital image. **Rp** is the diameter of the reference circular sticker measured in pixels as obtained from the digital image. The flow of this study is illustrated in Figure 3.

2.6 Accuracy of DSLR Camera for Indirect Anthropometry

The facial anthropometric parameters obtained using the indirect method was assessed against the direct method using the paired sample *t*-test. Each specific setting was considered accurate if the mean difference between direct and indirect methods was less than 2 millimeters and p-value more than 0.05. The statistical analysis was performed using IBM SPSS Statistics (IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.).

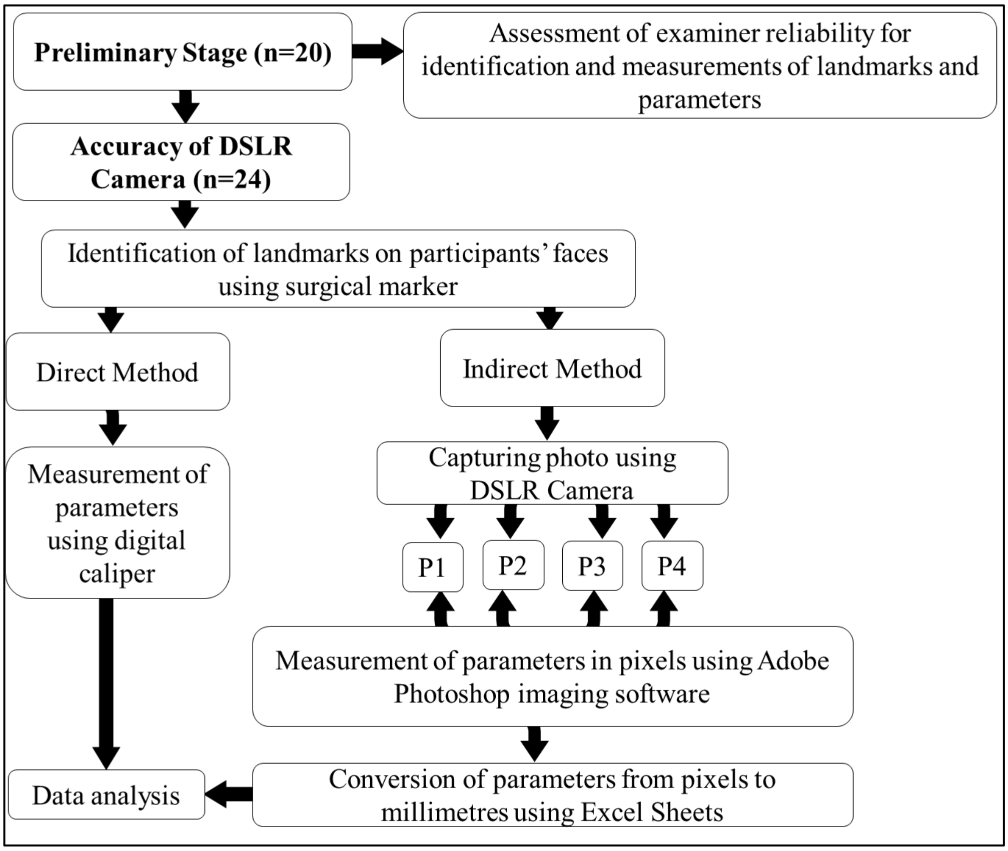

Figure 3: Flow of study

3. RESULTS

A total of 24 participants aged 20-45 years old with equal gender distribution were recruited in this study. The normality of distribution was tested depending on the results of skewness and kurtosis. All results of skewness were <2, and the results of kurtosis were <7. Hence, the

p-ISSN 1675-7939; e-ISSN 2289-4934

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presented results indicated that the variables were fairly normally distributed. The mean, standard deviation (SD), and results of paired sample *t*-test are listed in Table 4.

The results of the paired sample *t*-test indicated that when placing the camera at 2.0 meters from the subject with the aperture at f/6.3, nine out of 12 parameters were measured using with sufficient accuracy using DSLR camera as an indirect method (p > 0.05).

Table 5: Results of the Paired Sample *t*-Test

			N=24	**Mean (millimetres)**	**SD**	**Mean difference (control-test)**	**SD**	**p-value**
tr-n	Control	75.03	11.52					
	1.5 m, f/6.3	73.69	10.38	1.33	6.04			.291
	1.5 m, f/11	73.87	9.85	1.16	6.25			.372
	2 m, f/6.3	73.81	10.47	1.22	4.27			.175
	2 m, f/11	74.14	10.15	0.89	3.55			.231
tr-gn	Control	188.72	13.56					
	1.5 m, f/6.3	190.63	17.87	-1.92	11.72			.431
	1.5 m, f/11	191.75	18.79	-3.04[2]	13.36			.277
	2 m, f/6.3	190.86	17.20	-2.14[2]	11.59			.374
	2 m, f/11	192.15	15.37	-3.44[2]	8.20			.052
n-gn	Control	116.33	6.79		-			
	1.5 m, f/6.3	116.63	11.27	-0.30	6.15			.812
	1.5 m, f/11	117.49	12.50	-1.16	7.92			.480
	2 m, f/6.3	117.17	11.49	-0.84	7.37			.584
	2 m, f/11	117.67	9.77	-1.34	5.38			.235
sn-gn	Control	68.27	6.02					
	1.5 m, f/6.3	66.38	7.95	1.90	3.27			.009[3]
	1.5 m, f/11	66.75	8.42	1.52	4.28			.096
	2 m, f/6.3	66.88	8.11	1.39	4.51			.145
	2 m, f/11	67.04	7.80	1.23	3.95			.141
n-sn	Control	48.62	3.59		-			
	1.5 m, f/6.3	50.29	5.30	1.9	3.27			.009[3]
	1.5 m, f/11	50.65	5.78	-2.03[2]	3.97			.020[3]
	2 m, f/6.3	50.06	5.11	-1.43	3.60			.064
	2 m, f/11	50.74	4.47	-2.12[2]	2.32			.000[3]
en-en	Control	33.98	2.27					
	1.5 m, f/6.3	34.68	3.28	-0.70	2.22			.135
	1.5 m, f/11	34.63	3.08	-0.65	1.75			.080

p-ISSN 1675-7939; e-ISSN 2289-4934

	2 m, f/6.3	34.55	3.17	-0.56	2.18	.218
	2 m, f/11	34.47	2.83	-0.49	1.50	.124
ex-ex	Control	101.07	7.14		-	
	1.5 m, f/6.3	96.38	6.66	4.69[1]	5.48	.000[3]
	1.5 m, f/11	96.53	6.36	4.54[1]	5.66	.001[3]
	2 m, f/6.3	96.68	6.85	4.39[1]	6.26	.002[3]
	2 m, f/11	96.94	5.02	4.13[1]	5.07	.001[3]
en-exR	Control	34.78	3.30			
	1.5 m, f/6.3	30.72	2.65	4.05[1]	2.96	.000[3]
	1.5 m, f/11	31.04	2.54	3.74[1]	2.84	.000[3]
	2 m, f/6.3	31.04	2.41	3.74[1]	2.65	.000[3]
	2 m, f/11	31.25	2.45	3.52[1]	2.61	.000[3]
en-exL	Control	34.63	3.36		-	
	1.5 m, f/6.3	30.80	2.77	3.83[1]	2.51	.000[3]
	1.5 m, f/11	30.89	2.72	3.74[1]	2.48	.000[3]
	2 m, f/6.3	30.99	2.65	3.64[1]	2.52	.000[3]
	2 m, f/11	31.05	2.39	3.58[1]	2.28	.000[3]
zy-zy	Control	145.76	7.39			
	1.5 m, f/6.3	142.81	8.82	2.95[1]	7.15	.055
	1.5 m, f/11	143.52	9.89	2.24[1]	7.50	.156
	2 m, f/6.3	143.77	8.84	1.99	7.43	.203
	2 m, f/11	144.57	6.70	1.19	4.70	.226
al-al	Control	39.56	3.30		-	
	1.5 m, f/6.3	40.54	3.66	-0.98	2.11	.032[3]
	1.5 m, f/11	40.78	3.77	-1.22	2.20	.012[3]
	2 m, f/6.3	40.38	3.54	-0.82	2.14	.074
	2 m, f/11	40.80	3.26	-1.23	1.79	.003[3]
ch-ch	Control	50.79	6.48			
	1.5 m, f/6.3	50.09	5.55	0.70	3.27	.305
	1.5 m, f/11	50.24	5.57	0.55	2.88	.359
	2 m, f/6.3	49.99	5.45	0.80	3.67	.293
	2 m, f/11	50.31	5.22	0.48	3.52	.509

Note:
[1] mean difference more than 2 mm
[2] mean difference less than -2 mm
[3] p-value <0.05 indicating a significant difference between control and test group
Control refers to measurements obtained by direct method using a digital sliding caliper

p-ISSN 1675-7939; e-ISSN 2289-4934

4. DISCUSSION

Accuracy is defined as the closeness of the test results obtained by a system or device in comparison to the reference results [12 – 14]. In previous researches, an indirect method is considered accurate in collecting facial anthropometric measurements if the measurements are less than 2 mm difference compared to the direct method [14 – 15]. Two main factors that affect the accuracy of 2D photography are image distortion and resolution [6 – 7, 17]. Multiple guidelines in dental and medical photography recommended the usage of lenses with large focal length (more than 90mm) with a small aperture (f/22-f/32) to reduce distortion. A studio-based light source is also recommended to produce enough exposure and improve the resolution of the images. Distance to subject recommended at 1.2-1.5 meters [18 – 21]. These equipment tend to be very expensive and difficult to obtain. In this study, a low-cost 18-55mm lens (fixed at 5mm focal length) was used with a ring flash. The distance to subject was increased to reduce the distortion resulted from a reduction in focal length. The increase in aperture was to increase exposure value to improve image resolution.

In this study, nine out of 12 parameters were accurately obtained when the camera is placed at 2.0 meters from the subject with f/6.3 aperture. There are few published studies that evaluate the accuracy of 2D photography for the acquisition of facial anthropometry. Nechala et al. conducted a study to assess three techniques for obtaining digital 2D photographs (Digital camera, scanning of films derived from a 35 mm camera, scanning of photographs captured by Polaroid camera) and compare them to direct anthropometry [22]. Out of the 11 measured parameters, only three were inaccurately recorded by 2D digital images (upper facial height (n-sn), intercanthal distance (en-en), and nose height (n-sn)) [22]. Ghoddousi et al. explored the accuracy of three methods of facial measurements, which are the direct method, 2D photography, and 3D stereophotogrammetry. The results showed that all three methods were well repeated. 2D photography was found to be significantly more reliable than the direct method [23]. Another study conducted by Robin et al. about the accuracy of 2D photography by comparing it to 3D stereophotogrammetry and direct anthropometry. The researchers measured facial width to height ratio directly from participants' faces and from digital 2D images (using Canon EOS 5D MKII, and Nikon D3000), and digital 3D scans (using Di3D Imaging system). A high agreement was demonstrated across all measures [24]. Despite those published studies, none of them had published the exact camera settings used. Additionally, the first two studies are using old cameras, which might not be available to replicate now, while the third study might not be very reliable as they measured two parameters only.

One study evaluated the effect of the focal length of the lens on the digital image distortion [21]. It was found that distortion is increased when using a 50 mm lens compared to a 100 mm lens. The results are not in agreement with this study. In Swamy et al. 's study, they placed the camera at 1.2-1.5 meters from the face. While in this study, the distortion was reduced when the distance to subject was increased. Additionally, Swamy et al. 's study based their comments on visual inspection only.

In this study, three parameters were recorded inaccurately regardless of the settings. Those parameters are orbital parameters (biocular width (ex-ex), right eye fissure length (en-exR), and left eye fissure length (en-exL). There is a difficulty when recording orbital parameters with direct anthropometry. Fear of injuring vital orbital structure might result in locating the landmarks further, or in patients squinting their eyes. The produced inaccuracy could be a result

p-ISSN 1675-7939; e-ISSN 2289-4934

of the inaccuracy of direct anthropometry rather than image distortion [14, 20]. It was assumed that the DSLR camera accurately obtained all 12 facial anthropometric parameters when placed at 2.0 meters from the patient with a f/6.3 aperture.

5. CONCLUSION

The findings suggested that the accuracy of the DSLR camera as an indirect method for the acquisition of facial anthropometric parameters was established at the aperture setting of f/6.3 and the object distance at 2.0 meters. Therefore, it can be recommended as a facial anthropometry acquisition technique.

ACKNOWLEDGMENT

Authors would like to acknowledge Universiti Teknologi MARA(UiTM) and Faculty of Dentistry UiTM for ethically approving the conduction of this study and supported this study under the Postgraduate Research Grant. We would like to express our appreciation to Miss Sujana Ramli for the illustrations.

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p-ISSN 1675-7939; e-ISSN 2289-4934