

Compacted Care Beyond the Clinic: Designing and Implementing a Portable Dental Unit (PDU) for Remote and Mobile Services

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Abstract - For the sake of all those who need dental care in various places, this article presents the rationale for designing and implementing a portable dental unit and finding new and more modern ways to manufacture and evaluate it as well.

This device gives priority to durability, portability of the device in different work environments, infection control, and safety. The basic components include, but are not limited to, the air pressure system, the water tank, the Arduino microcontroller to control and manage the pressure, the electrical valves and filters that are subject to international standards, the foot switch, and the device's control panel. The handpiece assembly in this dental unit, which includes the electric motor handle, the triple syringe, the high-speed turbine, and the low-speed turbine, allows for a variety of dental treatments.

The effectiveness of the dental unit was confirmed through its experiment by specialists at Al Noor University in May 2023. Dr. Al Qubais Al Assaf, who supervised the examination, confirmed the effectiveness of the unit in delivering water and compressed air, in addition to its successful design, the ease of carrying and transporting the device, and the ease of its installation, in addition to its durability and resistance to aging Infection and protective functions. Dr. Al-Assaf also spoke about the importance of the mobile dental unit to provide dental care in remote areas or in cases where individuals cannot reach scientific clinics.

Keywords: Portable Dental Unit (PDU), Clinic, for Remote and Mobile Services, Dental unit.

I. INTRODUCTION

To at the present time, many people round the arena nonetheless war to attain ok dental and oral fitness care, especially in rural and far flung regions. According to the World Health Organization (WHO) [1], low- and center-earnings international locations do no longer have complete get entry to dental remedy and care due to many issues, which include the shortage of enough cash, the shortage of dental

specialists, and the weak infrastructure of the nation or society. The excessive lack of a enough number of dental clinics, as well as a scarcity of clinical body of workers chargeable for the oral fitness of people in rural, remotod, and far off areas, has created more demanding situations [2]. Deprivation of dental care in some regions exacerbates inequality in get entry to health care and exacerbates oral health issues. Lack of get right of entry to dental care and treatment is probable to have enormous repercussions, which include an growth in the prevalence of oral illnesses and capability influences on people's fitness and first-rate of life [3].

Studies and signs imply the significance of dealing with those issues. More present day resources point to the persevering with challenges that humans face in settings in which sources are confined, which includes the lack of ok infrastructure to offer dental care and the shortage of specialists [4]. There are other effects generated through limiting get admission to to dental treatment, which include the effect on public health and reducing the productivity and trendy monetary prosperity of those people [5]. Many measures had been taken, and some project-orientated strategies had been advanced to improve get admission to better oral health care, innovate solutions for fitness care shipping, and arrange dental applications in the network to solve the problem of inequality [6].

Governments and non-governmental agencies are obligated to unite and work collectively to deal with the issues and provide solutions to beautify dental and other health care. Although it's miles essential to gain oral fitness care, which displays on the overall health of the man or woman, many people still be afflicted by this, specifically individuals who stay in negative places or who do now not have enough mobility [7].

Technological advances have provided great solutions, including the portable dental unit (PDU), to deal with the hassle of loss of access to dental care and treatment [8]. The transportable dental unit (PDU) is a reasonably new tool that objectives to boom and improve get right of entry to

presenting dental care services, especially in areas some distance from dental clinics and isolated or negative, and this scientific tool can clear up the quandary of offering dental care in disadvantaged groups [9].

Taking into consideration mobility, ergonomics, protection aspects, and infection control measures, this paper gives the design and implementation of a portable dental unit (PDU). Which can advantage numerous bad and remote groups and groups that don't have adequate get right of entry to dental services, and also goals to lessen inequality in access to oral and dental health care in numerous locations around the world. PDU has the ability to sell and improve public fitness associated with oral and dental health by way of addressing crucial problems that deprive susceptible agencies of get admission to satisfactory fitness care.

II. LITERATURE REVIEW

In recent years, PDU gadgets have appeared to facilitate access to dental treatment in areas where there are not any dental services. The PDU is an effective manner to provide dental care in diverse regions because of its capacity to operate on regular electricity or batteries and its lightweight and sturdy shape. It is really worth noting that there are many medical discussions in PDU design and evaluation. An example of this is the PDU advanced in 2013 by Nilchian et al. It became evolved to suit rural and far flung regions. The capacity to transport round with this unit and its operation on a battery make it clean to use in far flung regions. Adapting it to the surroundings makes it suitable for plenty dental treatments, and among those treatments that this unit is able to offer are cleaning, fillings, and extractions [10].

Later, on the way to evaluate the effectiveness of this unit in Kenyan rural schools, Mandimba *et al.*, Finished pilot research in 2015. Their evaluation confirmed the performance and effectiveness of the PDU in imparting dental treatment for kids suffering from teeth decay [11]. In order to determine whether a PDU is more price-powerful than traditional dental care for treating tooth decay in Ghana's rural regions, Agyemang *et al.*, Carried out a randomized managed experiment in 2016. The conclusions of this experiment focused on the value performance of PDUs [12]. Jain *et al.* 2017 carried out a randomized trial to decide and evaluate the effectiveness of the PDU in treating dental caries in rural India amongst pregnant women dwelling there and evaluate this trial with normal dental care. Based on the results of this study, the PDU became capable of increase its effectiveness in reducing the spread of dental caries [13].

In 2018, Zhang and co-workers have been capable of reap significant advances in PDU era and technologies as they evolved devices that may be used correctly in distinctive city

or rural environments due to the development of a hard and fast of capabilities. This gadget increases the capacity to suction and spray water, in addition to being a excessive-velocity handpiece [14].

Following this, Wu *et al.*, Created an emergency-targeted PDU in 2019 that turned into outstanding by using its small size and light weight. This unit can function without outside electricity deliver for numerous hours because it carries an internal battery [15]. Ajayi *et al.*, conducted an intensive literature take a look at in 2020 to behavior an research and evaluation that blanketed the effectiveness of PDUs and their price-effectiveness as nicely. Their investigation tested the blessings and price benefits of PDU and as compared it with its widespread counterpart in dental remedy, even as also demonstrating its effectiveness in offering several forms of dental interventions [16].

Gul *et al.*, Accomplished a randomized controlled experiment in 2021 to assess the efficiency of PDUs compared to a portable dental vehicle or truck in imparting dental care to kids in rural areas of Pakistan. Their examine established the fee-performance of the PDU in comparison to a mobile dental truck [17].

Apilot examine with the aid of Magalhães *et al.*, In 2022, it studied the effectiveness of PDU in providing treatment to disabled people dwelling in rural Brazil to satisfy their dental treatment needs. Their evaluation proven the efficiency and effectiveness of PDU and received effective opinions from contributors and volunteers on this take a look at about PDU [18].

Akter *et al.*, Conducted a examine in 2023 to take a look at and look at the effectiveness and acceptability of PDUs in assembly the dental treatment requirements of youngsters residing in rural Bangladesh. The outcomes of this observe showed the extremely good effectiveness of PDUs and the absence of issues or negative events as a result of their use, similarly to the superb opinions received from the residents there [19].

The results of these studies and research tested the effectiveness and performance of PDUs as efficient techniques and equipment for imparting dental care in various far flung and disadvantaged regions. There is lots of proof proving the efficiency and effectiveness of PDUs in lowering the consequences of inequality in the provision of fitness care to anybody around the sector.

III. METHODS AND MATERIALS

In this section presents the layout and implementation of a portable dental unit (PDU), which became created to offer

dental care in various regions, consisting of far flung areas. This device contains a number of components that have been carefully selected, integrated and coordinated with each other to ensure the provision of higher performance, reliable efficiency and easy operation and use of the device.

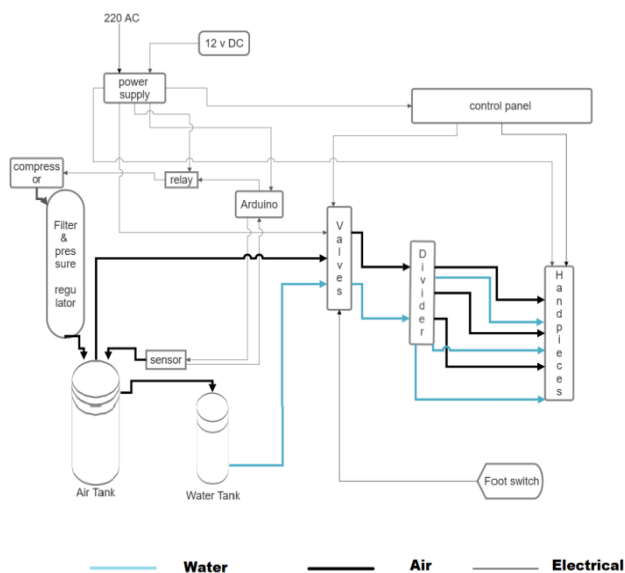


Figure 1: block diagram of PDU

3.1 Air Compressor and Air Tank

The internal assembly of the device contains many parts, the most important of which is the air compressor and an air tank that was carefully selected to be able to withstand a high air pressure of up to 12 bar. It also contains an Arduino microcontroller whose main function is to control the pressure level in the tank directly and in real time through a sensor that can sense the pressure inside the tank, and based on the pressure reading, it stops and starts the air compressor, so that it has been programmed to operate within a specific range of pressure. According to the requirements of the tools in the device, these tools require a pressure range from 2 bar to 4 bar, so that the Arduino turns on the air compressor when the pressure reaches 2 bar and turns it off when it reaches 4 bar. These levels can be easily adjusted by changing the values by connecting the Arduino to the computer.

The pressure of 2 bar to 4 bar is considered optimal according to what the dentist needs. There are also other parts that can divide the pressure reaching the tools according to the pressure needed by the tools, which will be mentioned later.

It is worth noting that there is a safety valve if something goes wrong with the Arduino when the pressure increases to levels above permissible, it discharges excess pressure. The material from which the air tank is made is rust-resistant metal compounds, so the tank is safe and solid, and it also contains a periodic drainage hole.

For greater efficiency and reliability, it is possible to convert the operation of the air compressor to a DC electrical current source through the 12-volt battery, which can easily be installed on the device through a dedicated port ready for this purpose. This way allows us to operate the unit on the battery and makes it easy to move the device in various places and there are no regular sources of energy.

The structure of the device contributes to saving some of the compressor noise, which reduces the noise emanating from the outside, but with the provision of ventilation holes and an air fan to cool the compressor, thus we obtain a higher efficiency from the compressor, which can provide pressure up to 10 bar, and this allows the handling of the compressor to be convenient. For the general design of the device. An example of the configuration with the air compressor and tank is shown in figure 2.



Figure 2: Visual representation of the Air Compressor and Tank Arrangement. On the right side, the image highlights the compressor, while on the left side; it illustrates the air tank configuration

3.2 Water Tank

A water tank that can tolerate pressures up to or higher than 12 bar is integrated into the dental unit. Pressurized air is fed into this water reservoir from the compressor and used by different parts of the device. Similar to the dynamics of air pressure, the Arduino microcontroller enables careful control and continuous monitoring of the water pressure.

The water tank is built from a sturdy plastic that was chosen specifically for its outstanding capacity to withstand pressure. This particular tank design was created with accessibility in mind, making it suitable for opening, cleaning, and sterilizing operations. A key component of the design is the incorporation of a one-way valve mechanism that limits the possibility of contamination by preventing water from flowing backward into the tank.

In order to reload the tank with water, a separate, dedicated channel is used, completely segregated from the other parts of the system. This specific path is used to drain

the tank of extra air and replenish it with water. Air is delivered into the tank while water is introduced more easily thanks to the air valve operating first and the water valve second. The water and air conduits are distinguished by this painstakingly crafted procedure, ensuring their independent operation. The water tank, the filling site, and the valve configuration are depicted in Figure 3 on the right and left, respectively.



Figure 3: Illustrates the water tank on right side, while on the left side designated filling location, and valve configuration under the cup

3.3 Pressure Sensor and Arduino Integration

Adding accuracy, a pressure sensor makes a crucial connection to the Arduino microcontroller, enabling the careful monitoring and evaluation of air pressure dynamics. By means of complex data processing, the Arduino proficiently controls the compressor's operation, creating an atmosphere that is favorable to the ideal pressure parameters relevant to dental operations.

The Arduino microcontroller is inherently configured to decipher and integrate pressure signals from the air tank, enabling it to make well-informed decisions about turning on or off the air compressor. It is easy to modify the desired pressure apex by changing a few simple parameters in the Arduino source.

In situations where the tank pressure is low, the Arduino communicates with a relay to trigger the air compressor. Compressor operation remains continuous until the tank pressure equalizes with the set threshold. This is the point at which the Arduino commands the relay to be turned off, which ultimately results in the air compressor turning off. Figure 4 shows the components of the Control Circuit, which include the Arduino, Relay, and Sensor.

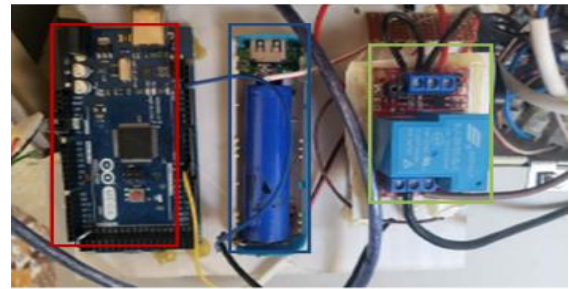


Figure 4: The Elements Comprising the Control Circuit, Encompassing the Arduino, Relay, and Pressure Sensor

In order to guarantee optimal relay responsiveness, a complex interaction between a battery and a transistor is utilized to amplify the Arduino signal. A safety feature kicks in when there are abnormalities, like the relay continuing to function even when the tank pressure is higher. This safety valve uses an aperture opening to proactively release pressure when it senses a pressure gradient between 6 and 7 bar. This redundancy mechanism, which harmoniously fits into the overall framework of safety considerations, is essential to guaranteeing the structural integrity of the system.

3.4 Incorporation of International Standard Filter

Integrating an international standard filter was a crucial feature to the dental unit. The air must be refined by this filtering mechanism before it can be distributed to the water tank and other essential instrument parts. Through the implementation of this filtration procedure, the unit ensures an operating purity level that meets established international standards, promoting a hygienic and safe atmosphere. Figure 5 depicts this setup.



Figure 5: The International Standard Filter

3.5 Electrical Valves and Foot Switch Implementation

The electrical circuit (Electrical Valves) was integrated and a foot switch was added to enable the quick control of the valves located in the dental unit. As seen in figure 6, distinct switches were assigned to the discrete control of each equipment component segment. This architecture gave the operational setup a level of control that ensured independence and accuracy in the handling of various device functions.

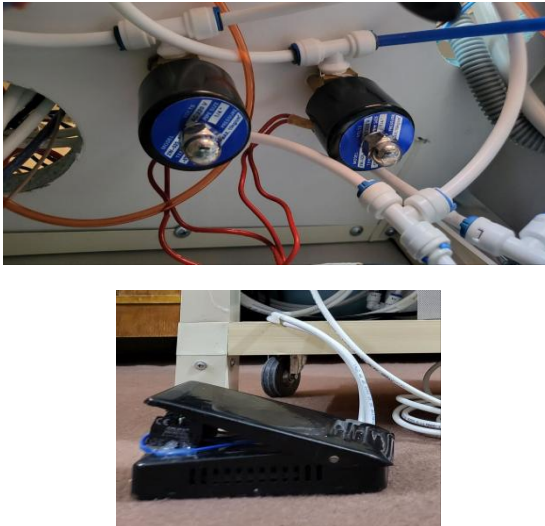


Figure 6: Representation of the Electrical Valves and Foot Switch Arrangement

3.6 Handpieces and Control Panel

- Handpieces and Control Panel: As seen in figure 7, the dental unit was equipped with a variety of handpieces, including an electric motor, a low-speed turbine, and a high-speed turbine. At the same time, the high-speed turbine enabled water supply by operating in the 300,000–450,000 RPM range. On the other hand, the low-speed turbine operated in the range of 20,000 to 45,000 RPM, providing water supply in a similar manner. The handpiece grip's ergonomic design allowed for the ability to control the rotation's direction. Specifically, highly developed valves located in the upper control panel took on the crucial responsibility of controlling the exact amount of air and water needed for dental operations.

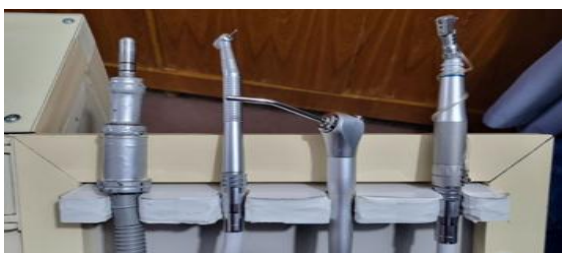


Figure 7: Handpieces

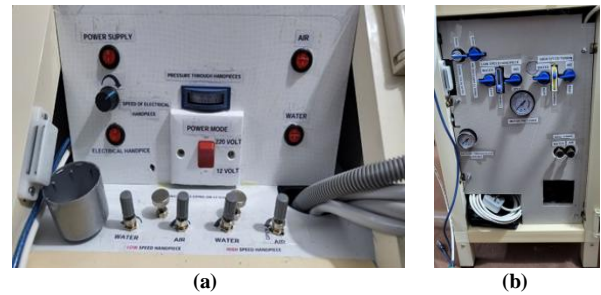


Figure 8: displays the control panel designed for the proposed system. In section a, it presents the electrical componentry of the control panel, while in section b, the lower segment of the control panel is depicted

- Triplex Syringe and Electric Motor: The triplex syringe was incorporated with the ability to dispense air, water, or a combination of both. It's intriguing that this syringe's flow rate might be independently adjusted. The final handpiece's electric motor increased its functional adaptability even further by enabling it to operate at rates up to 18,000 rotations per minute. The control panel's integrated control circuit allowed for the adjustment of handle speeds, which resulted in a prudent decrease in air consumption while performing clinical procedures. As seen in Figure 7, every handpiece was painstakingly made to be compatible with autoclaving and sterilizing processes.

The air engine can be used as a low-speed handpiece in addition to having an electric motor, however using the electric motor conserves compressed air, which lengthens the time the air is available for the high-speed turbine. The control circuit for an electric motor mounted in the control panel is depicted in Figure 9.

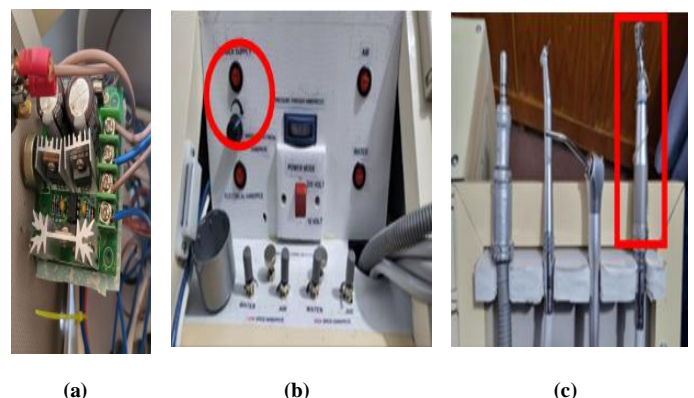


Figure 9: illustrates key components: subsection a presents the motor's control circuit, subsection b outlines the strategic circuit installation site responsible for motor speed regulation, and subsection c showcases the electric motor, amenable to the attachment of various low-speed turbines

Combining these techniques and supplies resulted in the creation of a portable dental clinic that stands out for its ability to provide basic dental care. This versatile device provided precise control over water and air pressure, a variety of handpiece options, and adjustable speed settings.

IV. RESULTS

Dr. Qubais Al-Assaf conducted a comprehensive test and evaluation of the portable dental unit device at Al Nour University in May 2023. He verified the features of the device in terms of portability, safe use of the device, infection control, and durability of the device.

It was demonstrated through its evaluation that water and air is efficiently provided by the device to enable a number of dental operations and treatments that can be provided by this device outside the dental clinic. It was also shown that the tools in the device are easy to use, and the design of the device is successful and ergonomic, which makes it easy to use and operate the device, and also that the ability of this device to be portable makes it easy to install and work in various environments.

The manufacturing quality and durability of this device provided a sufficient result to ensure that it can withstand the requirements of use and transportation, and the materials from which the device is made helped Insulated water systems have the ability to be sterilized, which contributes to combating infection and thus protecting the patient and the doctor at the same time.

Pressure regulators and emergency shut-off switches are two essential elements of safety and security in the portable dental unit and thus protect the operator and patient while providing dental care.

The effectiveness, design, ease of use, mobility, durability, safety precautions and infection control of the portable dental unit have all been confirmed by Dr. Al-Assaf's clinical evaluation on a model of artificial human teeth, which confirms the efficiency of the device as a reliable tool for providing dental care in a group of treatments.

Include a report that examines and assesses the performance of the medical device (portable dental unit), which was examined and assessed by an Al-Noor University College committee made up of dentists and specialists.

Report on the examination and assessment of the medical device's performance (portable dental unit)

General observations:

- Because the item is made locally and has indications placed on all of the equipment used in its construction, its outward appearance is deemed to be somewhat acceptable.
- One of the fundamental functions of the device is to control the start and stop of the drilling tools inside the mouth by means of a foot pedal that is activated when

the foot is pressed on. The pedal has two lines: one that operates on the AC 220V system and the other on the DC12V system. The first line functions on the majority of the device's important lines, while the second line is a newly developed line by the device that has high efficiency for use as a laboratory part.

- The device is more complex in terms of wiring quality and maintenance ease because most of the materials are made locally and some are taken from dental equipment because there isn't a better option. As a result, the device is rated as medium complexity.
- The device's insulation is deemed good in terms of electrical insulation, but adequate in terms of sound reproduction.
- The doctor finds the gadget straightforward to use with because all the necessary instruments, like handles and handle adjustment lines, are readily accessible and have indicators on them due to their external connection.

Extra observations to enhance the device's functionality:

With reference to electricity:

- Utilizing low-voltage power (12 & 24 volts) and controlling the electrical system from the back because the front side requires daily sterilization due to its close proximity to the control regions that the doctor needs to access.
- Redesigning the foot control to a smaller size and using the V12 system instead of the current foot control, which is larger and more taxing on the doctor. The smaller foot control is also safer in terms of electricity because it is in contact with the ground, exposed to dampness, and water.



Figure 10: shows Dr. Al-Assaf examining the device on an extracted human tooth

Clinical evaluation of a portable dental unit, Dr. Qubais Al-Assaf Alnoor University College May 2023.

Based on the official standards, the work of the designed device was evaluated. The results of the standards can be seen in Table 1:

Table 1: The results of the standards

Criteria	Evaluation	Remarks
1. Functionality		
Ability to deliver water	Yes	
Ability to deliver air	Yes	
Suction effectiveness	No	Device lacks suction
Support various treatments	Yes	
2. Ergonomics		
Design and controls	Yes	
Foot pedals	Yes	
Handpieces	Good (but not the best)	
Other components	Good	
3. Portability and Mobility		
Weight	Acceptable	About 13 kg
Unit size	Acceptable	Height: 80 cm, Width: 40 cm
Assembly/disassembly	Yes	
Transportability	Yes	Easily set up in different environments
4. Durability and Build Quality		
Sturdy construction	Yes	
Quality materials	Yes	
Reliability	Yes	

Criteria	Evaluation	Remarks
5. Infection Control		
Self-contained water systems	Yes	
Antimicrobial surfaces	Yes	
Cleaning/disinfection	Not bad	
6. Safety Features		
Pressure regulators	Yes	
Emergency shut-off switches	Yes	
Backflow prevention	Yes	Not at the required level
7. Noise Level		
Noise minimization measures	No	
Noise Level	High	A little high, but easy to get used to
8. Power Supply and Compatibility		
Batteries	Yes	External battery
Electricity	Yes	
Battery life	Depends on battery	
Charging options	AC & DC voltage	
Power outlets	Yes	
9. User Interface and Controls		
Water flow adjustments	Yes	

Criteria	Evaluation	Remarks
Air pressure adjustments	Yes	Good, but not the best
Suction power adjustments	No	Device lacks suction
Operational indicators	No	
10. Maintenance		
Ease of maintenance	Yes	
Spare parts availability	Yes	
Manufacturer support	Yes	

With these results, the effectiveness of this study for public health has been proven. Health care and diagnostic research is considered one of the most important trends in modern science [20] [21] [22] [23].

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