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THE DETECTOR METHODS OF COLOR CHANGING TO NON-INVASIVE AND ECONOMICAL *NANOFILLER* COMPOSITE RESIN BASED ON *OPTICAL IMAGING*

1

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Abstract*— It has been developed the detector method of color changing to non-invasive and economical *nanofiller* composite resin based on *optical imaging*. The method is chosen due to the easiness of information in images form to be understood. The color changing is represented by the changing of brightness intensity laser which transmitted by samples. The light source uses green pointer laser with 532 nm of wavelength of and webcam sensor which can be obtained in the local market. Fraunhofer diffraction principle is used to utilize set up and test material treatment. By utilizing IC LM 317, it is made a series of regulators so that the laser pointer can be the input voltage from voltage source (AC). The light source of laser pointer is exposed to the test materials for detecting the intensity of transmission. Samples are made as thin as possible in order to transmit light and are given treatment in form of immersion in tea and coffee solution. Immersion is done for 1 week for 4 hours per day. The transmission intensity of samples captured by webcam and processed using the Delphi program. The data collections in form of transmission intensity are in pixel scale. The results indicate that the longer time immersion used affect the transmission intensity of samples decrease. These results can be seen from graph of the relation between transmission intensity with longer time of immersion. This detector can be used to help characterization of color's stability determination on the material which is portable gear.

Keywords*— *Fraunhofer diffraction, nanofiller composite resin, intensity, color stability, effective

I. INTRODUCTION

The use of dental restorative substances is very important in dentistry studies [1]. There have been many researches about dental restorative substances or it is commonly called as dental patch substances such as the research of substances suitability on lighting environment, depth patched area, color suitability, and color stability [2][3].

Tooth is one of the most important human organs which have the significant role[4]. This organ is not only for cutting and chewing, but it also helps in shaping cheekbone and speaking clearly. Moreover, mouth and teeth are the human organs which help in early detection of the disease[5][6]. Nowadays, people start to care with their dental appearance due to aesthetic and healthy reasons[7].

One of the most aesthetic problems faced by society is discoloration of the teeth including dental patch substance, especially for people with their professions dealing directly with public such as celebrity, teacher, presenter, secretary, etc [8]. Color is perception based on three elements: illumination (distribution of the spectrum energy), absorption and scattering (illumination object), and observer (spectral response relating to wavelength)[9][10][11]. According to lighting side, color perception can be defined as the brightness of relative area illuminated by white color or maximal light transmitting [12][13]. Thus, discoloration on teeth and dental patch substances can be defined as brightness change on teeth or dental patch substances translated into intensity change. This discoloration on teeth can affect psychological disorders like the lack of self-confidence which can obstruct the performance. Therefore, non-invasive and economical methods are needed to detect the color of dental patch substances so the substances with well color endurance can be reached and applied to dental patch substance or denture's substance.

Composite resin has been widely used in patching posterior teeth or anterior teeth since it was first introduced in dentistry field [14][15]. Discoloration of dental composite resin can be affected by several intrinsic and extrinsic factors [16][17].

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Intrinsic factor can be from the substance of composite resin itself in which there is a matrix change in this substance so it separates the matrix from its padding. Moreover, there can be the oxidation and hydrolysis processes in the composite resin substance so that the thinning process will happen on the substance due to lack of mechanical power. In other words, this composite is able to absorb other substances so that discoloration happens. The extrinsic factors can cause discoloration on composite resin due to absorption process from other colored substances. It is the result of contamination from many exogenous sources from food or drink consumed by people.

Non-invasive and economical method, which has been researched, designed by using concept of composite resin substance analysis focusing on its endurance in maintaining the brightness from other substances' effect absorbed in (extrinsic factor). There are several composite resin substances widely used in dentistry field; *macro filler* composite resin, *micro hybrid* composite resin, *nanohybrid* composite resin, and *nanofiller* composite resin (3M ESPE Dental Products) [18][19]. For this research, the researcher analyzes the sample from *nanofiller* composite resin or *nano composite*. Discoloration, which happens in this composite resin substance, can be detected by several methods. One of the methods used in this discoloration research is optical method based on optical imaging with the main physical quantities is intensity.

Principles of optics used are light intensity transmission and diffraction Fraunhofer is applied for analyzing a substance. This optical method has several advantages compared to colorimeter [20], such as a higher accuracy, non-invasive (no effect on the substance), and using non-ionic radiation which can minimize the side effect on the composite resin. This method has been done by Apsari *et al.* (2008)[5], utilizing diffraction principles Fraunhofer by using CCD line sensory with monochromatic light, He-Ne laser, with wavelength 632,8 nm. But, the set-up of the research used is complex because the tools must be prepared. Then, the setting of distance among tools before fetching the data is not mobile, and needs expensive sensory.

Furthermore, the tools which are more portable and economical must be developed so they may be produced massively as the next step to help in detecting the discoloration in dentistry field. Moreover, in the data processing and interface also use software which is compatible with the characteristics of the webcam. This is expected to be more valued than the previous research done by Apsari *et al*. (2008), using computerized CCD line sensory imported from abroad [5].

The detection of brightness change on *nanofiller* composite resin with this optical method can be done after giving some treatments to the sample, the *nanofiller* composite resin. This research uses some submersion treatments, submersion with specific time and same concentration. The brightness intensity change, which appears on the *nanofiller* composite resin, will be analyzed based on light intensity transmitted.

This research is done because of *nanofiller* composite resin belong to the new substance for denture in dentistry field and it needs to be explored more about its characteristics, especially its color endurance towards the effect of liquid which directly interact with this substance. *Nanofiller* composite resin itself has been recommended by its manufacturer that this substance appropriate with posterior and anterior teeth, although the long-term-clinical ability and the color stability are still unknown and evidenced [14][21]. From this research, people are expected to be able to get the information about the characteristic of this substitute substance based on discoloration, and the description of the tools.

II. METHOD

A. Research Material

Materials used in this research are *nanofiller* composite resin with Filtek TM's brand Z350 3M ESPE, shaped transparent pieces with diameter size of 5 mm as the materials tested [5]. The test materials are shown in Fig. 1.

Figure. 1 Filtek Z 350 [22]

Solution used in the submersion is coffee and tea solution.

B. Research Instruments

Instruments used in this research is green pointer laser that functioned as light source that will be used in *nanofiller* composite resin, with specification of wavelength is approximately 532 nm and also modified by giving the adaptor so that pointer laser with the AC current input will be gotten.

Black acrylic is functioned as instrument cover material and also as the holder instrument of each instrument component. CCD line sensor is functioned as transmission intensity detector and determination of diffraction type formed and functioned as calibrator. A4Tech PK-710 Webcam sensor is functioned as detector of transmission intensity size (in pixels) which produced with resolution of 5 MP. Delphi software is functioned as data compressor of each image produced by Webcam sensor. Digital Avometer is functioned as gauge of laser output tension. Klise is functioned as filter to decrease the noise from excessive laser light intensity. Convex lens with the focus of 20 cm functioned as focus regulator of transmission light from research materials. Computer (PC)/notebook are functioned as the instrument to show the result of analysis by software with specification Processor Intel Core 2 Duo and NVidia Graphic 512 MB.

C. Stages of Research

1. The organization of initial Set Up and Length Calibration

Instrument set up presented in Fig. 2. Data collections are done twice with two different sensors. For the data collection using CCD line sensor, it started with turn on the light source which is green pointer laser directed to the prepared test materials. Light from each test material captured using CCD line sensor connected to PC.

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CCD software at PC is opened and determined by the value x1, x2, dx, y1, y2, and dy from signal distribution pattern formed from each test materials. It is done by achieving horizontal cursor (y1 and y2) and vertical cursor (x1 and x2). The center location is determined by using Equation tools which is Peak Finder. After geting those values, it is determined Gaussian Plot by giving input value in graphic regulation. Center Location gotten from Peak Finder, Peak Value which is values y2 and Width is the value of dx [5].

After the form of *Gaussian Plot*, the wide of distribution pattern formed is determined by directing *vertical cursor* at two sides of graphic. This width is called minimum length between (ΔS) as written in the equation$D = \frac{\lambda L}{\Delta S}$. The data is then analyzed to determine number Fresnel Value in the equation $F = \frac{D^2}{\lambda L}$. It is done to determine that diffraction happened is Fraunhofer diffraction. If the formed diffraction already fulfill Fraunhofer diffraction requirement which is Fresnel number <<1 [5], the value of y2 is noted as maximum intensity which could be transmitted by each test material.

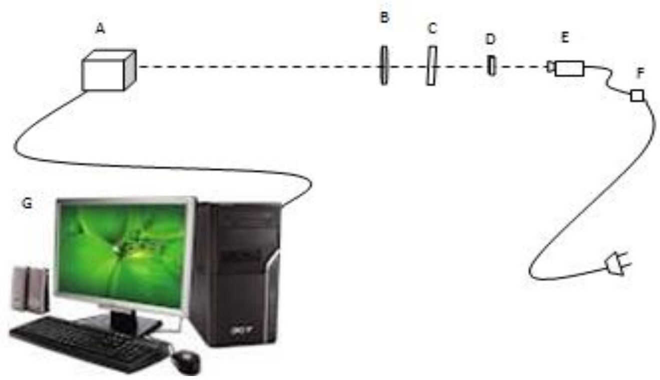

Figure. 2 *Set up* instruments used as length determination (a) CCD line sensor (b) convex lens (c) klise (d) sample (e) laser pointer (f) regulator series (g) computer/ PC

2. The production and submersion of sample

Sample that is used in this research is kind of paste that can be printed and dried using UV radiation or fluorescent light. This *Nanofiller* composite resin sample is taken with average mass for each sample is approximately 5.10^{-3} gram and put on mica plastic. Its purpose is when the process of printing, it can be produced flat sample that follows the mica plastic. The result of sample preparation before printed presented in Fig. 3.

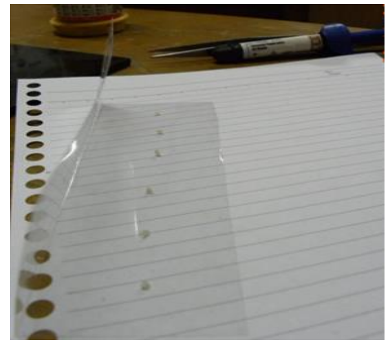

Figure. 3 Sample preparation

Sample is given the load on the mica so that composite resin shaped like thin sheet weighing 500 kg. The constriction instrument is presented on Fig. 4.

Figure. 4 Constriction instrument

Nanofiller composite resin is pressed until produced diameter size in approximately 5 mm (the thickness is not measured because it is feared the material can be broke). The test material is dried using halogen lamp radiation. Coffee and tea solution are prepared in a container for the submersion from the first until seventh day. The submersion in each container is done based on the predetermined time, which is 4 hours per day [23]. The test material is taken from container and dried in order to be easy to analyze and decrease the *noise* produced by submersion solution. After that, the sample is ready to be taken and to be analyzed. The data collection is done repeatedly from the first until seventh day.

3. Overall Instrument Designation

The solid series of instrument component is based on the first stage data. The first stage, it made the outer frame of beam instrument using black acrylic with the hinge on top side so it can be opened and easier to make a change of test material, and also set the output laser voltage monitored using digital Avometer. The holder made from rectangular plate to be a buffer of instrument components when it is sequenced in

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predetermined *set-up*. The size of each holder is appropriated with the size of components used. *Webcam* and green pointer laser are placed and glued in the designated holder and position. For the test materials, put on the special holder designed to get the easiness while changing with other test materials. The length calibration from the first data collection produce the same length as presented in Fig. 5.

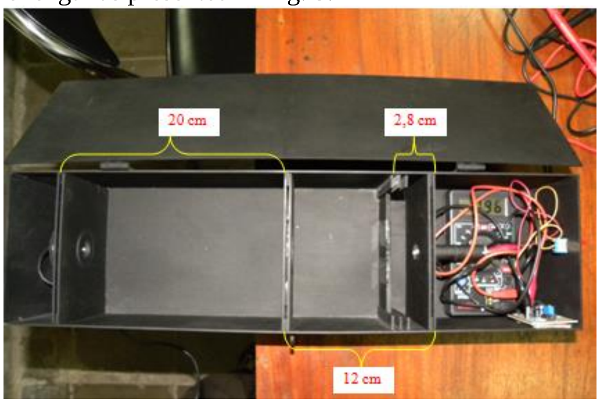

Figure. 5 Length between each component in the detector instrument

Besides making the instrument framework, program that used to capture the intensity through *webcam* is also made using Delphi program. Functionally, this program is needed to capture the image from transmission intensity, analyze the image to determine the number of pixels in which value of 255.

4. Data Collection and Analysis

The first step for data retrieval by using the fix tool is by connecting it to the PC via USB cable on webcam. The next step is open the display of Delphi software that was created for the data retrieval. Then, writer was taking a picture or image from the light of intensity transmission through the *interface* Delphi program. The image that has been captured by a webcam is analyzed the brightness by finding the pixels amount (dots in digital units) with the amount maximum of 255 or white colour pixels. It is done to get the assumption that the pixels with the amount of 255 is the light transmission from the test material where the *pixels*from *image* of that test materials, absorption material immersion solvent has not occured, so it was able to transmit the laser light optimally. After knowing how many *pixels* are detected with amount of 255 or maximum intensity within the picture, the data is noted to compare with the data that has been taken by using a CCD line.

III. RESULT AND DISCUSS

A. *The Results of the Set Up test using CCD Sensor Line*

Before taking the data for the treated samples, people should take the data for untreated data firstly or soaked samples. Value of x1, x2 and dx are continually for the samples before soaked, there are 1437, 1591 and 154. While the value of y1, y2 and dy continually are 806, 3781 and 2851. After get all these values, these values are used to show the *Gaussian plot* to obtain between the minimum gap (ΔS). After gaining the value for ΔS on the samples before soaked is 3731 µm. The distribution of the pattern signal for the not soaked samples is presented in Fig. 6.

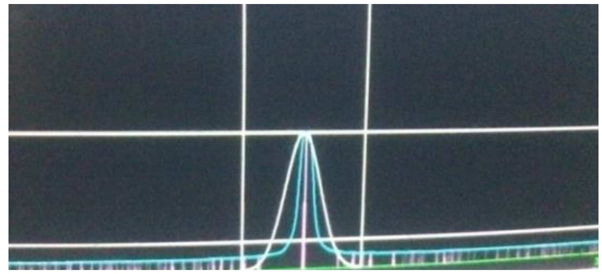

Figure. 6 *Gaussian Plots* from the sample before processing

The data x1, x2, dx, y1, y2, dy middle value and ΔS are presented in Table 1 and Table 2.

Table 1. The data observation of transmission intensity using the CCD line to the samplewhich is soaked in a tea liquid

Materials Variable	Pre-Soaked	Day-1	Day-2	Day-3	Day-4	Day-5	Day-6	Day-7
Materials Variable	1437	1512	1335	1340	1311	1446	1395	1383
x1 (pixels)	1591	1598	1530	1557	1476	1583	1513	1535
x2 (pixels)	154	86	195	217	165	137	118	152
dx (pixels)	806	764	491	882	1046	1183	1404	760
y1 (lux)	3781	3735	3694	3686	3662	3629	3587	3567
y2 (lux)	2851	2971	3202	2804	2616	2446	2183	2807
dy (lux)	1514	1553	1427	1410	1398	1511	1452	1437
Median (lux)	3731	4789	4669	5180	3948	3629	2905	2730

Table 2. The data observation of transmission intensity using the CCD line to the samplewhich is soaked in a coffee liquid

Materials Variable	Pre-Soaked	Day-1	Day-2	Day-3	Day-4	Day-5	Day-6	Day-7
x1 (pixels)	1437	1493	1328	1343	1311	1485	1432	1390
x2 (pixels)	1591	1591	1533	1463	1510	1579	1546	1505
dx (pixels)	154	98	205	120	199	94	114	115
y1 (lux)	806	682	550	1510	644	2110	1462	897
y2 (lux)	3781	3714	3654	3647	3581	3570	3528	3489
dy (lux)	2851	3032	3104	2137	2938	1460	2066	2593
Median (lux)	1514	1538	1427	1412	1432	1517	1479	1447
ΔS (µm)	3731	3034	4858	2814	4704	2261	2737	2828

From the determination of Fresnel numeral, the result data shown in Table 3 and Table 4 below.

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Table 3. The data value from the width of the gap (D) and the Fresnel numeral (F) on the test material that were soaked in tea liquid

Submersion	width of the gap/D (m)	Fresnel numeral/F
Pre-Soaked	$3{,}992495.\ 10^{-6}$	$1{,}070087025.\ 10^{-3}$
Day-1	$3{,}110461474.\ 10^{-6}$	$6{,}495012475.\ 10^{-4}$
Day-2	$3{,}190404798.\ 10^{-6}$	$6{,}833165128.10^{-4}$
Day-3	$2{,}875675676.10^{-6}$	$5{,}551497445.10^{-4}$
Day-4	$3{,}773049645.10^{-6}$	$9{,}556863335.10^{-4}$
Day-5	$4{,}104712042.10^{-6}$	$1{,}1311086261.10^{-3}$
Day-6	$5{,}127710843.10^{-6}$	$1{,}76513282.10^{-3}$
Day-7	$5{,}456410256.10^{-6}$	$1{,}998685075.10^{-3}$

Table 4. The data value from the width of the gap (D) and the Fresnel numeral (F) on the test material that were soaked in coffee liquid

Submersion	width of the gap/D (m)	Fresnel numeral/F
Pre-Soaked	$3{,}992495.\ 10^{-6}$	$1{,}070087025.\ 10^{-3}$
Day-1	$4{,}909690178.\ 10^{-6}$	$1{,}618223526.\ 10^{-3}$
Day-2	$3{,}066282421.10^{-6}$	$6{,}311820546.10^{-4}$
Day-3	$5{,}293532338.10^{-6}$	$1{,}881141556.10^{-3}$
Day-4	$3{,}166666667.10^{-6}$	$6{,}731859412.\ 10^{-4}$
Day-5	$6{,}588235294.\ 10^{-6}$	$2{,}913859042.10^{-3}$
Day-6	$5{,}442455243.10^{-6}$	$1{,}988474696.10^{-3}$
Day-7	$5{,}267326733.10^{-6}$	$1{,}862562494.10^{-3}$

From the data in Table 3 and 4 above, the graph is made due to the relationship between the lengths of immersion time with maximum intensity to find out the brightness changes which is related with the transmission intensity as reported by Apsari *et al.* (2008)[5]. The maximum intensity from the CCD line is shown by the y2 variable. The graphic relationship between the maximum intensity (y2) and the length of immersion time of the test material in tea liquid are presented in Fig. 7. The graph of the relationship between the maximum intensity and the duration of thesoaking time of materials test on the coffee liquid is presented in Fig. 8.

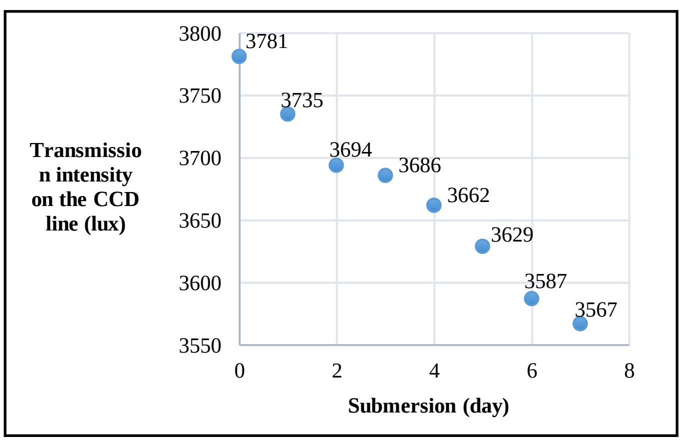

Figure. 7 The relation between transmission intensity with time of immersion in a tea liquid

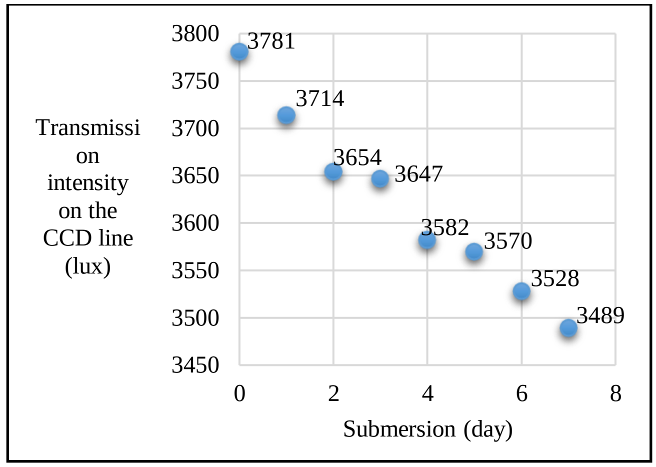

Figure. 8 The relation between transmission intensity with time of immersion in a coffee liquid

B. *Designation Results of Changing Color Detector*

This study uses several components which are arranged into a set up based on results of calibration in the previous stage. The whole display of this detector in black box form which has length of dimensions, width and height adjust with the predetermined set up. The whole hardware which used in the study is presented in Fig. 9.

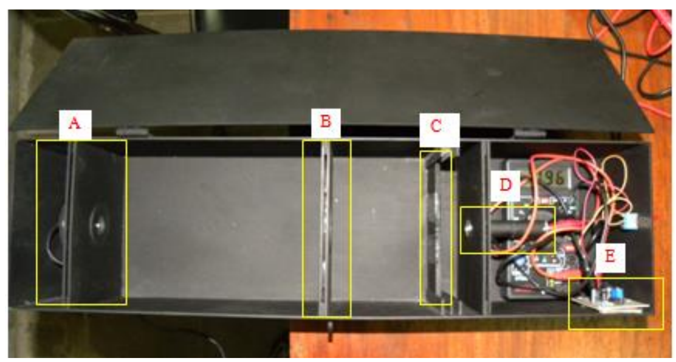

Figure. 9 The whole series of tools (a) webcam (b) convex lenses (c) test materials area (d) laser pointers (e) regulator circuit

C. *Trial Results of Changing Color Detection*

The data observation of immersion in tea solution samples is represented in Table 5, while for the coffee solution is represented in Table 6.

Table 5. The observation data of transmission intensity is using a detector for immersion in tea solution samples.

Day-	Transmission intensity (pixels)
0	$(2{,}04 \pm 0{,}008).10^2$
1	$(1{,}94 \pm 0{,}010).10^2$
2	$(1{,}86 \pm 0{,}016).10^2$
3	$(1{,}74 \pm 0{,}005).10^2$
4	$(1{,}66 \pm 0{,}000).10^2$
5	$(1{,}57 \pm 0{,}007).10^2$
6	$(1{,}50 \pm 0{,}005).10^2$

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Table 6. The oobservation data transmission intensity is using a webcam sensor for immersion of coffee solution samples.

Day-	Transmission intensity (pixels)
0	$(2{,}05 \pm 0{,}009).10^2$
1	$(1{,}95 \pm 0{,}000).10^2$
2	$(1{,}86 \pm 0{,}010).10^2$
3	$(1{,}75 \pm 0{,}007).10^2$
4	$(1{,}64 \pm 0{,}007).10^2$
5	$(1{,}50 \pm 0{,}010).10^2$
6	$(1{,}35 \pm 0{,}005).10^2$

The relation graph of longer time of immersion in tea solution with intensity (pixels) are captured using webcam is represented in Fig. 10, while graph immersion in coffee solution samples with intensity (pixels) is represented in Figure. 11.

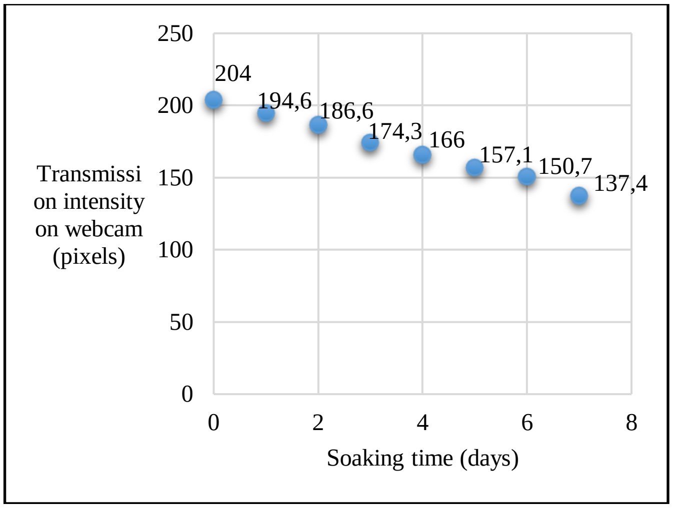

Figure. 10 Relations transmission intensity (pixels) with immersion time in solution of tea

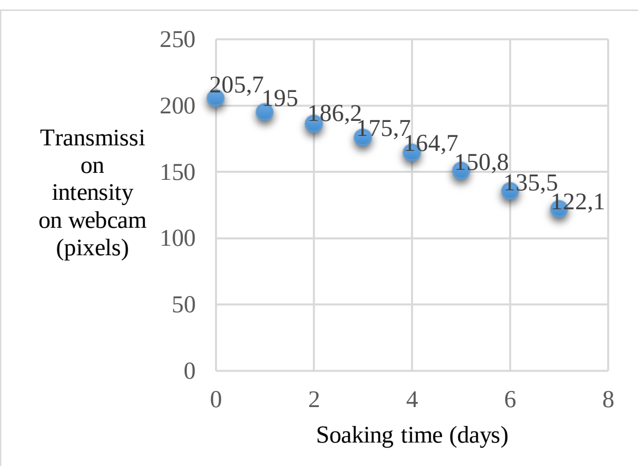

Figure. 11 The relation transmission intensity (pixels) with immersion time in coffee solution

D. *Discussion*

The data collection is done by using the instrument that has been designed based on the intensity of laser pointer transmission used in test material. The intensity is captured by webcam, then processed as an image and analyzed by using software that has been made by Delphi's program.

Image that has been taken using Delphi's program, then analyzed by calculating how much points (pixel) valued at 255 are. The pixel valued at 255 is a white color points without another color value (R, G, B) that influence. The term Algorithm used when the image has been gotten from webcam, then at x-axis y-axis in image will be calculated the number of points valued at 255. While the points valued less than 255 will be passed or not calculated. In this algorithm, it is assumed that points valued at 255 in image intensity captured by using webcam is not influenced by the solution of tea and coffee. The points valued less than 255 assumed to be affected by test material, so the light that transmitted through the test material can't be maximum because of the slue of light by absorbed material (material in the solution of tea and coffee).

The treatment length also influence the intensity of transmission detected. From the data taken by this instrument, it can be seen that as long as of immersion in the solution of tea and coffee, the intensity of transmission is decreasing (units of pixel). It is caused by the longer the immersion, the solution's material which is absorbed by test material is more increasing. While, as the comparison, the data taken by the instrument that has been designed as a model has the same characteristics compared with the data taken by sensor set up CCD line when deciding the appropriate set up distance, decreasing of intensity which is transmitted by the test material along with the increasing of immersion treatment in test material. It is proved on table 5 and table 6, where as long as the immersion, so the intensity which is detected by the detector will be decreasing. Beside comparing with the first data that is taken using y CCD line, the data that has been designed can also be compared with the research done by Apsari *et al.* (2008) [5]. This is the data from Apsari *et al.* (2008), shown in Table 7 and Table 8 [5].

Table 7. The immersion of tea's solution [5]

Long immersion	**Maximum intensity**	**GPLOT (average, maximum, wide)**	**ΔS (μm)**	**D= λL/ΔS (μm)**	**F = D^2/λL**
One day	3322	(1362,3322,230)	4963	0,000073	0,01477
Three days	3178	(870,3178,282)	6522	0,000055	0,00839
Five days	1324	(575,1324,306)	6678	0,000054	0,00808
Seven days	-	-	-	-	-

Table 8. The immersion of coffee's solution [5]

Long immersion	**Maximum intensity**	**GPLOT (average, maximum, wide)**	**ΔS (μm)**	**D= λL/ΔS (μm)**	**F = D2/λL**
One day	3302	(1308,3302,166)	3962	0,000091	0,02295
Three days	1395	(1374,1395,226)	4998	0,000072	0,01437
Five days	-	-	-	-	-
Seven days	-	-	-	-	-

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From the Table 7 and Table 8, it is known that maximum intensity which is produced after the immersion of the test material in tea and coffee solution is decreasing along with the increasing of long immersion. From the Table 7 and Table 8 also known the different of parameter measurement and if it is compared with Table 5 and Table 6, according to literature the influence of immersion's time in maximum intensity, distance among the minimum and wide space [5]. In this research, parameter that will be seen is the influence of immersion's time towards maximum intensity. It is purposed to detect the transmission changing of brightness in the sample.

This graph shows the influence of long immersion towards maximum intensity by Apsari's *et al.* research (2008) can be seen in Fig. 12 [5].

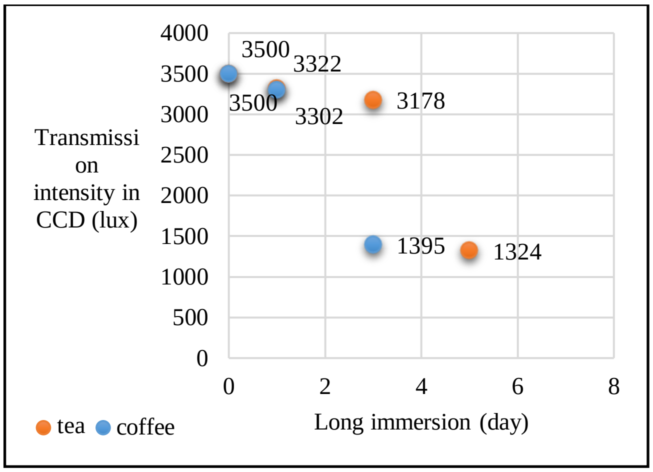

Figure. 12 The graph of transmission intensity towards long immersion [5]

By comparing the data taken by using detection instrument and the data produced by Apsari's *et al.* research (2008), it can be proven that the detection instrumen that has been made having the same characteristic with research *set up* used by Apsari *et al.* (2008) [5]. It is proven by decreasing of transmission intensity along with the increasing of long immersion, which is shown in Fig. 10, 11 and 12. The differences of the data taken by using the detection instrument that has already been designed with the data which produced by Apsari's *et al.* research (2008) are the set up distance, test material and units used [5].

Besides the comparison with set up used by Apsari *et al.* (2008), the instrument that has been designed can also be compared with Prasetyo E.A's research (2008) which use type of photo cell BPY-47 as the detector [24]. This is the graph's connection between transmission intensity with long immersion in Prasetyo E. A's research (2008) shown in Fig. 13 [24].

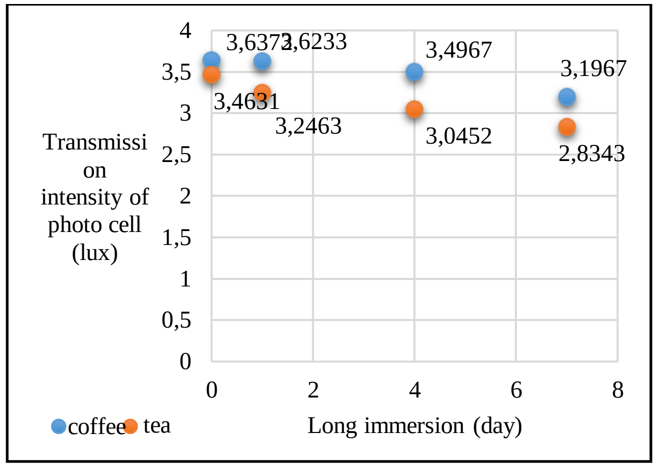

Figure. 13 The graph of maximum transmission towards long immersion [24]

Transmission intensity tendency produced by the instrument that has been made based on optical imaging method can be compared with the tendency that happened in another research. Another difference of tendency occurred in soaking treatment can be explained in Table 9.

Table 9. The differences of transmission intensity tendency with another research [5][24]

No	The research	Immersion's treatment	Transmission intensity tendencies
1	Detection instrument of discoloration	Immersion in tea's solution	Decrease
		Immersion in coffee's solution	Decrease
2	Set up CCD line	Immersion in tea's solution	Decrease
		Immersion in coffee's solution	Decrease
3	Set Up Apsari *et al.* (2008)	Immersion in tea's solution	Decrease
		Immersion in coffee's solution	Decrease
4	Prasetyo E. A (2008)	Immersion in tea's solution	Decrease
		Immersion in coffee's solution	Decrease

From the Table 9, it is known that the characteristic of transmission intensity produced by the instrument has been made, it has the decreasing tendency along with increasing of long immersion that is given to the sample. It is same with another research which is used as the comparison, Apsari *et al.* (2008) and Prasetyp E. A (2008).

IV. CONCLUSION

The discoloration detection instrument has been successfully made based on economical optical imaging and

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noninvasive, it is portable and also complied with Fraunhofer's diffraction principal. From the result of instrument testing based on optical imaging method, it is concluded that the instrument is able to detect discoloration of *nanofiller* composit resin based on another result of research. Researcher recommend this optic-method to be used as the alternative color detection instrument in dentistry.

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