The Test of Chewing Efficiency by the Two-colored Gum Mixing Ability and the ViewGum Software

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Abstract

Chewing efficiency is the ability to grind some food in the given time. Evaluation of chewing efficiency is important in assessing the success of dental treatment or detecting the masticatory function problem that could be arising from some systemic diseases. The smartphone is an available device that everyone carries at all times. Using a smartphone as part of the chewing efficiency analysis will simplify the method and facilitate clinical diagnosis. Therefore, this study aimed to determine the reliability of the two-color chewing gum test, in which digital images were taken by a smartphone and analyzed by the ViewGum software for chewing efficiency. Twenty-one participants with normal chewing function were assessed by chewing a two-color chewing gum for 20 seconds, and the chewing ability is evaluated by the mixing of colors. The digital images of chewing gum specimens were captured by a scanner or a smartphone to be analyzed for the variance of hue (VOH) using the ViewGum software. The degree of incomplete mixing chewing gum presents with a range of VOH. Pearson correlation showed a highly positive correlation between the VOH obtained from scanned and smartphone images ($r=0.749$, $P<0.01$). The Intraclass Correlation Coefficient (ICC) was 0.75 considered good reliability ($p<0.001$; 95% CI 0.477-0.890). This study suggested that both scanned and smartphone digital images are equally valid for the analysis by the ViewGum software to determine chewing efficiency. Using a smartphone to capture digital images will simplify the method and increase clinical use.

Keywords: *chewing efficiency, a two-color mixing ability test, ViewGum software, smartphone image*

1. Introduction

Chewing is the first process in the digestive system which is important for the maintenance of elderly patients' nutritional status and quality of life (Mioche, Bourdiol, and Peyron, 2004). Helkimo, Carlsson, and Helkimo (1978) defined chewing efficiency as the ability to grind some of a test food during a given time. The Glossary of Prosthodontics also defined masticatory efficiency as the effort required to achieve a standard degree of comminution of food (Ferro et al., 2017). The chewing efficiency, therefore, reflects the masticatory function. It can be assessed for the success of dental restoration and teeth substitution, or detection of masticatory function problems (Prithviraj et al., 2014).

Earlier studies reported that the chewing efficiency may be measured objectively, subjectively, or by a combination of both. The subjective measurement or self-assessed chewing efficiency can be described in terms of subjective responses of the person to the questions about mastication. It can be evaluated through questionnaires or personal interviews (Woda, Hennequin, and Peyron, 2011). Self-assessment or subjective evaluation method has been used in epidemiological studies frequently because it is inexpensive and simple (Johansson et al., 2007; Lexomboon et al., 2012). However, Miura et al. (1998) suggested that the self-assessment of chewing ability might be insufficient for the evaluation of mastication. The subjective and objective measurement may not be positively correlated (Ahmad, 2004; Pedroni-Pereira et al., 2018) and suggesting the problem of validity between the two approaches of measurement. (Boretti, Bickel and Geering, 1995; Woda, Hennequin and Peyron, 2011; Andries Van der Bilt, 2011; Johansson et al., 2007; Lexomboon et al., 2012).

Many objective methods have been developed to assess chewing efficiency. The Sieving method is an objective test that is considered a gold standard method for clinical and experimental purposes (Manly and Braley, 1950; Edlund and Lamm, 1980). Briefly, the chewed specimen was spat out after the chewing test and rinsed through a stack of sieves with various sizes of mesh apertures. Finally, the ability to grind food was analyzed from the number and size of the individual particles through the mesh. Thus, this method requires special equipment, time, and expertise for analysis. The sieving method was reported to be highly repeatable with validity and reliability (Manly and Braley, 1950; Helkimo, Carlsson and Helkimo, 1978). However, the procedure is complicated, time-consuming, and expensive. The frail patients with impaired or compromised oral function may not be able to perform this test. (Mowlana et al., 1994; Van Kampen et al., 2004).

Another objective method is a measurement of color change in chewing gum after chewing. Ishikawa et al. (2007) developed a novel approach to evaluate the color-changeable chewing gum and handheld colorimeter to assess masticatory ability. They suggested that this method is useful for an objective evaluation in denture wearers for improvement of the prostheses. Their following studies have used the colorimetric approach and color scales for the evaluation of color-changeable chewing gum. The recent studies confirmed the validity and reliability of the colorimetric method with color-changeable chewing gum using different alternative measurements ((Kamiyama et al., 2010; Hama et al., 2014). This method makes the testing of chewing efficiency clinically practical without the need for special equipment.

Similarly, the two-colored chewing gum mixing ability test is to evaluate the degree of blending of the two-colors chewing gum as an indicator of chewing efficiency. The degree of mixing of the two colors can be evaluated either visually on a reference scale (Schimmel et al., 2007; Andries Van Der BILT et al., 2012) and optoelectronic method (Schimmel et al., 2015). This test correlates significantly with the sieving test in dentate subjects (Speksnijder et al., 2009; A Van Der Bilt et al., 2010; Sato et al., 2003). Therefore, it can be used as an objective measure for chewing efficiency (Speksnijder et al., 2009; Kaya et al., 2017).

The optoelectronic assessment of the two-color mixing ability can be used by several software programs such as Mathematica software, Adobe Photoshop Elements software, or the ViewGum software. Mathematica software will calculate the difference in color intensity of each digital pixel and its neighbor, thus providing a measure for mixing. Its outcome variable is called the 'DiffPix' score. However, the procedure to crop the area of the bolus from the background of the image was not clear, and the DiffPix algorithm structure is not available for reproduction (Weijenberg et al., 2013; Buser et al., 2018). Adobe Photoshop Elements software is also the optoelectronic assessment. The 'magic wand tool' and the 'histogram function' of this program were used to select and count the pixel of unmixed gum. Then the ratio of unmixed pixels to the total pixels of the original template was calculated as "unmixed fraction (UF)" as an inverse measure of the masticatory efficiency (Schimmel et al., 2007; Molenaar et al., 2012). This program is a commercial software package and time-consuming for analysis (Vaccaro, Peláez, and Gil-Montoya, 2018). Another one is the ViewGum software (dHAL Software, Greece, www.dhal.com). This software is reliable and accurate to be used for optoelectronic assessment of the two-color mixing ability (D. Halazonetis et al., 2013; Schimmel et al., 2015). This method was originally described by D. J. Halazonetis et al. (2013), that the software assesses the variance of hue (VOH) in the images. The area of inadequate mixing presents the color with a high variation on the hue axis than the color of the complete mix area. The VOH is therefore considered as the indicator for mixing ability. This software is freeware and can be easily accessed from any clinical setting or laboratory. Today, the smartphone is a common device that is carried by people at all times. Many applications are useful for healthcare purposes. Therefore, this study applied images captured by smartphone to simplify the previous protocol of the two-color chewing gum mixing ability test, before using the ViewGum software for chewing efficiency analysis.

2. Objective

To determine the reliability of the digital images of the two-color chewing gum taken by a smartphone in comparison with the images scanned by the scanner for the chewing efficiency analysis using the ViewGum software.

3. Materials and Methods

3.1 Subjects

From December 2019 and January 2020, dental students and staff at the Faculty of Dentistry, Chulalongkorn University, were recruited for oral examination by one researcher. The subjects who were healthy and aged between 18 to 50 years old with full dentate (28 teeth) and Angle's classification I occlusion were included in this study. Any subject who presented with Angle's classification II or III occlusions, temporomandibular joint dysfunction (TMD), oral infections, or more than four decayed or restored teeth that required dental treatment were excluded (Halazonetis et al., 2013). All participants signed informed consent before participation. Ethical approval was granted by the research ethics committee at the Faculty of Dentistry, Chulalongkorn University (No.076/2019).

3.2 Chewing gum specimens

Hubba-Bubba Tape Gums (WM. Wrigley Jr. Company, Chicago, USA) in the flavors 'Sour Berry®' (azure color) and 'Fancy Fruit®' (pink color) were used as the two-colored chewing gum for color mixing ability test (Figure 1). The gum was prepared according to the original protocol (Schimmel et al., 2007). Briefly, strips in the dimension of 30 mm x 18 mm x 3 mm were cut from both and manually stuck together before the chewing test (Figure 2).

Figure 1 Hubba-bubba-bubble tape gum

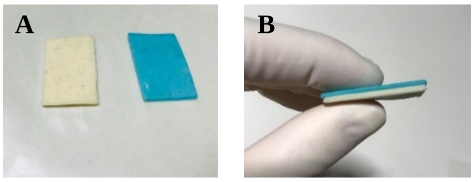

Figure 2 Preparation of the two-colored chewing gum (A) One piece of chewing gum was cut (30mm x18mmx3mm) from the original package. (B) Two-colored chewing gum was prepared by sticking the two strips of chewing gum together.

3.3 The two-color chewing gum mixing ability test

Before the test, the patient's gender and age were recorded. All participants were instructed by only one researcher to chew on the prepared, two-colored, chewing gum. During the tests, the participants were asked to sit in the upright position and continuously chew at a leisurely rate for 20 seconds (Weijenberg et al., 2013; Weijenberg et al., 2015). The chewing motion was recorded in a video clip for later counting the number of chewing cycles, which is the number of the movement of the lower jaw when each participant chewed the gum. When finished, each chewing gum specimen was collected, spat, and placed into a transparent plastic bag. The specimens were then flattened into a pre-made block thickness of 1.5 mm by pressing it with the glass plate (Figure 3A). Then, a glass plate was used to press on the specimen until it flowed to fill in the block and reached the thickness of 1.5 mm (Figure 3B). Both sides of the specimens were scanned with the scanner and then photographed with the smartphone to obtain digital images.

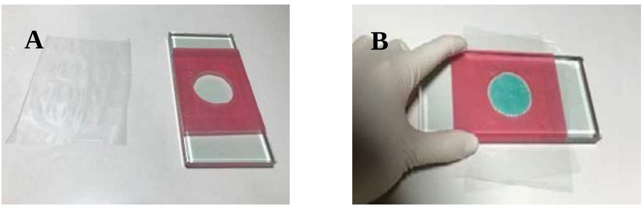

Figure 3 Preparation of compressing specimen (A) The transparent plastic bag and the glass plate with a pink block (B) The specimen was in 40 mm diameter with a thickness of 1.5 mm.

3.4 Digital Image analysis

To capture the images of chewed gum for analysis by the ViewGum software, a flatbed scanner (resolution of 300 dpi, Epson Perfection V39, Seiko Epson Corp., Nagano, Japan) and a smartphone (iPhone® 7, Apple Inc., California, USA; Dual 12MP wide-angle, 12-megapixels) were used (Figure 4). To capture the images using a smartphone, the wood board of 4' x 8' and white plastic box were set up to control the light and distance between the specimen and the smartphone camera (Figure 5). Then, both sides of the specimens were captured using the smartphone camera. When the digital images were saved, a computer notebook (Acer, 11th Gen Intel®core™, 1 GHz, 512 MB, Acer Inc., Taipei, Taiwan) with MS Windows 10® (Microsoft Corporation, One Microsoft Way, Redmond, WA, USA) was used for image processing and running the analysis in the ViewGum software.

The digital images from both methods were assessed by using the ViewGum Software Version 1.2, www.dhal.com as originally described by D. J. Halazonetis et al. (2013). The software transformed the images into the Hue, Saturation, Intensity (HSI) color space, and measured a change of standard deviation of the hue component in the gum images (variance of hue, VOH). Hence, inadequate mixing area presented colors with larger variance on the hue axis than the complete mixing area. The variance of the hue (VOH) would be considered as the measure of mixing ability.

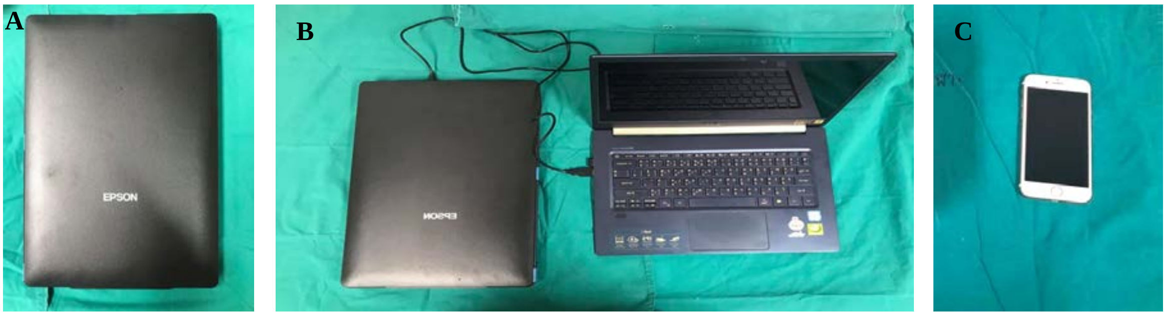

Figure 4 Equipment for importing the chewed gum image to analyze by ViewGum software
(A) A flatbed scanner (B) A computer (C) A smartphone; iPhone 7(12-megapixels)

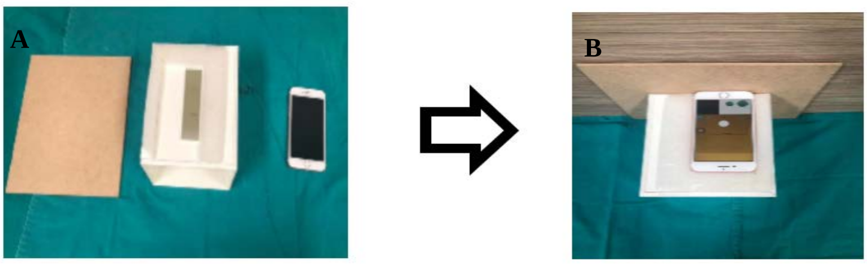

Figure 5 Equipment for digital images captures by smartphone. (A) White plastic box and wood broad for controlling the environment (B) Setting box for capturing by a smartphone

3.5 Statistical analysis

Intraclass correlation coefficient (ICC) (Bartko, 1966; McGraw and Wong, 1996) was used to determine an agreement of images recorded by the smartphone and the scanner. The ICC is close to 1 when the similarity is high. In contrast, when disagreement of the measurements in each individual is high, the ICC is low and approaching 0 (Vetter and Schober, 2018). Moreover, Pearson correlation was also used to investigate the relationship between the variance of hue (VOH) analyzed by the ViewGum software from scanner images and smartphone images at the statistical significance level of 0.05. All statistical analyses would be conducted using SPSS version 22 for Windows.

4. Results and Discussion

Twenty-one healthy participants were included based on the inclusion criteria. Among these participants, there were fourteen women and seven men with a mean age of 29 years (SD = 4). The examples of the chewing gum images, captured by the scanner (Figure 6A) and smartphone camera (Figure 6B) to be analyzed by ViewGum software, are demonstrated. The ViewGum software analyzed the VOH of chewing gum images for chewing efficiency (Table 1). The results showed the mean VOH (and its range) from the scanned images was 0.042 (SD = 0.024) and from the smartphone's images was 0.056 (SD = 0.024). The mean VOH from the scanned images was 0.024 (SD = 0.005) in men and 0.051 (SD = 0.024) in women, and those from the smartphone image was 0.041(SD = 0.014) in men and 0.063 (SD = 0.025) in women. Besides, the mean chewing cycle number of male participants was 35 cycles (SD = 9), 28 cycles (SD = 5) for female participants. All participants had been chewing in an average of 30 (SD = 7) cycles within 20 seconds (SD = 7).

Table 1 Chewing efficiency analyzed by ViewGum software through image obtain from a scanner and A smartphone, including the number of chewing cycles.

	n	The mean VOH from scanned images (±SD)	The mean VOH from smartphone images (±SD)	The number of chewing cycles (cycle±SD)
Male	7	0.024±0.005 (range = 0.017-0.032)	0.041±0.014 (range = 0.027-0.065)	35±9 (range = 29-52)
Female	14	0.051±0.024 (range = 0.027-0.113)	0.063±0.025 (range = 0.036-0.122)	28±5 (range = 17-33)
Total	21	0.042±0.024 (range = 0.017-0.113)	0.056±0.024 (range = 0.027-0.122)	30±7 (range = 17-52)

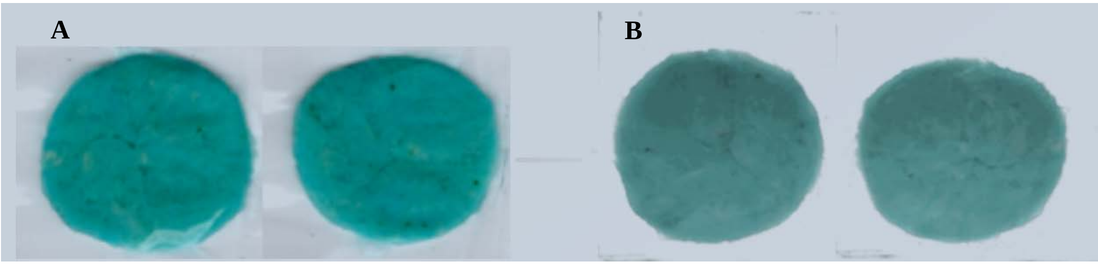

Figure 6 Examples of digital images of the chewed gum (A) The images were taken by the scanner and (B) the smartphone camera. These digital images were ready for analysis using the Viewgum software.

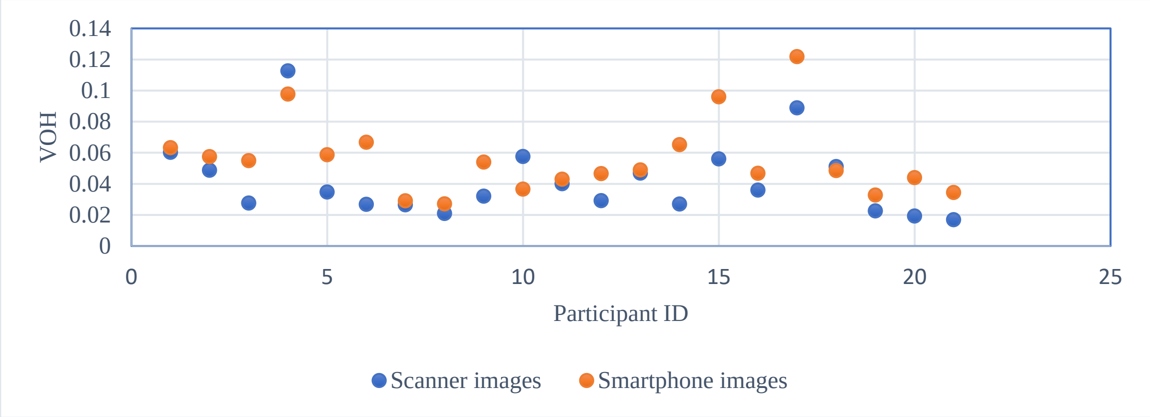

Figure 7 The similarity of detection when using images from a scanner or a smartphone.

The chewing gum samples were obtained from each participant before the images were immediately captured by a scanner (blue), or a smartphone (orange). The variance of hue (VOH) was analyzed by the Viewgum software and they demonstrated that the VOH of the images from a scanner (blue) was similar to those from the smartphone (orange) in the same participant. It was consistent with the data analyzed by Pearson correlation that showed highly correlated approaches (r=0.749, P<0.01).

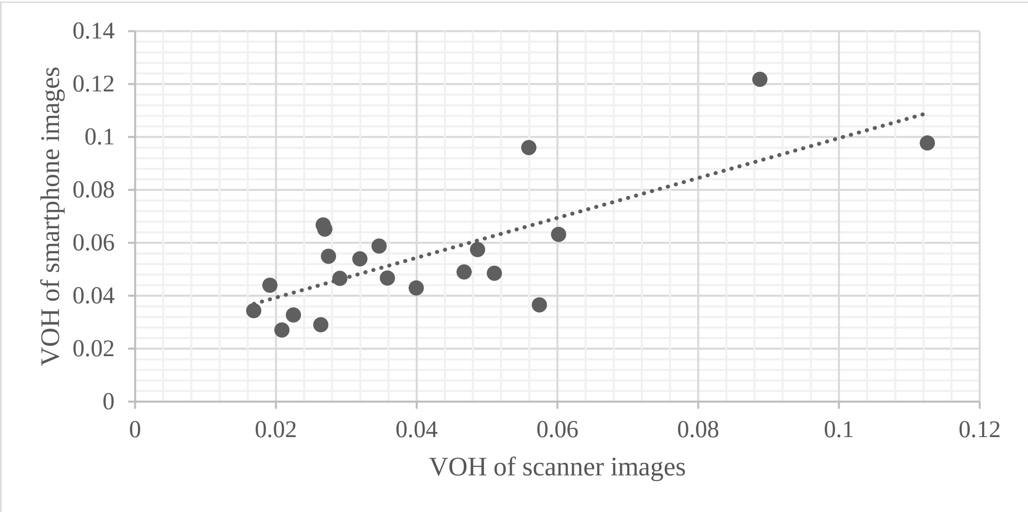

Figure 8 The scatterplot showed a strong relationship between the variance of hue (VOH) analyzed by the ViewGum software from scanner images and smartphone images. Pearson's correlation coefficient (r) = 0.749, P<0.01

The chewing test was modified from the original method described by D. Halazonetis et al. (2013). The previous study commented the use of the scanned images followed by computer analysis that the process was too complicated for routine use, especially special equipment or specialists are required (Fankhauser et al., 2020). Therefore, the use of a smartphone to capture digital images followed by the use of software was added to simplify the method in this study and aim to make this process clinically practical. This study demonstrated that the use of a smartphone to capture images of a two-color chewed gum after the chewing test was highly correlated with the images scanned from the scanner. The chewing gum samples were imaged immediately after each test to minimize a bias from material color self-change. The variance of hue (VOH) analyzed from scanner and smartphone images showed a similar trend within the same sample (Figure 7). The Intraclass Correlation Coefficient (ICC) between the VOH from the scanner and the smartphone images was 0.75, indicating good reliability (Koo and Li, 2016) between both measurements (at $p<0.001$; 95% CI 0.477-0.890). Therefore, the smartphone images were analyzed through ViewGum software for evaluating the chewing efficiency with good reliability in comparison with the scanned images. Moreover, There was a significant positive correlation between the VOH from scanned and smartphone images. The highly correlated approaches were analyzed significance by Pearson correlation ($r=0.749$, $P<0.01$) as shown in Figure 8.

This result was similar to the previous study of Buser et al. (2018), which showed a good correlation between a standard flatbed scanner with ViewGum software and a smartphone photograph with a custom-built application (Hue-CheckGum® mobile application; Artorg center, University of Bern, Switzerland) for assessment of a color mixing ability test. Their study used iPhone® 6 (8-megapixel camera resolution, Apple Inc., California, USA) to take the images and analyzed them using software on a custom mobile application. Their smartphone was also from Apple, which was the same as in this study, but their resolution of the camera was lower. They developed this application to facilitate even ease-of-use for mixing ability tests and make the assessment of chewing efficiency easier. However, this mobile application showed some systemic error and cannot be downloaded in general.

The quality of smartphone images could be improved by control of environmental factors such as brightness, shadow, artifacts, and distance. Thus, the process in this study was performed in a control box with the same light and distance to minimize interference factors as possible.

However, there were also many studies using other software for digital process assessment. For example, Weijenberg et al. (2013) showed the validity and reliability of the two-color chewing gum mixing ability with Mathematica software to assess a mixing ability. The images of the two-color chewing gum were taken from a digital camera with a 12.2-megapixel sensor, fixed focal length lens, under standard tungsten lighting. (Canon 450D; Canon Inc., Tokyo, Japan). They recommended this method to assess masticatory function for elderly persons with dementia. Later, this method was used to assess masticatory performance in elderly persons with dementia and showed associations between mixing ability and general cognition and between mixing ability and verbal fluency (Weijenberg et al., 2015). Adobe Photoshop Elements® software was also used for digital process assessment in several studies. This software computed subsequently a ratio of unmixed gum for "unmixed fraction (UF)" as an inverse measure of the masticatory efficiency. Schimmel et al. (2007) showed the reliability of this software to assess the degree of color mixture of the two-color chewing gum for chewing efficiency analysis. Their study showed significantly impaired chewing efficiency in stroke patients in a longitudinal study by using a mixing ability test with Adobe Photoshop Elements® software to evaluate chewing efficiency (Schimmel et al., 2013). Although the method of analysis through the said software is easy to learn, scan, and pixel count, its subsequent mathematical calculations are unrealistic in a clinical setting. Whilst the ViewGum has been proven to be a reliable and discriminative tool to optoelectronic (L. C. Silva et al., 2018), this software is usually used with the computer and the flab scanner to assess the two-color chewing gum mixing ability test to evaluate chewing efficiency. For example, it was used to evaluate masticatory performance in children with mixed dentition (Kaya et al., 2017), stroke patient (Schimmel et al., 2017), patients treated with narrow diameter implants (Enkling et al., 2017), or patient with complete denture wearers (L. Silva et al., 2018). This software is freeware and easily accessed in clinical settings. It is a simple and safe evaluation. Therefore, this study used the ViewGum software for chewing efficiency analysis.

The two-colored gum mixing ability test was performed in this study. Because it was showed the validity and reliability for the assessment of chewing efficiency in many studies (A Van Der Bilt et al., 2010; Kaya et al., 2017; Silva et al., 2018). In addition to this method was suggested as a reliable and precise method to evaluate chewing efficiency, it also recommended for use in subject with compromised oral function or the elderly (Schimmel et al., 2007; Weijenberg et al., 2013).

Many health factors affect chewing efficiency such as tooth loss, improper tooth restoration, occlusal contact area, or oral motor function (Hatch et al., 2001). Therefore, the analysis of chewing efficiency is not only useful to follow up the improvement after dental treatment but also to detect a decrease of the chewing efficiency, which could be a good indicator for overall health decline such as malnutrition, cognitive impairment, dysfunction of the muscular system. It may detect the problems leading to the cause and proper treatment.

5. Conclusions

In conclusion, the two-color mixing chewing gum test can be used to analyze the chewing efficiency through the ViewGum software. Digital images taken from the smartphone are simple and quick to proceed with a two-color mixing ability test. The variance of hue can measure the mixing color of chewing gum. The results from this study provide a simplified approach to assess chewing efficiency. The evaluation of chewing efficiency will provide information for diagnosis in patients with chewing deficiencies and determine the success of oral rehabilitation during treatment and in follow-up visits.

6. Acknowledgements

The authors would like to thank all staff at Geriatric Dentistry and Special Patients Care Clinic, Faculty of Dentistry, Chulalongkorn University for providing subjects and location for this research.

7. References

Ahmad, S. F. (2004). *Assessment of Masticatory Performance in Complete Denture Wearers*: University of Glasgow (United Kingdom).

Bartko, J. J. (1966). The intraclass correlation coefficient as a measure of reliability. *Psychological reports, 19*(1), 3-11.

Boretti, G., Bickel, M., & Geering, A. H. (1995). A review of masticatory ability and efficiency. *The Journal of Prosthetic Dentistry, 74*(4), 400-403. Retrieved from http://www.sciencedirect.com/science/article/pii/S0022391305803816. doi:https://doi.org/10.1016/S0022-3913(05)80381-6

Buser, R., Ziltener, V., Samietz, S., Fontolliet, M., Nef, T., & Schimmel, M. (2018). Validation of a purpose-built chewing gum and smartphone application to evaluate chewing efficiency. *Journal of oral rehabilitation, 45*(11), 845-853.

Edlund, J., & Lamm, C. J. (1980). Masticatory efficiency. *Journal of Oral Rehabilitation*, *7*(2), 123-130. Retrieved from https://doi.org/10.1111/j.1365-2842.1980.tb00428.x. doi:10.1111/j.1365-2842.1980.tb00428.x

Fankhauser, N., Kalberer, N., Müller, F., Leles, C. R., Schimmel, M., & Srinivasan, M. (2020). Comparison of smartphone-camera and conventional flatbed scanner images for analytical evaluation of chewing function. *Journal of oral rehabilitation, 47*(12), 1496-1502.

Ferro, K. J., Morgano, S. M., Driscoll, C. F., Freilich, M. A., Guckes, A. D., & Knoernschild, K. L. (2017). The glossary of prosthodontic terms. *J Prosthet Dent*, *117*(5S), e1-e105.

Halazonetis, D., Schimmel, M., Antonarakis, G., & Christou, P. (2013). Novel software for quantitative evaluation and graphical representation of masticatory efficiency. *Journal of oral rehabilitation, 40*(5), 329-335.

Halazonetis, D. J., Schimmel, M., Antonarakis, G. S., & Christou, P. (2013). Novel software for quantitative evaluation and graphical representation of masticatory efficiency. *Journal of Oral Rehabilitation, 40*(5), 329-335. Retrieved from https://onlinelibrary.wiley.com/doi/abs/10.1111/joor.12043. doi:10.1111/joor.12043

Hama, Y., Kanazawa, M., Minakuchi, S., Uchida, T., & Sasaki, Y. (2014). Reliability and validity of a quantitative color scale to evaluate masticatory performance using color-changeable chewing gum. *Journal of medical and dental sciences, 61*(1), 1-6.

Hatch, J., Shinkai, R., Sakai, S., Rugh, J., & Paunovich, E. (2001). Determinants of masticatory performance in dentate adults. *Archives of oral biology, 46*(7), 641-648.

Helkimo, E., Carlsson, G. E., & Helkimo, M. (1978). Chewing efficiency and state of dentition: a methodologic study. *Acta Odontologica Scandinavica, 36*(1), 33-41.

Ishikawa, Y., Watanabe, I., Hayakawa, I., Minakuchi, S., & Uchida, T. (2007). Evaluations of masticatory performance of complete denture wearers using color-changeable chewing gum and other evaluating methods. *Journal of medical and dental sciences, 54*(1), 65-70.

Johansson, A., Unell, L., Johansson, A.-K., & Carlsson, G. E. (2007). A 10-year longitudinal study of self-assessed chewing ability and dental status in 50-year-old subjects. *International Journal of Prosthodontics, 20*(6).
Kamiyama, M., Kanazawa, M., Fujinami, Y., & Minakuchi, S. (2010). Validity and reliability of a Self-Implementable method to evaluate masticatory performance: use of color-changeable chewing gum and a color scale. *Journal of Prosthodontic Research, 54*(1), 24-28.
Kaya, M., Güçlü, B., Schimmel, M., & Akyüz, S. (2017). Two-colour chewing gum mixing ability test for evaluating masticatory performance in children with mixed dentition: validity and reliability study. *Journal of oral rehabilitation, 44*(11), 827-834.
Koo, T. K., & Li, M. Y. (2016). A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *Journal of chiropractic medicine, 15*(2), 155-163.
Lexomboon, D., Trulsson, M., Wårdh, I., & Parker, M. G. (2012). Chewing ability and tooth loss: association with cognitive impairment in an elderly population study. *Journal of the American Geriatrics Society, 60*(10), 1951-1956.
Manly, R. S., & Braley, L. C. (1950). Masticatory performance and efficiency. *Journal of dental research, 29*(4), 448-462.
McGraw, K. O., & Wong, S. P. (1996). Forming inferences about some intraclass correlation coefficients. *Psychological methods, 1*(1), 30.
Mioche, L., Bourdiol, P., & Peyron, M.-A. (2004). Influence of age on mastication: effects on eating behaviour. *Nutrition research reviews, 17*(1), 43-54.
Miura, Araki, Hirai, Isogai, Hirose, & Umenai. (1998). Evaluation of chewing activity in the elderly person. *Journal of Oral Rehabilitation, 25*(3), 190-193. Retrieved from https://onlinelibrary.wiley.com/doi/abs/10.1046/j.1365-2842.1998.00237.x. doi:10.1046/j.1365-2842.1998.00237.x
Molenaar, W., Gezelle Meerburg, P., Luraschi, J., Whittle, T., Schimmel, M., Lobbezoo, F., . . . Minami, I. (2012). The effect of food bolus location on jaw movement smoothness and masticatory efficiency. *Journal of oral rehabilitation, 39*(9), 639-647.
Mowlana, F., Heath, M. R., Bilt, A., & Glas, H. W. (1994). Assessment of chewing efficiency: a comparison of particle size distribution determined using optical scanning and sieving of almonds. *Journal of Oral Rehabilitation, 21*(5), 545-551. Retrieved from https://doi.org/10.1111/j.1365-2842.1994.tb01168.x. doi:10.1111/j.1365-2842.1994.tb01168.x
Pedroni-Pereira, A., Marquezin, M. C. S., Araujo, D. S., Pereira, L. J., Bommarito, S., & Castelo, P. M. (2018). Lack of agreement between objective and subjective measures in the evaluation of masticatory function: A preliminary study. *Physiology & behavior, 184*, 220-225.
Prithviraj, D., Madan, V., Harshamayi, P., Kumar, C. G., & Vashisht, R. (2014). A comparison of masticatory efficiency in conventional dentures, implant retained or supported overdentures and implant supported fixed prostheses: a literature review. *Journal of Dental Implants, 4*(2), 153.
Sato, S., Fueki, K., Sato, H., Sueda, S., Shiozaki, T., Kato, M., & Ohyama, T. (2003). Validity and reliability of a newly developed method for evaluating masticatory function using discriminant analysis. *Journal of oral rehabilitation, 30*(2), 146-151.
Schimmel, M., Christou, P., Herrmann, F., & Müller, F. (2007). A two-colour chewing gum test for masticatory efficiency: development of different assessment methods. *Journal of oral rehabilitation, 34*(9), 671-678.
Schimmel, M., Christou, P., Miyazaki, H., Halazonetis, D., Herrmann, F. R., & Müller, F. (2015). A novel colourimetric technique to assess chewing function using two-coloured specimens: validation and application. *Journal of dentistry, 43*(8), 955-964.
Schimmel, M., Leemann, B., Schnider, A., Herrmann, F. R., Kiliaridis, S., & Müller, F. (2013). Changes in oro-facial function and hand-grip strength during a 2-year observation period after stroke. *Clinical oral investigations, 17*(3), 867-876.
Silva, L., Nogueira, T., Rios, L., Schimmel, M., & Leles, C. (2018). Reliability of a two-colour chewing gum test to assess masticatory performance in complete denture wearers. *Journal of oral rehabilitation, 45*(4), 301-307.

Speksnijder, C. M., Abbink, J. H., Van Der Glas, H. W., Janssen, N. G., & Van Der Bilt, A. (2009). Mixing ability test compared with a comminution test in persons with normal and compromised masticatory performance. *European journal of oral sciences, 117*(5), 580-586.

Vaccaro, G., Peláez, J. I., & Gil-Montoya, J. A. (2018). A novel expert system for objective masticatory efficiency assessment. *PloS one, 13*(1), e0190386.

Van der Bilt, A. (2011). Assessment of mastication with implications for oral rehabilitation: a review. *Journal of oral rehabilitation, 38*(10), 754-780.

Van Der Bilt, A., Mojet, J., Tekamp, F., & Abbink, J. (2010). Comparing masticatory performance and mixing ability. *Journal of oral rehabilitation, 37*(2), 79-84.

Van Der BILT, A., Speksnijder, C. M., de Liz Pocztaruk, R., & Abbink, J. H. (2012). Digital image processing versus visual assessment of chewed two-colour wax in mixing ability tests. *Journal of oral rehabilitation, 39*(1), 11-17.

Van Kampen, F., Van Der Bilt, A., Cune, M., Fontijn-Tekamp, F., & Bosman, F. (2004). Masticatory function with implant-supported overdentures. *Journal of dental research, 83*(9), 708-711.

Vetter, T. R., & Schober, P. (2018). Agreement analysis: what he said, she said versus you said. *Anesthesia & Analgesia, 126*(6), 2123-2128.

Weijenberg, R., Lobbezoo, F., Visscher, C., & Scherder, E. (2015). Oral mixing ability and cognition in elderly persons with dementia: A cross-sectional study. *Journal of oral rehabilitation, 42*(7), 481-486.

Weijenberg, R., Scherder, E., Visscher, C., Gorissen, T., Yoshida, E., & Lobbezoo, F. (2013). Two-colour chewing gum mixing ability: Digitalisation and spatial heterogeneity analysis. *Journal of oral rehabilitation, 40*(10), 737-743.

Woda, A., Hennequin, M., & Peyron, M.-A. (2011). Mastication in humans: finding a rationale. *Journal of oral rehabilitation, 38*(10), 781-784.