A New Protocol to Evaluate Superior-Resistant Attributes of Liquid Foundation for Javanese-Indonesian Brides

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Background

Highly resistant against water, sebum, sweat, and tears become essential attributes for foundation makeup as nowadays the products are expected to last even under extreme wear conditions such as wedding event. This study proposed in vitro methods to evaluate the smudge-proof, sweat-proof, water-proof, tear-proof properties of liquid foundation using image analysis on PMMA plate immersed in various liquids and compared with the in vivo result.

Methods

Three commercial foundations were spread on PMMA plates and immersed in artificial sebum, sweat, and tear; and water to assess the performance of smudge-proof, sweat-proof, tear-proof and water-proof respectively, in in vitro approach. The digital images of foundation film of each sample before and after treatment were analyzed and correlated with the results of extreme wear in vivo testing.

Results

All the in vitro methods have strong positive correlation to the in vivo results, as follows: smudge-proof (ρ=1.0, p=0.5), sweat-proof (ρ=1.0, p=0.5), water-proof (ρ=1.0, p=0.5), tear-proof (ρ=0,5, p=0.766).

Conclusion

The findings of this study demonstrate potential in vitro methods to evaluate smudge-proof, sweat-proof, water-proof, tear-proof properties of liquid foundation makeup. This provides a new approach in predicting the superior-resistant attributes required when formulating the perfect foundation for Javanese-Indonesian brides or similar target consumers.

Keywords: Javanese-Indonesian brides, smudge-proof, tear-proof, water-proof, sweat-proof

Introduction

Cosmetics have become a daily necessity within society and merged to have a high demand in the world [1]. Cosmetics can be classified for skin or body care or as decorative purposes. Decorative cosmetics are used for the application and coverage of skin defects,

resulting in improved appearance as well as psychological effects such as increased self-confidence [2].

Foundation is one of the decorative cosmetics which is used to cover uneven facial skin surfaces, scars, acne, and pores [1]. Consumers' demands for facial makeup that does not break down after a few hours continue to rise, thus long-wear foundations that are able to stay put for long periods of time become desirable in both standard wear setting (standard room temperature and humidity) and more intense or extreme conditions (e.g., higher temperature or higher humidity, exercising, wedding parties, stage concerts, and customary events).

Long-lasting performance does not only depend on the formula, but also physiological factors (sweat, sebum, tears, saliva), mechanical factors (rubbing), or combinations thereof (speaking, laughing, face movement) as well as physical factors (pigments sunlight photo-aging, color fading) [3]. Sebum is relatively non-polar material and is made up of triglycerides, free fatty acids, squalene, wax esters, and cholesterol, while sweat is comprised of 99% water and 1% minerals with pH between 4.5-7 [4]. Both sebum and sweat have a very strong impacts on the adhesion of foundation to the skin that they can delaminate or plasticize makeup films [4], thus undermining the long-wear performance of foundation makeup.

Javanese tribe is the major ethnics who covers 40,2% of Indonesian population [5] that has many traditions, one of which is a cultural wedding ceremony involving the use of high coverage of decorative makeup. The big challenges for formulators are developing decorative cosmetics with superior-resistant attributes which can counter several disturbances in make-up resistance due to the cultural wedding ceremonies e.g., *Siraman* (brides flower-showering ceremony) and *Sungkeman* (asking for blessing from the parents) [6]. Those customs can interfere the make-up performance extremely due to the water exposure from the showering process as well as the tears production during the ceremonial event. Therefore, as the base makeup, it is essential for liquid foundations to have highly resistance properties or "superior-resistant" against water, sebum, sweat, and tears to meet the needs of those who practice Javanese-Indonesian traditional wedding or similar extreme activities.

Many scientific journals have been published for the evaluation against specific attributes, e.g., smudge-proof, water-proof, sweat-proof [7]. However, publication related to the integrated approach of superior-attributes evaluation for a foundation is lack of development. By developing the in-vitro methods, the involvement of human volunteers can be reduced and allow for the easier and more effective comparison of products for

the formulators during the earlier stage of cosmetic development, hence less time-consuming and more cost-effective.

This study proposed in vitro methods to evaluate the superior-resistance attributes of liquid foundation (e.g., smudge-proof, sweat-proof, water-proof, tear-proof) based on image analysis. This approach was tested for its ability to distinguish different character of three commercial foundations, and compared with in vivo results.

Materials and Methods

In Vitro Materials and Methods

Products

Three commercial foundations with different resistance properties were evaluated in this study.

Substrate

PMMA plates (Helioplate HD6 molded PMMA plates, 48 mm x 48 mm with a 5.8 µm roughness, HelioScreen, Creil, France) were used as the substrate for the foundation samples.

Test Protocol

Test samples weighing 50 mg were spread on the surface of the PMMA plate using a drawdown bar (BYK-Gardner GmBH, Germany) to create a foundation layer with 30 µm thickness. The foundation samples were set to dry in an oven at 50°C for 10 minutes then immersed in various liquids as follows: reverse osmosis water, artificial sebum (synthetic sebum formulation, Nanochemazone, Kurukshetra, India), artificial sweat (artificial eccrine sweat, pH 4.5, Nanochemazone, Kurukshetra, India), artificial tears (Stericon Pharma Pvt. Ltd., Bangalore, India) for water-proof, smudge-proof, sweat-proof and tear-proof testing respectively at 25 ± 2°C.

The condition of the foundation samples was evaluated every 2 hours with a total period of 8 hours (for water, artificial sweat, and artificial tears) and after 24 hours (for artificial sebum). In each evaluation period, the plates were removed from the liquid, and the remaining liquid on the plates was allowed to dry for 15 minutes (for water, artificial sweat, and artificial tears) or 30 minutes (for artificial sebum). The digital images of foundation film on PMMA plates placed on a black cardboard background were then taken using a digital camera (Sony Alpha A7R IV A body camera with Sony FE 90mm with F2.8 Macro G OSS lens, Sony Corporation, Japan). Image analysis were performed by calculating the percentage of area reduction of the foundation on the PMMA Plate

after treatment using a Keyence Digital Microscope image analysis (Keyence VHX-7000, Japan).

In Vivo Materials and Methods

Subjects

For each super-resistance attribute study, three Indonesian females were recruited ranging in age from 18-35 (26.5 ± 12 years). Prior to participation, written informed consent was obtained from all volunteers to ensure that they were fully aware of the purposes and conditions of this study. Exclusion criteria included subjects: (a) with chronic or relapsing inflammatory and/or allergic skin conditions such as atopic dermatitis, rosacea, psoriasis and alike including telangiectasias (spider veins) (b) active herpes infections or currently on treatment for herpes infections (c) who were pregnant or nursing mothers (d) who have a history of facial keloids, serious adult acne or currently on treatment for adult acne.

Test Protocol

The entire study was performed under specific environmental conditions, relative temperature and humidity was controlled and maintained during testing. The study was performed in dedicated room and under temperature 25 ± 1°C and relative humidity 53 ± 5% for water-proof, smudge-proof and tear-proof assessment, and temperature 29 ± 1°C and relative humidity 68 ± 2% for sweat-proof evaluation.

All subjects were ensured to clean off their makeup and sunscreen before testing. Subjects spread a total of 3-4 pumps of foundation samples on their face using puff applicator evenly and allowed to dry for 15 minutes to ensure the foundation layer was completely set before the treatment was performed to assess each resistance attribute of foundation. The smudge-proof, water-proof, sweat-proof and tear-proof properties for all samples were evaluated before and after treatment.

Facial images were taken with a digital camera (Sony Alpha A7R IV A with Sony FE 90mm with F2.8 Macro G OSS lens, Sony Corporation, Japan) and analyzed quantitatively using image analysis software (Image-Pro® 10.0.11, Media Cybernetics, USA). The intensity-based segmentation tool was used to define facial area impacted by the treatment at five crucial spots (i.e., forehead, nose, right cheek, left cheek, and chin) resulting in total area value of pixels. The lower total area value implied a more even foundation layer or more flawless look.

Smudge-proof Test

To evaluate the impact of facial sebum on foundation performance, the test products were applied on face of three female volunteers whose average facial sebum value ≥ 182

µg/cm^2 (Sebumeter® SM 815, Courage + Khazaka electronic GmbH, Germany) for 8 hours portraying the typical average duration of a wedding ceremony in Java. The facial images were analyzed at 0 h (after the applied foundation was completely set), and 8 h after application.

Water-proof test

A total of 250 ml of reverse osmosis water was poured from the hairline to the entire face for 27 times consecutively to evaluate the water-proof property during extreme water exposure such as Javanese *Siraman* ceremony [8]. The water-proof attribute was determined by facial images analysis before and after treatment (the remaining water on face was allowed to dry first for 20 minutes).

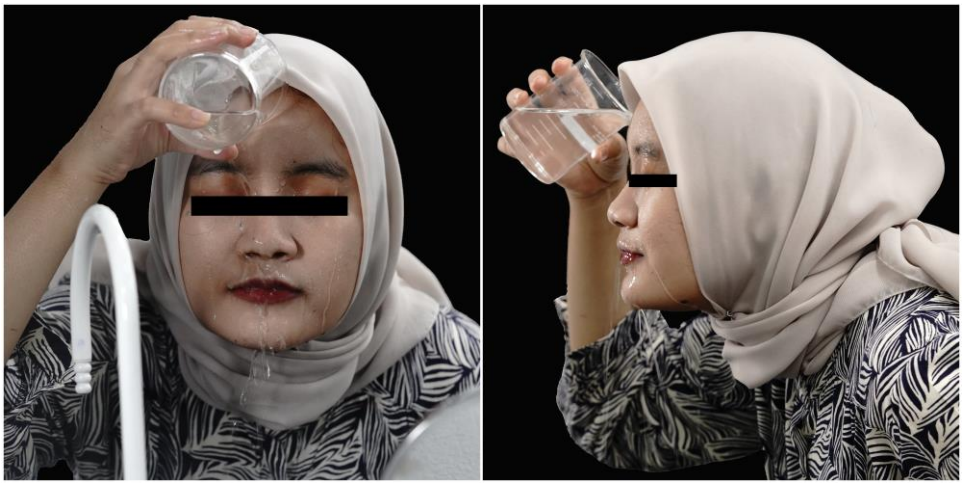

Figure 1. Visualization of water-proof test procedure.

Sweat-proof test

To assess the sweat-proof property of the products, sweat secretion of subjects was induced through performing running exercise on a treadmill (electric treadmill, OB Furni Interindo, Indonesia) for 20 minutes at a speed of 6.0 mph under controlled temperature at 29 ± 1°C and relative humidity 68 ± 2%. After running, the remaining sweat on the face was allowed to dry naturally at room temperature for 10 minutes. Facial image before and after treatment were taken for analysis.

Tear-proof test

To measure the impact of tears on foundation performance, a total of 50 mL artificial tears (25 mL per eye) were used in this test. Artificial tears were put in a 15 mL syringe, and slowly sprayed from the eyelids until it ran down the foundation layer on face. The remaining liquid on the face was allowed to dry at room temperature for 10 minutes. Facial image before and after treatment were taken for analysis.

Figure 2. Visualization of tear-proof test procedure

Results

The Spearman's correlation analysis between the proposed method against in vivo setting for each attribute was showed on table 1.

Test	Sample	In Vivo		In Vitro		Spearman's Correlation	
		ΔTotal Area Value	SDEV	ΔTotal Area Value	SDEV	ρ	p
Smudge-proof	A	534,17%	439,33%	18,43%	10,68%	1	0,5
	B	157,50%	60,97%	7,33%	2,70%		
	C	201,86%	166,91%	15,42%	6,78%		
Sweat-proof	A	243,97%	61,66%	11,47%	0,42%	1	0,5
	B	138,07%	190,30%	10,42%	2,29%		
	C	43,48%	42,50%	8,76%	0,43%		
Water-proof	A	199,78%	160,43%	4,48%	0,26%	1	0,5
	B	269,46%	301,89%	5,18%	0,06%		
	C	406,67%	382,26%	6,27%	1,53%		
Tear-proof	A	113,78%	110,97%	5,07%	0,89%	0,5	0,766
	B	322,37%	364,50%	5,34%	0,74%		
	C	222,07%	323,91%	6,23%	1,55%		

Table 1. The correlation of in vivo against the in vitro method of various attributes (i.e., smudge-proof, sweat-proof, water-proof, tear-proof)

Based on the Table 1, the smudge-proof, sweat-proof, and water-proof in vitro evaluation for all foundation samples showed a positive spearman's correlation against in vivo (ρ=1.0, p=0.5) while the tear-proof measurement also exhibited a strong positive spearman's correlation with different significant value (ρ=0.5, p=0.766), indicating that the proposed in vitro methods for all attributes have a strong positive correlation with the findings on the human skin.

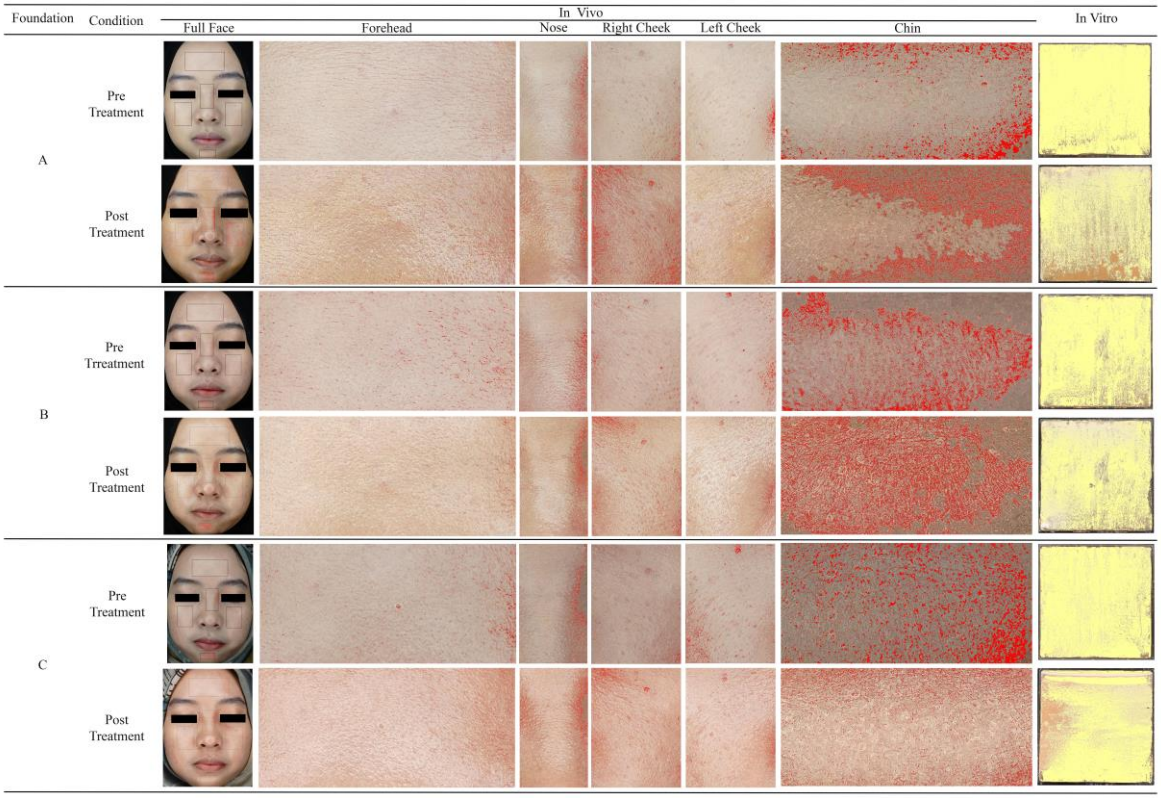

Table 2. The in vivo and in vitro visualization of the observed samples during smudge-proof evaluation before and after treatment

The facial image of smudge-proof evaluation also indicated a strong correlation through the sample A result which had the greatest degradation of foundation layer both on the skin and PMMA plate, manifested by the increasing amount of total area value of intensity after the treatment was done during in vivo test (ΔTotal Area Value = 534,17%.) as well as in vitro (ΔTotal Area Value = 18.43%).

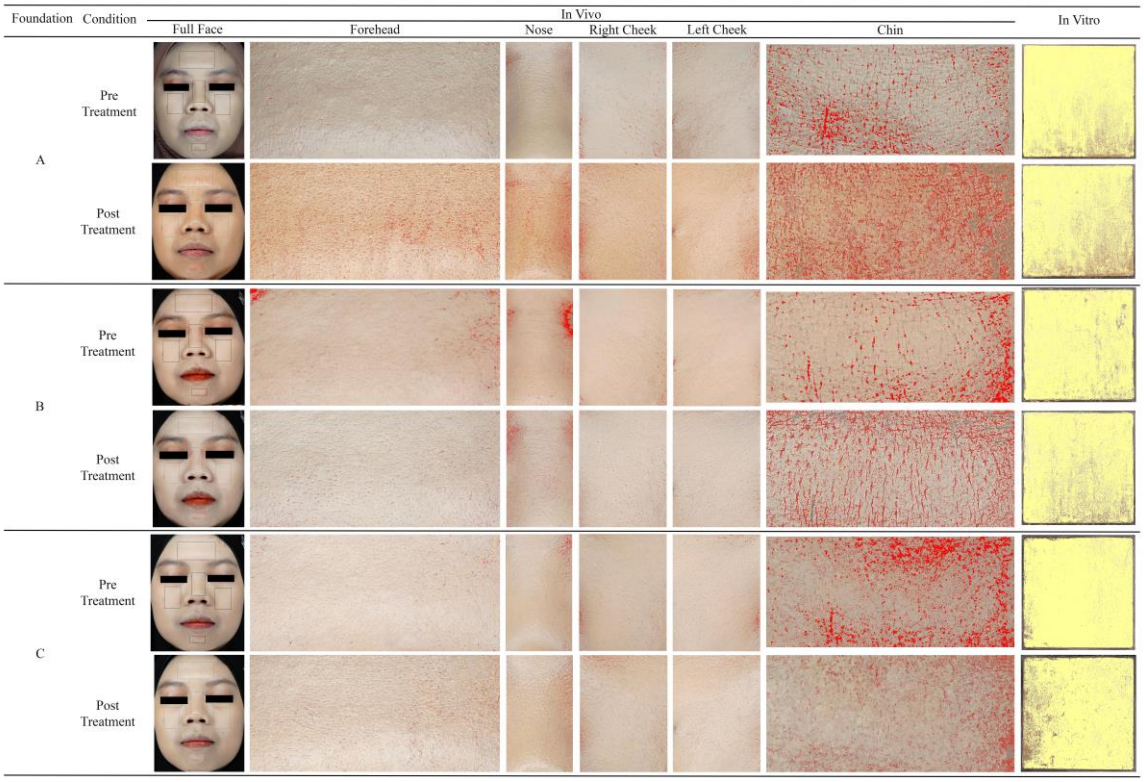

Table 3. The in vivo and in vitro visualization of the observed samples during sweat-proof evaluation before and after treatment.

Another method also showed a strong physical appearance correlation in the sweat-proof. Sample A has the biggest significance difference of appearance between pre- and post-treatment conditions in vivo as well as in vitro. The ΔTotal Area Value in the sample A performed as the most significant difference among the rest of the samples (in vivo Δ Total Area Value = 243.97%, in vitro ΔTotal Area Value = 11.47%).

Table 4. The in vivo and in vitro visualization of the observed samples during water-proof evaluation before and after treatment.

The water-proof evaluation demonstrated that sample C performed as the most significance sample which had wider red area in in-vivo test compared to other samples. This phenomenon also correlates with the numerical data presented in the Table 1 (in vivo ΔTotal Area Value = 406.67%, in vitro ΔTotal Area Value = 6.27%).

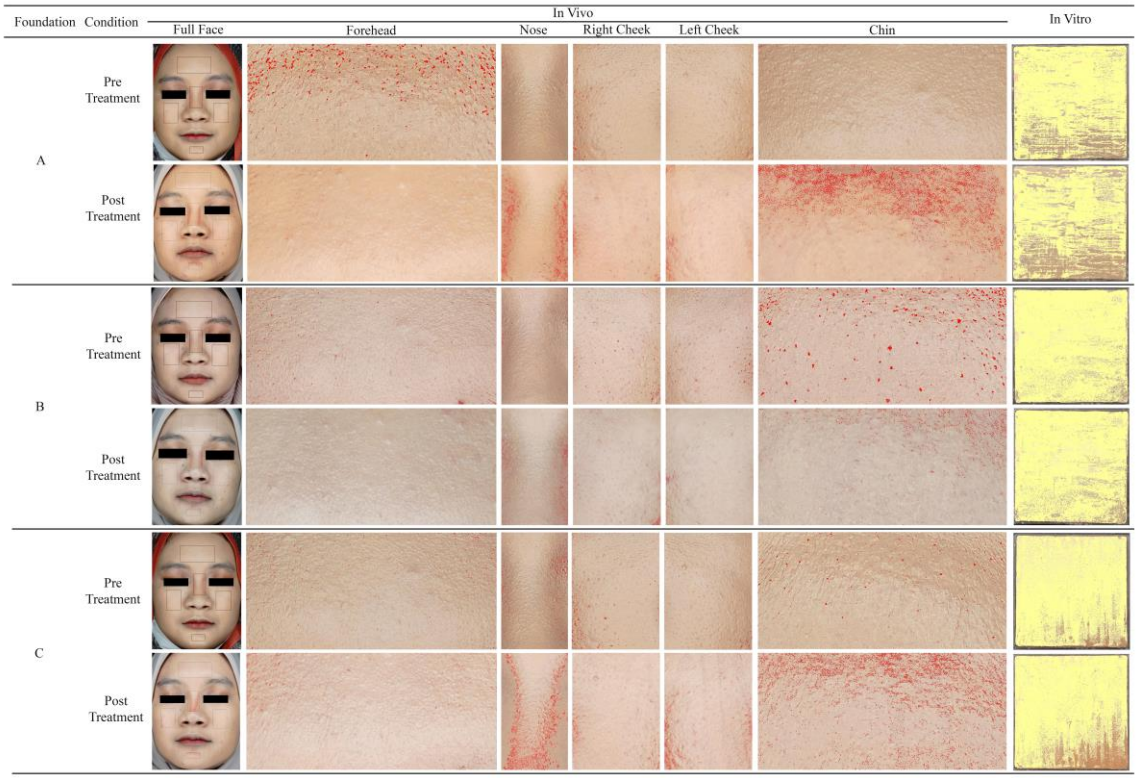

Table 5. The in vivo and in vitro visualization of the observed samples during tear-proof evaluation before and after treatment.

The last assay was tear-proof, the sample B had the most significance difference in vivo area of coverage (ΔTotal Area Value= 322.37%) while sample C had the biggest difference of area of coverage in vitro (ΔTotal Area Value= 6.23). Those results reflected that the tearproof assay had a lack of correlation in vivo/in vitro.

Discussion

We emphasize that Javanese-Indonesian brides and those who face similar circumstances need differentiated products in the makeup category, especially long-wear foundations that are able to resist all the intense exposure during traditional wedding ceremony or "extreme wear" including sebum, sweat, water, tear, high temperature and high humidity. Although visual assessment-dependent subjective evaluation is commonly used and remains indispensable in evaluating the effects of make-up products, there is a need to objectively and quantitatively assess their effectiveness [9]. We proposed quantitative simulated approach to evaluate the superior-resistant properties of foundation. For this in vitro study, PMMA plates were used to replace human skin that enables more control over test variables to yield more reproducible data [7]. To determine the accuracy of the PMMA methodology, its correlation with in vivo result was established using Spearman's ranked correlation coefficient.

The findings showed that in vitro measurement can represent in vivo assessment, for water-proof, smudge-proof, and sweat-proof attributes; but unsignificant (due to Spearman's correlation assessment). This can happen because of the complex physicochemical phenomenon on the skin surface which formed hydrolipidic film that could delaminate make up which only captured on the in vivo condition. This phenomenon could not be portrayed by the in vitro evaluation which conducted separately [10]. Further parametric (Pearson's) correlation analysis should be conducted followed by the high number of volunteers in various skin type which represented the world's population in order to define the numerical correlation between in vitro and in vivo regressions.

Conclusion

The findings of this study demonstrate potential in vitro methods to evaluate smudge-proof, sweat-proof, water-proof, tear-proof properties of liquid foundation makeup. This provides a new approach in predicting the superior-resistant attributes required when formulating the perfect foundation for Javanese-Indonesian brides or similar target consumers.

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Conflict of Interest Statement

All the authors confirmed that there was no conflict of interests.

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