Dental unit prototype with dental suction and handpiece micromotor parameters

Hanifah Rahmi Fajrin*, Heri Sarwono, Kuat Supriyadi
Medical Electronics Department, Universitas Muhammadiyah Yogyakarta, Yogyakarta, Indonesia
*hanifah.fajrin@vokasi.umy.ac.id

Abstract. A dental unit is a device for dental examination and treatment, including drilling, filling, cleaning and examination. In 2018, Basic Health Research Center Indonesia recorded the proportion of oral and dental problems of 57.6% and 10.2% of those who received services from dental medical personnel. Equitable distribution of dental health services at public health centers for the middle to lower-income community still faces a lack of facilities due to the dental unit's high cost. Judging from the above problems, the author wants to make an economical Dental Unit but has entered into the standard of a dental examination. In designing the dental suction device and handpiece, this micromotor utilizes an LCD display as a pressure reading on dental suction, which has been converted by the MPX4115C6U5V sensor as well as the micromotor handpiece. There are up and down buttons for selecting the rotation speed from 1000 RPM to 25000 RPM. The tests carried out include testing the suction pressure at dental suction and testing the rotational speed of the micromotor handpiece. Based on the results, the sensor used as a pressure reader for the calibrator tool has the largest correction value of 0.36 KPa at -10 KPa pressure measurement, the micromotor handpiece testing has the highest error of 2.2% and the lowest error of 0.3.%. Thus, it can be concluded that the design of the dental suction device and the micromotor handpiece can be used in the examination of teeth and mouth as a saliva suction device and tartar cleaning.

1. Introduction
One of the health factors that needs to be considered is oral health because oral health can affect the overall health of the body. Nevertheless, oral and dental disease is a public health problem in Indonesia. This is based on a report on the high prevalence of sufferers of the disease and is one of the top ten disease most frequently complained about by the public. According to Basic Health Research Center in 2018, the proportion of dental and oral problems was 57.6%, and only 10.2% received medical treatments [1].

A dental unit is a tool used by dentists for the examination and care of teeth and mouth (drilling, filling, cleaning and examination) [2]. There are several parts of the dental unit, such as dental chair and dental light, three ways syringe, suction dental, handpiece, etc. The price of dental units on the market is around IDR 90 million to IDR 200 million, so that health care facilities such as Health Communities Center (Puskesmas) and clinics in Indonesia cannot afford this tool because the price of the equipment is relatively expensive [3]. In this study, the authors designed a dental unit prototype device that is more...
economical than the tools on the market, for the price range of tools made by the author is under IDR 20 million.

In the previous research [4] discussed the use of low-pressure suction. In this study, two pressure modes were used, namely 90 mmHg and 120 mmHg. Researchers tested the suction power of 1 liter for a pressure of 90 mmHg, which had a suction speed of 201.2 seconds and for 120 mmHg was 201.4 seconds. In this study, the authors used the pork belly as an experimental material. The drawback of this tool is that the suction still uses a manometer as a viewer, which makes it difficult for the user to interpret it. In further research, a tool was made by [5], the data collection method was carried out 20 times on seven pressure parameters (27 mmHg, 100 mmHg, 200 mmHg, 300 mmHg, 400 mmHg, 500 mmHg, 563 mmHg) with the greatest correction at a maximum pressure of 562 mmHg-563 mmHg, namely 2.65 mmHg.

The weakness of this study is that the equipment made is only a prototype of dental suction without any other complementary tools that can support the continuity of the examination process, while dental units generally have many additional parameters that are needed in the process of dental examination or care. A further study conducted by [6] in this discusses controlling the speed of a dental micromotor with a microcontroller system which is set via the up / down button as the rates per minute (rpm) speed setting. This study hopes to facilitate the work of operators in the formation and polishing of dental prostheses required for someone who has had tooth extraction due to cavities. The drawback of this tool is that the rotation speed cannot be done automatically when the micromotor is used and the selection range of rotation speed provided on this tool is 25000 rpm, with a multiple of an increase of 5000 rpm.

The next research [7] discusses the design, development and realization of electrosurgery drill equipment. The purpose of this research is to produce an electric surgical drill product that has competitive and innovative without changing its function and use. The data collection was through the measurement of a micromotor device using a contact tachometer as a calibrator and a comparison to determine the actual value of the speed of this electric micromotor device. Based on the results of measurement and testing, this tool has an error of 4.68% at the maximum speed setting of 7000 rpm and an error of 4.7% at the speed setting of 5000 rpm. The drawback of this tool is that there is still a reasonably large error in selecting rpm 7000, which is 4.6%, and the rpm appearance on the display is still unstable.

Looking at the existing chronology, in this study, the author wants to make a dental unit prototype with the parameters of Dental Suction and Micromotor Handpiece with the resulting display of these two parameters being made digital to ensure the suction power and drill rotation produced by dental suction and micromotor handpieces are in accordance with the user wants during the maintenance process. The suction power used in the dental suction is -6 KPa to -65 KPa [8], then the speed of the micromotor handpiece is 1000 rpm up to 25000 rpm [9]. This proposed tool uses economical materials so that it can be used as teaching materials, especially electro-medical, and can be used for health services at the health center level.

2. Methodology
2.1. Dental Suction and Handpiece Micromotor Flowchart
In Figure 1(a), it can be seen that when the power ON/OFF button is pressed to the ON position, the program starts working and immediately initializes the LCD. After that, the operator can adjust the required suction power by turning the selector on the appliance. Then the operator can activate the vacuum motor by pressing/stepping on the footswitch [10] on the device, and the MPXV4115C6U sensor [11] will start to detect the pressure generated by the vacuum motor, which will be displayed on the LCD display. After the motor has removed the suction/vacuum, the tool can be used to suck the liquid in the patient's mouth, and the liquid will be collected in a container of saliva. Meanwhile, the figure 1(b) shows that when the power button is pressed, the program starts working and immediately initializes the LCD. Then the operator can adjust the handpiece rotation speed using the push button up and down according to the requirements needed, and the speed that has been set will be displayed on the LCD. The micromotor handpiece will work according to the speed that has been set when the user
presses/steps on the footswitch on the tool. If the handpiece speed setting is not appropriate, then return the speed setting to position 0 by pressing the reset button and resetting the micromotor handpiece speed. If the handpiece rotation speed is what the operator wants, then the micromotor handpiece can be used for patient examination.

![Flowchart](image1.png)

**Figure 1.** (a). Dental Suction Flowchart, (b). Handpiece Micromotor Flowchart

### 2.2. Hardware Design

Figure 2 shows the design of a motor driver circuit using the L298N IC. The motor driver module gets a 30 VDC input voltage from the power supply to turn on the micromotor and a 5 VDC voltage input from the power supply to turn on the L298N IC [11]. Pin 1 and 2 on the motor driver as Arduino input on pins 2 and 3 to regulate micromotor movement and enable pin A on the motor driver as input to pin 9 on Arduino to regulate micromotor speed by adjusting the PWM on Arduino. Output pins 1 and output 2 on the motor driver are used as input for the micromotor.

![Motor Driver Circuit](image2.png)

**Figure 2.** Motor Driver Circuit

Meanwhile figure 3 shows the design of a microcontroller system that functions as the brain and controls all work carried out by the tool. It uses the Atmega328p IC, which is equipped with six internal
ADC pins and 13 digital pins. In the microcontroller, there is also a port to the downloader / ISP (In-System Chip Programming) program, which functions to enter the programs needed by the module using USB TTL (Universal Serial Bus Transistor-Transistor Logic) [12]. To make dental suction and micromotor handpiece, it uses two Arduino system series, and not all of the pins on Arduino are used. In the Arduino circuit, the system used in dental suction devices uses pin 2 ADC, which is the SCL and SDA pin as serial communication to use LCD 20 x 4 and I2C module, 1 pin ADC as input from the pressure sensor, and 1 digital pin as input from the DC motor driver.

Figure 3. Microcontroller Schematic

It also can be seen in figure 4 which is the design of the MPXV4115VC6 pressure sensor circuit, which functions as a pressure value reader in dental suction. The characteristics of this sensor have an output in the form of an analog signal [11], so it is necessary to use the ADC pin as the input pin of the sensor output. The sensor output is connected to pin A0 on the Atmega328P IC, and then it will be processed by the microcontroller. It will be read and displayed on the character LCD in the form of a pressure value with KPa units.

Figure 4. MPXV4115VC6 sensor circuit

2.3. Tool Design

The design tool is seen in figure 5, it consists of:
1. Handpiece micromotor.
2. 4 Buttons: start, up, down, reset
3. Handpiece’s stand
4. Foot switch
5. LCD
6. Handpiece micromotor’s connector
7. Automatic Water pump
8. Control unit Box
9. Dental chair
10. Flexible arm
11. Switch
12. Dental light
13. LCD
14. Valve regulator
15. Spittoon Bowl
16. Pneumatic

3. Result and Discussion

3.1. Micromotor Handpiece Rotation Speed Test

Table 1 shows the results of the rotation speed test on the micromotor handpiece. Testing is done by comparing the rotational speed of the micromotor handpiece with the tachometer measuring instrument [13]. Tests were carried out 20 times at the rotation speed settings of 5000, 10,000, 15,000, 20,000, and 25,000 rpm [14]. The average values and errors percentage will be calculated.

| No. | Tachometer Settings (RPM) | 5000  | 10000 | 15000 | 20000 | 25000 |
|-----|--------------------------|-------|-------|-------|-------|-------|
| 1   | 5072                     | 10261 | 15095 | 20358 | 25149 |
| 2   | 5075                     | 10206 | 15242 | 20269 | 25162 |
| 3   | 5090                     | 10202 | 15240 | 20279 | 25126 |
| 4   | 5085                     | 10253 | 15100 | 20129 | 25092 |
| 5   | 5142                     | 10265 | 15208 | 20166 | 25116 |
| 6   | 5137                     | 10250 | 15163 | 20300 | 25106 |
| 7   | 5052                     | 10224 | 15204 | 20153 | 25113 |
| 8   | 5049                     | 10216 | 15320 | 20158 | 25079 |
| 9   | 5036                     | 10216 | 15280 | 20157 | 25076 |
| 10  | 5032                     | 10174 | 15282 | 20145 | 25079 |
| 11  | 5027                     | 10171 | 15271 | 20195 | 25063 |
| 12  | 5023                     | 10133 | 15290 | 20175 | 25053 |
| 13  | 4994                     | 10292 | 15200 | 20085 | 25036 |
| 14  | 5002                     | 10310 | 15202 | 20287 | 25030 |
| 15  | 5034                     | 10293 | 15210 | 20106 | 25033 |
| 16  | 5024                     | 10342 | 15370 | 20108 | 25036 |
| 17  | 5024                     | 10268 | 15334 | 20082 | 25090 |
| 18  | 5073                     | 10200 | 15319 | 20350 | 25089 |
| 19  | 5008                     | 10278 | 15380 | 20127 | 25070 |
| 20  | 5043                     | 10150 | 15180 | 20161 | 25050 |
| Avg | 5048.67                  | 10224 | 15232.9| 20180.5 | 25077.5 |
| Error| 1.0%                    | 2.2%  | 1.5%  | 0.9%  | 0.3%  |

Based on the data in Table 1, the average value of the 5000 RPM setting is 5048.67, and the error percentage is 1.0%, and the 10,000 RPM setting has an average of 10224, and the error percentage is 2.2%, at The 15,000 RPM setting got an average value of 15232.9 and an error percentage of 1.5%, at the 20,000 RPM setting an average value of 20180.5 and an error percentage of 0.9% was obtained, and at the 25,000 RPM setting the value was obtained an average of 25077 and the percentage error of 0.3%. The existing error values can be caused by several factors, including human error, the unevenness of the plate used as a measuring medium by the tachometer [13], and the lack of precision between the tachometer and the micromotor when the measurement was made.

3.2. Dental Suction Pressure Test

Table 2 presents the data on the results of the pressure test on the dental suction device. The test is done by comparing the existing pressure value with the pressure value read on the suction pump calibrator of the fluke biomedical digital pressure meter [15]. Tests were carried out 20 times at the pressure setting (-6, -8, -10, -20, -30, -45, -50, and -65 KPa) [16], and the average values and percentage errors.
Table 2. Pressure test

| Pressure setting | Correction (KPa) | Error (%) | Average Value (KPa) |
|------------------|-----------------|-----------|---------------------|
|                  | Proposed Tool   | DPM4 G2   |
| - 6 KPa          | 0.05            | 4.80%     | -6.29               | -6.24               |
| -8 KPa           | -0.05           | 3%        | -8.24               | -8.19               |
| -10 KPa          | 0.36            | 3.10%     | -10.31              | -10.67              |
| -20 KPa          | -0.11           | 0.45%     | -20.09              | -19.98              |
| -30 KPa          | -0.33           | 0.26%     | -29.92              | -29.59              |
| -45 KPa          | -0.17           | 1%        | -45.44              | -45.27              |
| -50 KPa          | 0.14            | 0.30%     | 50.155              | 50.015              |
| -65 KPa          | -0.15           | 0.16%     | -65.11              | -64.96              |

From Table 2 it can be seen that the highest error in the pressure test is 4.80% with a correction value of 0.05 KPa at the pressure point -6 KPa while the lowest error is 0.16% with a correction value of -0.15 KPa at the pressure point -65 KPa. The results of the mean reading of tools made with a comparator (calibrator) have a close value so that the average pressure value of the proposed tool is still below the tolerance threshold of 5% [8]. The existence of an error value can be caused by changes in reading that are too fast in the proposed tool and the comparison tool (calibrator) so that errors occur in data collection.

4. Conclusion

From the results of the tests, it can be concluded that the dental suction and micromotor handpiece can function properly, and the pressure sensor on the dental suction can measure the pressure value given from the vacuum motor. In the dental suction module, the highest correction value is obtained at the pressure setting of -10 KPa with a correction value of 0.36 KPa and an error value of 3.1%, and the lowest correction value is at setting -6 KPa with a correction value of -0.05 KPa and with an error value of 4.8%, for the comparison tool, from the largest correction value it can be seen that the difference between the dental suction readings and the DPM-G2 calibrator has a difference that is not too far away and is still within the tolerance value. Meanwhile, the micromotor handpiece module resulted in the largest error value at the 10,000 RPM speed setting with 2.2%. In comparison, the lowest error value was found at 25,000 rpm, with 0.3%.

References

[1] P. W. Kang, J. H. Kim, H. Kim, and J. R. Morrison, “Improving dental service via communication during treatment,” 8th Int. Conf. Serv. Syst. Serv. Manag. - Proc. ICSSSM’11, pp. 3–8, 2011, doi: 10.1109/ICSSSM.2011.5959428.

[2] M. A. Boyle, M. J. O’Donnell, R. J. Russell, N. Galvin, J. Swan, and D. C. Coleman, “Overcoming the problem of residual microbial contamination in dental suction units left by conventional disinfection using novel single component suction handpieces in combination with automated flood disinfection,” J. Dent., vol. 43, no. 10, pp. 1268–1279, 2015, doi: 10.1016/j.jdent.2015.07.018.

[3] Cobra Dental, “e-Catalog Dental Unit,” Indonesia, 2019.

[4] W. S. A. T. Sutdaen, “Development Of Simple Low Pressure Suction Machine,” Environ. Biosci, vol. 44, pp. 100–104, 2012.

[5] H. Kishimoto and M. Urade, “Assess Dental Plaque and Suction-Extricated Bacteria Adequately,” Chest, vol. 137, no. 2, p. 500, 2010, doi: https://doi.org/10.1378/chest.09-1686.
[6] D. Offner, L. Brisset, and A. M. Musset, “Evaluation of the mechanical cleaning efficacy of dental handpieces,” *J. Hosp. Infect.*, vol. 103, no. 1, pp. e73–e80, 2019, doi: 10.1016/j.jhin.2018.11.011.

[7] R. L. Poole, S. C. Lea, J. E. Dyson, A. C. C. Shortall, and A. D. Walmsley, “Vibration characteristics of dental high-speed turbines and speed-increasing handpieces,” *J. Dent.*, vol. 36, no. 7, pp. 488–493, 2008, doi: 10.1016/j.jdent.2008.03.006.

[8] C. Dragoumanis and I. Pneumatikos, “Can continuous oral suctioning with a saliva ejector in critically ill people be more effective?,” *Int. J. Nurs. Stud.*, vol. 50, no. 8, pp. 1151–1152, 2013, doi: 10.1016/j.ijnurstu.2013.01.014.

[9] A. C. Ionescu, M. G. Cagetti, J. L. Ferracane, F. Garcia-Godoy, and E. Brambilla, “Topographic aspects of airborne contamination caused by the use of dental handpieces in the operative environment,” *J. Am. Dent. Assoc.*, vol. 151, no. 9, pp. 660–667, 2020, doi: 10.1016/j.adaj.2020.06.002.

[10] K. Sano, E. Yagi, and M. Sato, “A study on estimation of walking intention using foot switches and hip joint angles for walking assist of non-handicapped persons,” in *The SICE Annual Conference 2013*, 2013, pp. 1527–1532.

[11] Freescale, “MPX4115C6U5V Calibrator suction pump,” 2009.

[12] H. R. Fajrin, Z. Rahmat, and D. Sukwono, “Kilovolt peak meter design as a calibrator of X-ray machine,” *Int. J. Electr. Comput. Eng.*, vol. 9, no. 4, pp. 2328–2335, Aug. 2019, doi: 10.11591/ijece.v9i4.pp2328-2335.

[13] H. Huang, N. Baddour, and M. Liang, “A method for tachometer-free and resampling-free bearing fault diagnostics under time-varying speed conditions,” *Measurement*, vol. 134, pp. 101–117, 2019, doi: https://doi.org/10.1016/j.measurement.2018.10.074.

[14] J.-I. Sasaki and S. Imazato, “Autoclave sterilization of dental handpieces: A literature review,” *J. Prosthodont. Res.*, vol. 64, no. 3, pp. 239–242, 2020, doi: https://doi.org/10.1016/j.jpor.2019.07.013.

[15] M. M. Ahmed, “Medical Equipment Calibration and Quality Assurance,” Pharos University in Alexandria, 2016. doi: 10.13140/RG.2.2.27148.31361.

[16] N. Torsutkanok, N. Thongpance, and A. Wongkamham, “The Development of Smart Dental Unit,” in *2018 11th Biomedical Engineering International Conference (BMEiCON)*, Nov. 2018, pp. 1–4, doi: 10.1109/BMEiCON.2018.8609925.