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Portable Dental Unit

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Abstract: The concept of a portable dental unit emerges as a solution to the challenges that hinder the provision of comprehensive dental services, particularly for those who cannot access dental clinics for treatment, including remote, mountainous, and elderly areas, individuals with special diseases, and others who face difficulties in traveling. Additionally, it offers the convenience of delivering dental services in schools, similar to the administration of vaccines and other healthcare services for children. The idea of creating a mobile dental unit was conceived to provide dental students with a reliable device for their studies at the lowest possible cost, aligning with the global concept of "Portable Dentistry."

In this project, the mobile dental unit was developed by eliminating the service part of the fixed dental unit (Dental Chair). Various components, including the chair, lamp, and spittoon, were removed, while incorporating the compressor inside the unit. This resulted in a small, cost-effective mobile dental unit that does not require an external compressor and avoids additional weight that could hinder transportation to the aforementioned target groups.

Chapter 1: Introduction

1.1 Introduction

Dentistry, an essential branch of medical science, plays a crucial role in promoting oral health and overall well-being. Just like other medical specialties, dentistry relies heavily on specialized tools and equipment to deliver high-quality care. At the core of a dentist's practice lies the dental chair, which has undergone remarkable advancements in design and functionality over time, adapting to the evolving needs of dental professionals and patients. This project aims to explore a ground-breaking dental innovation known as a portable dental unit, representing a significant milestone in the field. The portable dental unit incorporates dental chair-based equipment and tools, enhancing the accessibility and effectiveness of dental care.

Access to quality healthcare, including oral health services, is a significant challenge in low and middle-income countries (LMICs), which constitute the majority of the global population and bear a substantial burden of disease. Scarce funds, limited resources, and disadvantaged populations result in insufficient health coverage, leaving billions of people with unmet health needs and unnecessary suffering. Oral health services are particularly affected, with inadequate availability, affordability, and accessibility reported in many LMICs. According to the World Health Organization (WHO), oral diseases, such as dental caries, periodontal diseases, and oral cancers, pose significant health problems worldwide, especially in developing countries [1].

In LMICs, the affordability and accessibility of health services are crucial determinants of healthcare utilization. Unfortunately, many countries heavily rely on out-of-pocket payments as the primary source of healthcare financing. Furthermore, oral health services in LMICs often lag behind general health services, with limited availability of dental materials and equipment necessary for effective oral care. Conventional dental systems, typically fixed and dependent on

electrical and plumbing networks, pose challenges, particularly in rural areas. These barriers hinder the delivery of dental healthcare to a large portion of the population.

To address these challenges, portable dental units have emerged as crucial tools in providing dental healthcare, particularly for elderly and disabled populations, as well as those residing in remote areas with limited access to dental services. Previous studies have highlighted the usefulness and cost efficiency of mobile dental units. However, these mobile dental units often come with a high price tag, emphasizing the need for locally designed and affordable dental units tailored to LMICs.

This study describes the design and realization of various low-cost mobile dental units that meet the ideal qualities of a dental unit and are economically accessible to healthcare services in LMICs. These systems are constructed using local materials. The development of these cost-effective mobile dental units aims to improve oral healthcare delivery in LMICs, bridging the gap in accessibility and affordability.

1.2 Objectives

The project aims to achieve several important objectives through the innovation of the portable dental unit.

- **Firstly,** the project aims to contribute to the advancement of the field of biomedical engineering within the realm of dentistry. By developing and refining the portable dental unit, the project aims to pioneer new technological solutions and promote interdisciplinary collaboration between dentistry and engineering.
- **Secondly,** this study enhances the accessibility to dental care by enabling dentists to reach remote areas where traditional dental health centres may be absent. By bringing the dental unit directly to these underserved regions, the project aims to address the oral health needs of communities that would otherwise have limited access to dental services.
- **Thirdly,** the project seeks to provide convenient dental care for school students by making the dental unit easily accessible within educational institutions. This approach ensures that students receive necessary treatments without the need to leave their school premises, saving time and effort for both students and parents.
- **Furthermore,** the project aims to address the shortage of dental chairs in training institutions. By utilizing the portable dental unit, dental students can receive practical training without being hindered by the limited availability of traditional dental chairs, thus enhancing their learning experience.
- **Lastly,** the project aims to cater to individuals who face mobility challenges, allowing dentists to bring the dental unit directly to their locations. This objective ensures that people with limited mobility can receive essential dental care without the need to travel to conventional dental health centres.

1.3 Motivation

The motivation behind the development of the portable dental unit stems from the challenges associated with traditional dental chairs. Conventional dental chairs are not only expensive but also require specific locations, adequate lighting, and special conditions to function optimally. These factors limit the accessibility and affordability of dental care, particularly in remote areas and underserved communities.

To overcome these limitations, the idea of designing a portable dental unit emerged. The primary objective was to create a flexible and easily transportable unit that can be utilized in various

settings, including clinics, homes, and schools. By introducing a portable alternative, the project aims to reduce costs associated with dental treatments and make oral healthcare more accessible to a wider population.

1.4 Project keywords

Biomedical Engineering: Biomedical engineering is a field that combines principles of engineering and healthcare to develop solutions and technologies for improving medical and healthcare practices. It involves the application of engineering principles and techniques to address challenges in biology and medicine, with a focus on developing innovative medical devices, equipment, and diagnostic tools.[22]

Biomedical Engineer: A biomedical engineer is a professional who applies engineering principles and techniques to the field of healthcare and medicine. They utilize their knowledge of engineering concepts to develop and improve medical devices, technologies, and systems. Biomedical engineers work on a wide range of projects, including designing prosthetics, developing imaging systems, creating artificial organs, and enhancing medical equipment. Their aim is to contribute to the advancement of healthcare by integrating engineering solutions into medical practices, ultimately improving patient care, diagnosis, and treatment outcomes [23].

Remote Areas: Remote areas refer to geographical locations that are situated far away from urban centres or have limited access to basic services, including healthcare facilities. These areas are typically characterized by a lack of infrastructure, transportation difficulties, and a scarcity of resources. Remote areas often face challenges in accessing healthcare services, including dental care [24].

Dental Chair: A dental chair is a specialized piece of equipment used in dental clinics to provide a comfortable and adjustable seating position for patients during dental procedures. It typically features an adjustable headrest, armrests, and footrests to ensure patient comfort and facilitate the dentist's access to the oral cavity. Dental chairs are equipped with various controls and attachments to assist dentists in performing dental examinations, treatments, and surgeries effectively [25].

Portable Dental Unit: Portable dental unit means a non-facility in which dental equipment used in the practice of dentistry is transported to and used on a temporary basis at an out-of-office location at either group homes for juveniles or public and private schools [26].

Dental Tools: Dental tools, also known as dental instruments or dental equipment, are specialized instruments used by dental professionals during dental procedures. These tools encompass a wide range of instruments designed for specific dental tasks, such as examination, diagnosis, cleaning, and treatment. Dental tools include items such as dental mirrors, probes, scalers, drills, forceps, and various handpieces. They are essential for dentists to perform accurate diagnoses, maintain oral hygiene, and carry out various dental procedures, such as fillings, extractions, and root canals [27].

1.5 Project Outlines

1.5.1 Chapter One

This chapter introduces the main subjects of the project, the objectives and the motivation for the project.

1.5.2 Chapter Two

This chapter presents the theoretical background and literature review of the project. The chapter also provides a background on teeth and dental unit, including the structure of the teeth, teeth disease, teeth care and dental chair parts.

1.5.3 Chapter Three

This chapter includes the practical aspect of the project, represented by dismantling the device from small to large pieces, assembling them, and explaining the mechanism of the device

1.5.4 Chapter four

This chapter includes a brief summary of the entire project in a few words, as well as recommendations and possible future developments that can be implemented.

Chapter 2: Literature review

2.1 Introduction

Oral diseases remain one of the major global public health challenges, and the worldwide urban–rural disparities in oral health are significant. Residents in rural areas generally suffer from a higher prevalence and severity of dental caries and periodontal disease, yet they face numerous difficulties and barriers in accessing oral healthcare [2]. Conventional strategies, such as building of dental clinics or, hospitals, or the provision of outreach services by using disposable materials, are neither practical nor effective in rural settings. Mobile dental units (MDUs) have been proposed as an alternative strategy to supplement the traditional oral healthcare in many regions. They have usually been utilized in school-based oral health programs, providing dental care to the homeless or migrants, and screening programs for the population for various oral diseases. Due to their high mobility, MDUs are particularly valuable for the underserved populations living in rural areas. The advance of dental devices enables MDUs to be operated in a self-sufficient manner. This allows the MDU to function almost as well as a conventional dental clinic, providing a variety of dental treatments, including scaling, restoration, and oral surgery.[3]

This chapter discusses the use of MDUs as a solution to urban–rural inequality in receiving oral healthcare, in addition knowing the basic structure of teeth and the gums and knowing the diseases that affect the teeth and how to prevent these diseases and treat them when infected by personal or surgical methods at the dentist with the help of MDUs.

2.1.1 Urban–Rural Disparity in Oral Health Conditions

Studies have reported on the urban–rural disparities of different oral health-related conditions. People living in rural areas are more likely to suffer dental caries and have untreated decay. Preschool children living in rural areas showed a higher prevalence of dental caries than urban children. A similar result was also observed in older people. In addition, some studies supported the idea that rural residents presented a worse periodontal health status than urban residents. The prevalence of gingivitis and calculus in 12-year-old children was higher if they were living in rural areas. Fewer middle-aged (35- to 44-year-old) people in rural areas were classified as healthy using the community periodontal index. Furthermore, significantly more people living in rural areas reported low oral health-related quality of life than in urban areas, suggesting that poor oral conditions have a greater negative impact on rural inhabitants. The rationales behind these disparities have been under discussion. The inequalities of oral health services, accessibility, utilization, oral health knowledge and practices, and health insurance coverage might exist between urban and rural areas.[4]

Not only in rural areas, many elderly people who they live in Urban areas also report that moving to a dental clinic is a barrier to dental treatment. So, one of the limitations of the dental profession has been its dependency on fixed equipment such as the dental units or chairs. The dental units generally need connecting to electrical, as well as drainage and plumbing systems.[5]

Mobile or portable dental unit services eliminate the transportation barrier by bringing the service to the client. The portable dental unit will provide greater assistance to disabled clients living in

those out of reach places. They make it possible for the elderly as well as rural and remote areas to receive the care they deserve.[4]

2.1.2 Tooth structure

The anatomic crown of a tooth is the area covered in enamel above the cement enamel junction (CEJ) or "neck" of the tooth. Most of the crown is composed of dentin with the pulp chamber inside. dentin composes most of the root, which normally has pulp canals. Canines and most premolars, except for maxillary first premolars, usually have one root. Maxillary first premolars and mandibular molars usually have two roots. Maxillary molars usually have three roots. Additional roots are referred to as supernumerary roots. Tooth consists of four parts: enamel, dentine, cementum and pulp [5] as shown in figure (2-1).

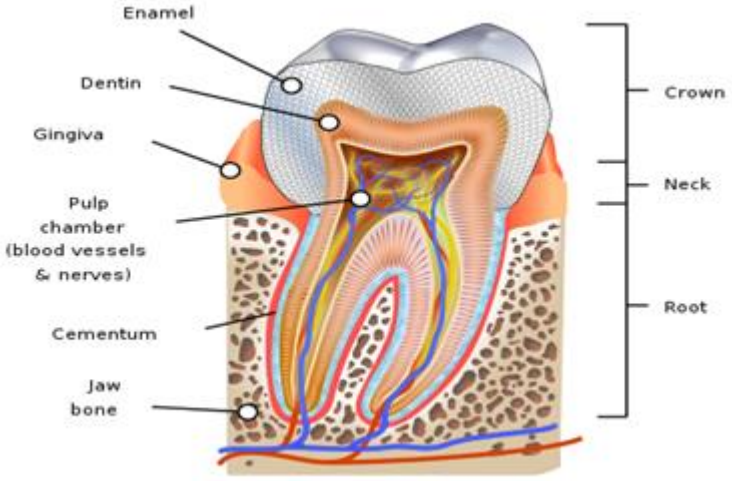

Figure 0–1: Tooth anatomy structure [6]

2.1.3 Enamel

Enamel is the hardest and most highly mineralized substance of the body, it does not contain any nerves or blood vessels; therefore, it is insensitive to pain .it cannot regenerate so the damage caused by progressive decay or injury is permanent.[5][7]

2.1.4 Dentine

Dentin is the substance between enamel or cementum and the pulp chamber, it is very sensitive to pain but normally is sheltered from pain stimuli by it is outer coating which acts as a protective layer of insulation. Dentine is harder than the bone but less solid than enamel.[7][8]

2.1.5 Cementum

Is a specialized bone like substance covering the root, is thickest at the root apex? Its coloration is yellowish and it is softer than dentin and enamel, the cementum is acellular due to its lack of cellular components.[8]

2.1.6 Pulp

The dental pulp is the central part of the tooth filled with soft connective tissue. This tissue contains blood vessels and nerves that enter the tooth from a hole at the apex of the root. The pulp is commonly called "the nerve" of the tooth.[7]

2.1.7 Supporting structures

The periodontium is the supporting structure of a tooth, helping to attach the tooth to surrounding tissues and to allow sensations of touch and pressure. It consists of the cementum, periodontal ligaments, alveolar bone, and gingiva. Of these, cementum is the only one that is a part of a tooth.

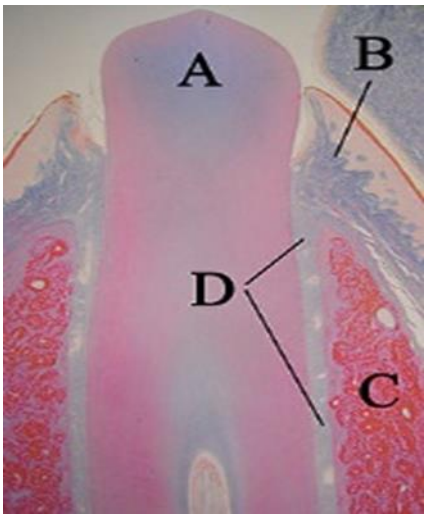

Figure 0–2: Histologic slide of tooth erupting into the mouth

A: tooth

B: gingiva

C: bone

D: periodontal ligaments.[9]

Periodontal ligaments connect the alveolar bone to the cementum. Alveolar bone surrounds the roots of teeth to provide support and creates what is commonly called an alveolus, or "socket". Lying over the bone is the gingiva or gum, which is readily visible in the mouth.[5]

2.1.8 Teeth Disease

Teeth diseases are a common oral health problem that affects many people worldwide. These diseases can range from minor conditions like cavities and gum disease to more serious conditions like oral cancer. Poor dental hygiene, unhealthy eating habits, and tobacco use are some of the main risk factors for teeth diseases. Symptoms of teeth diseases can include tooth pain, sensitivity, swelling, and bleeding gums. Treatment for teeth diseases depends on the specific condition and may include dental procedures like fillings, root canals, and extractions. Prevention is key to maintaining good dental health, and regular brushing and flossing, along with regular dental check-ups, can help prevent teeth diseases from developing.[18]

2.1.9 Prevention

The burden of oral diseases and other noncommunicable diseases can be reduced through public health interventions by addressing common risk factors.

These include:

1. promoting a well-balanced diet low in free sugars and high in fruit and vegetables, and favoring water as the main drink;
2. stopping use of all forms of tobacco, including chewing of areca nuts;
3. reducing alcohol consumption; and
4. encouraging use of protective equipment when doing sports and travelling on bicycles and motorcycles (to reduce the risk of facial injuries).

5. Adequate exposure to fluoride is an essential factor in the prevention of dental caries.

Twice-daily tooth brushing with fluoride-containing toothpaste (1000 to 1500 ppm) should be encouraged.

2.2 Tooth care

2.2.1 Oral hygiene

The practice of keeping the mouth clean and is a means of preventing dental caries, gingivitis, periodontal disease, bad breath, and other dental disorders. It consists of both professional and personal care. Regular cleanings, usually done by dentists and dental hygienists, remove tartar (mineralized plaque) that may develop even with careful brushing and flossing. Professional cleaning includes tooth scaling, using various instruments or devices to loosen and remove deposits from teeth.[8]

2.2.2 Protective treatments

Fluoride therapy is often recommended to protect against dental caries. Water fluoridation and fluoride supplements decrease the incidence of dental caries. Fluoride helps prevent dental decay by binding to the hydroxyapatite crystals in enamel. The incorporated fluoride makes enamel more resistant to demineralization and thus more resistant to decay. Topical fluoride, such as a fluoride toothpaste or mouthwash, is also recommended to protect teeth surfaces. Many dentists include application of topical fluoride solutions as part of routine cleanings. Sealants are applied in a dentist's office, sometimes by a dental hygienist, in a procedure similar in technique and cost to a fluoride application.[8][6]

2.3 Dental Unit

A dental operation unit provides the dentist with water, electrical, and air systems during the examination and treatment of patients. The unit should be designed to be compacted in structure, good looking shape, multifunction, convenience for use, and does not occupy additional space needed by the assistant.

Previously, the dental unit was very simple in construction. It was composed of only one motor that drives the whole unit, turbine and the hand pieces, only one drill (hand piece) can be used at a time, so that every time the dentist wants to use different hand piece, he has to take the used one away and replaces another one. But nowadays every dental unit must be designed to give a high degree of comfort for both patient and doctor, constructed from main components as shown in figure 4 to work efficiently.[12]

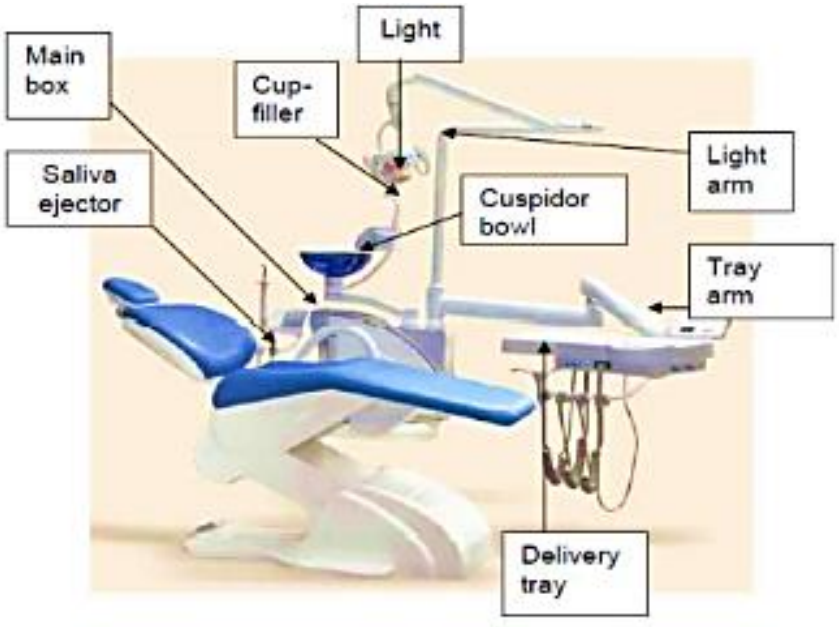

Figure 0–3: Typical characterization of dental unit components.[12]

1. Dental Light

The dental or operator light is used to illuminate inside the mouth or oral cavity of the patient seated on the dental chair. It is usually positioned 30-50 inches from the mouth of the patient to avoid the light from shining in the patient's eyes and causing discomfort.

The light has dimmer switches so that the intensity of the light may be adjusted. Protective barriers such as a plastic wrap or aluminium foil are placed on the handles and the switches of the light. The lights are frequently cleaned and movable parts of the light are lubricated weekly.

2. Dental Chair Controls

Dental chair controls are comprised of control buttons that can move the dental chair upwards or downwards depending on what is best suited for the clinician.

3. Cup Holder

Every dental chair has a cup holder. Disposable cups are primarily used for patients to take in water, gargle it, and then spit it out into a spittoon bowl. This is so that patients don't feel uncomfortable with blood or debris in their mouth.

4. Bracket Table

Bracket tables are used to hold hand instruments and materials such as cotton, cotton holders, cement mixtures, and diagnostic instruments among many others.

5. Air-Water Syringe

An air-water syringe is a dental device that can produce a stream of compressed air, water, or a combination of both. It is primarily used to clean the teeth's surface during a dental treatment.

6. Spittoon Bowl

A spittoon bowl is a bowl or basin used for patients to spit saliva from their mouth during dental procedures. It is connected to a water pipe supply which is used to clean out the bowl and drain the waste into a drain.

7. X-Ray Viewer

X-ray viewers help examine and interpret the radiographs of a patient's oral cavity or tooth. They can help determine if there are areas of tooth decay or infection, which appear darker on the radiograph as they don't absorb much of the X-ray.

8. Foot Control Monitor

The foot control monitor is especially helpful for dentists when they have full hands. It has similar operating buttons such as the manual foot press and is considered safe to use.

2.4 Literature review

In 1917, The Cleveland Chapter of the Preparedness League of American Dentists presented a "dental ambulance" to the army in the name of Red Cross. Four dentists and one or two assistants operated the ambulance. The earliest records suggesting the utilization of "Mobile Dental Van" other than military setting are credited to Dr. Talley Ballou, dental director of the Bureau of Mouth Hygiene, Virginia. Portable dentistry began during the World War II. The dental officer of each tactical unit was supplied one large shoulder pouch and his assistant carried two smaller pouches, containing instruments for emergency use in combat when M. D. Chest No. 60 was not available. The pouches included items required for the relief of pain, simple extractions, emergency treatment of maxillofacial injuries and temporary fillings. Application of mobile and

portable dental services Dental Public Health deals with community as a whole. Mobile and portable dentistry is a potential method to deliver oral health-care in the public sector.[12]

In 2013, and in response to mentioned limitations, a prototype portable dental chair/unit was designed by Is-fahan dental school. The basic system includes an operator light source, an examination kit, a portable head rest, and a first aid kit for dental purposes figure (2-4). These portable dental units used have a rotary instrument and an operator light fixture that is packed in two cases figure (2-4).[13]

Figure 0–4: The portable dental units designed in Isfahan dental university [11]

More complex portable units include a vacuum canister, ultrasonic scaler, radiographic equipment along with compressors for air-water syringes and high- and low-speed hand-pieces. This equipment is stored and trans-ported in durable boxes and cases. [13]

A study by Smith et al. (2019) evaluated the use of a portable dental unit in providing dental care to underserved communities in rural Alaska. The study found that the portable unit was effective in providing dental care to patients who would have otherwise gone without treatment. The study also found that the use of PDUs resulted in a significant reduction in the number of patients who required follow-up care. [15]

In another study, Dym et al. (2019) assessed the feasibility of using a portable dental unit in a school-based dental program in California. The study found that the portable unit was effective in providing preventive and restorative dental care to children in underserved areas. [16]

A review article by Kalladka et al. (2021) explored the use of PDUs in dental outreach programs in India. The authors concluded that the use of PDUs had significant benefits in terms of improving access to dental care, reducing the cost of providing dental care, and reducing the burden on traditional dental clinics. [17]

PDUs are increasingly becoming important in providing dental care in underserved and remote areas, as well as during emergencies. They offer flexibility in scheduling appointments and can be easily transported and set up in different locations, making it possible for dental professionals to provide dental care where it is needed most. The available literature shows that PDUs are effective in providing dental care and have significant benefits in terms of improving access to dental care and reducing the cost of providing dental care.

Therefore, the aim of this review was to explore dentists' perceptions of the use of portable dental units in community outreach programs.

Chapter 3: The Practical Aspect

3.1 Introduction

Since the emergence of the idea of mobile dentistry, there have been many devices developed to achieve the best results and obtain a complete dental unit that can be transported from place to place for the treatment of dental conditions. It all started with simple tools carried by war doctors figure (3-1), and then with advancements, it led to the invention of mobile dental clinics figure (3-2), which are originally trucks designed to carry all the tools needed by a dentist for transportation from place to place. However, even mobile clinics may be difficult to transport to remote, rural, or mountainous areas due to their large size. This led some biomedical engineers to invent the mobile dental unit, which includes a foldable external chair and a dental unit that originally contains tools attached to holders at the dentist's hand figure (3-3). But even with the reduction in size of these units and their compactness, they faced the problem of providing external compressed air, which required carrying an external compressor, which was certainly cumbersome and tiring as it required carrying both the mobile dental unit, the movable chair, and the compressor. Here comes the role of what we have created in this project, where we have eliminated the need for an external compressor and integrated it within the mobile unit, making it a complete and portable mobile dental unit that can be carried to remote areas where access to dental clinics is difficult, thus making dental care easily accessible to them. [21]

Figure 3–1: Dental Instruments in War. [20]

Figure 3–2: Mobile dental clinics. [19]

Figure 3–3: The portable dental units designed in Isfahan dental university. [11]

3.2 Portable Dental Unit

The portable dental unit is considered one of the most advanced technologies in dentistry. It is a small box-like device that contains the essential components needed by a dentist, similar to the larger fixed dental chair unit in the clinic. The dental chair unit consists of two parts, the treatment and service sections, which include the chair itself, dental light, X-ray viewer, and others. In our

case, we do not need all these tools, so what we aim to do here is to meet a specific need rather than creating a complete dental clinic. It offers lower costs, smaller size, and increased efficiency, which we will explore in this chapter from the simplest tools and parts to assembly and achieving the final result, which is the portable dental unit.

3.3 Portable Dental Unit Component

3.4 Components List

The following Table 3-1 provides a comprehensive inventory of the components used in the construction of the portable dental unit.

Table 0–1: Portable Dental Unit Components List.

No.	Components	Quantity
1.	Air Adjuster	1
2.	Water Relay	2
3.	Bottle Water Switch	1
4.	Water switch	1
5.	Air switch	2
6.	Handpiece Pressure Gauge	1
7.	Water Bottle Cover	1
8.	Control Foot Switch	1
9.	Foot Switch Valve	1
10.	Automatic Handpiece Holder	4
11.	Suction Unit	1
12.	Triple Syringe	1
13.	Tube Dental Handpiece	2
14.	High Speed Turbine	1
15.	Low Speed Hand Piece	1
16.	Compressor	1

3.4.1 Air Adjuster

Air pressure regulators are used to provide a constant outlet of pressure, separately from the inlet pressure or flow. They are most commonly used to reduce the pressure level required for downstream equipment, stabilising the force applied to cylinders or minimizing pressure variation.

Figure 0–5: Air Adjuster.

3.4.2 Water Relay

A water relay in a dental unit is a system that controls the flow of water used in various dental procedures. It is typically a set of valves and tubing that regulate the flow of water from the main water supply to different components of the dental unit, such as handpieces and air-water syringes, Water relay is shown in figure (3-5).

Figure 0–6: Water Relay.

3.4.3 Bottle Water Switch

On/Off Air Switch for portable Dental Unit Water Bottle.

Figure 0–7: Bottle Water Switch.

3.4.4 Water switch

Allows individual adjustment of water coolant to the handpieces. Turn the knob counter clockwise to increase the flow, clockwise to decrease the flow.

Figure 0–8: Water Switch.

3.4.5 Air switch

Allows air flow adjustment to be made to the handpieces. Turn the knob counter clockwise to increase the flow, clockwise to decrease the flow.

Figure 0–9: Air Switch.

3.4.6 Handpiece Pressure Gauge

Indicates drive air pressure to the handpiece.

Figure 0–10: Handpiece Pressure Gauge.

3.4.7 Water Bottle Cover

The water bottle is connected to the water delivery system via a series of tubes and valves. When the dental unit is turned on, the water is drawn from the water bottle through the tubes and into the dental instruments by the pressure generated by the compressor or pump.

Figure 0–11: Water Bottle Cover.

3.4.8 Control Foot Switch

All the basic functions and controls can be activated by the foot control, this ensures saving the time and allows the dentist to give a full attention to the patient.

Figure 0–12: Control Foot Switch.

3.4.9 Foot Switch Valve

This valve controls the flow of water and air in dental procedures. It is used by dentists to control various dental instruments, such as handpieces and triple syringe.

Figure 0–13: Foot Switch Valve.

3.4.10 Automatic Handpiece Holder

Signals the automatic control system to supply drive air and air/ water coolant to the handpiece as it is lifted from its holder. When the handpiece is placed back in the holder, a signal to the automatic control system stops the drive air and air/water coolant supply.

Figure 0–14: Automatic Handpiece Holder.

3.4.11 Suction Unit

Suction unit is used to pull saliva, secretions and solid particles which are collected in the patient's mouth during treatment, to keep the working site dry.

Figure 0–15: Suction Unit.

3.4.12 Triple Syringe

Basically, dental unit has one triple syringe (shown in fig. 10), that provides a flow of air, water, or a combination spray of air and water. It is usually used before or after drilling, to wash and dry the area of the drilling.

Figure 0–16: Triple Syringe.

3.4.13 Tube Dental Handpiece

- The tubing can used for high/low speed handpiece.
- Suitable for dental air turbine motor/handpiece connection.
- The tubing is durable and flexible inside with a smooth silicone sleeve on the outside of the tubing.

- Color: Grey
- Outer Tube Length 1.5m
- Inter Tube Length 1.75m

Figure 0–17: Tube Dental Handpiece.

3.4.14 High Speed Turbine

High speed turbine is used to remove the defected parts of the tooth, clean, and prepare it for repairing and filling. It runs at very high speed up to 400.000rpm, to remove the high stiffness enamel layer. The high-speed hand pieces are supplied by means of air system. The main function of the air is to rotate the air turbine.

Basically, this means the air system is the main power source for these hand pieces. High speed turbine is shown in figure (3-16).

Figure 0–18: High Speed Turbine.

3.4.15 Low Speed Hand Piece

Low speed hand piece (figure 3-17) is used to complete the work of the high-speed turbine in making a cavity in the stiffness layer (dentine) which is located near the nerve of the tooth. Also, it can be used for cleaning the out layer by a special brush, and in some surgical operations in the jaw of the mouth. Its rotation speed is about (15000-30000) rpm. As in the high-speed turbine, the air system is the main power source.

Figure 0–19: Types of Low Speed Turbine

3.4.16 Compressor

An air compressor in the unit provides compressed air. This enables most dental unit to operate up to three dental hand pieces and the three-way syringe. This system is located inside the portable dental unit and it is safety and soundproof. Compressor is shown in figure (3-18).

Figure 0–20: Air Compressor

3.4.16.1 Air compressor specification

- Power 0.75 Hp 0.55 kW
- Intake air 110 l/min
- Sound level 79dB
- Oil less
- Coaxial, direct transmission, which guarantees maximum power in any activity
- Twin-cylinder electric motor, super silent.
- Pump group mounted horizontally on the engine; intake air volume 110 l/min, max usable pressure 8 bar
- 6 litter tank, 2 mm thick, with integrated purge valve, very useful for carrying out periodic cleaning operations from incrustations and residues formed inside

3.4.16.2 The Air Compressor Component

3.4.16.2.1 Switch Control Valve

the air compressor pressure switch control valve is a device that regulates the pressure in an air compressor by turning it on or off at certain pressure levels. The 90-120 PSI 240V pressure switch control valve is designed to operate at pressures between 90 and 120 PSI and is powered by a 240V electrical supply.

Figure 0–21: Switch Control Valve.

3.4.16.2.2 Check Valves

also known as one-way valves or non-return valves, are used here to allow the flow of fluid in one direction while preventing backflow in the opposite direction. They are preventing cross-contamination between different water lines or components. Check valves ensure that water or air flows in the intended direction and does not flow back into other parts of the dental unit.

Figure 0–22: Check Valves.

3.4.16.2.3 Safety Valve

The safety valve in an air compressor is a critical component that helps to ensure safe operation of the compressor by releasing compressed air from the tank if the pressure inside the tank exceeds a safe level.

Figure 0–23: Safety Valve.

3.4.16.2.4 Air Filter

The air filter in a compressor used for a dental unit is an essential component that removes impurities and contaminants from the compressed air, protecting both the patient and the dental instruments from potential harm.

Figure 0–24: Air Filter.

3.4.17 External Frame Design

An external frame for the system has been designed, taking in the account the main characteristics of the frame such as stability, durability, suitable shape, and the ability to contain all the parts inside it. It is made from aluminum, to resist the stress and the rust.

The external frame, shown in figure 5.10, has cuboid shape, with dimensions about (53*44*49) cm^3, it contains four wheels, the total weight of the device is equal 26,400 Kg. These features allow the user to carry the system easily, perform maintenance when it is needed, and put all needed parts inside it.

Figure 0–25: External Frame Design.

3.5 Air Lines Connections

In accordance with the concepts presented in Chapter Three, the connection of air lines to various components such as high and low-speed turbines, the triple syringe, and the water tank is essential. Figure 3-25 provides a visual representation of the water and air connection circuit.

Upon the arrival of air from the compressor, it enters the multichannel air adjuster. This adjuster consists of two air channels. One of these channels directly connects to the triple syringe via the T-distributor. The other output of the T-distributor is directed to the bottle water switch, and the air outlet of the bottle water switch is connected to the clean water bottle.

The second channel of the air adjuster is directly linked to the foot switch, which allows dentists to control the use of handpieces using their feet. The air outlet of the foot switch passes through the T-distributor and goes to holder 1, while the other output of the T-distributor connects to holder 2. These two main outputs are utilized to activate the air actuators responsible for rotating the micro motors of the handpieces. However, this pathway is only active when the foot switch is pressed.

The purpose of the holder valve is to provide a convenient and efficient means of controlling the air and water flow to the handpiece during dental procedures. By automatically opening when the handpiece is lifted from the holder, it enables dental professionals to activate the handpiece without manually adjusting a separate valve or button. This feature saves time and effort, streamlining the workflow in the dental operatory.

The air outlet of holder 1 passes through the T-distributor and connects to air switch 1, while the other output of the T-distributor is directed to Water Relay 1. Similarly, the air outlet of holder 2 goes through the T-distributor and connects to air switch 2, with the other output of the T-distributor linking to Water Relay 2.

The air outlet of air switch 1 passes through the T-distributor and connects to the high-speed handpiece. The other output of the T-distributor is directed to the gauge. Likewise, the air outlet of air switch 2 passes through the T-distributor and connects to the low-speed handpiece, with the other output of the T-distributor also going to the gauge.

3.6 Water Lines Connections

The system depicted in Figure 3-24 utilizes a 600 mm water bottle to supply water to the high-speed turbine and triple syringe. When the air from the bottle water switch enters the clean water bottle, a pressure difference is created between the higher-pressure end (generated by the compressor or pump) and the lower-pressure end (within the dental instrument). This pressure differential facilitates the flow of water through the system and into the dental instrument, where it can be utilized for various procedures, including cleaning and cooling.

The clean water bottle is connected to the triple syringe through a direct water line, without the need for a valve as the syringe features a push button on its head. Additionally, a regulator is not required since the syringe can operate effectively under varying air and water pressures. The other output of the T-distributor connects to the water switch.

Furthermore, the clean water bottle is connected to water relay 1, which consists of four channels - two inputs and two outputs. One input receives air from the T-distributor to control the on/off function of the water valve, while the other input receives water from the outlet of the water switch. One of the water outlets supplies water relay 2, while the other outlet directs water to the high-speed handpiece.

Water relay 2 comprises three channels - two inputs and one output. One input receives air from the T-distributor to control the water valve, and the other input receives water from water relay 1. The output channel delivers water to the low-speed handpiece.

A water relay serves as a system of valves and tubing responsible for regulating the water flow from the main water supply to different components of the dental unit, such as handpieces.

3.7 Suction Unit Lines Connections

Upon the arrival of air from the air compressor, it is directed straight to the suction unit holder. The air outlet of the holder is then connected to the suction valve, while the saliva outlet of the valve suction leads to the dirt bottle. The principle governing the operation is based on the pressure difference that drives the fluid to move from high-pressure regions to low-pressure regions, following the Venturi principle.

The suction mechanism relies on the creation of a vacuum within the container by the suction valve. This container also features an open terminal that is connected to the suction handpiece. Once the vacuum is established within the container, external fluid is drawn in and collected due to the pressure difference, effectively facilitating the suction process.

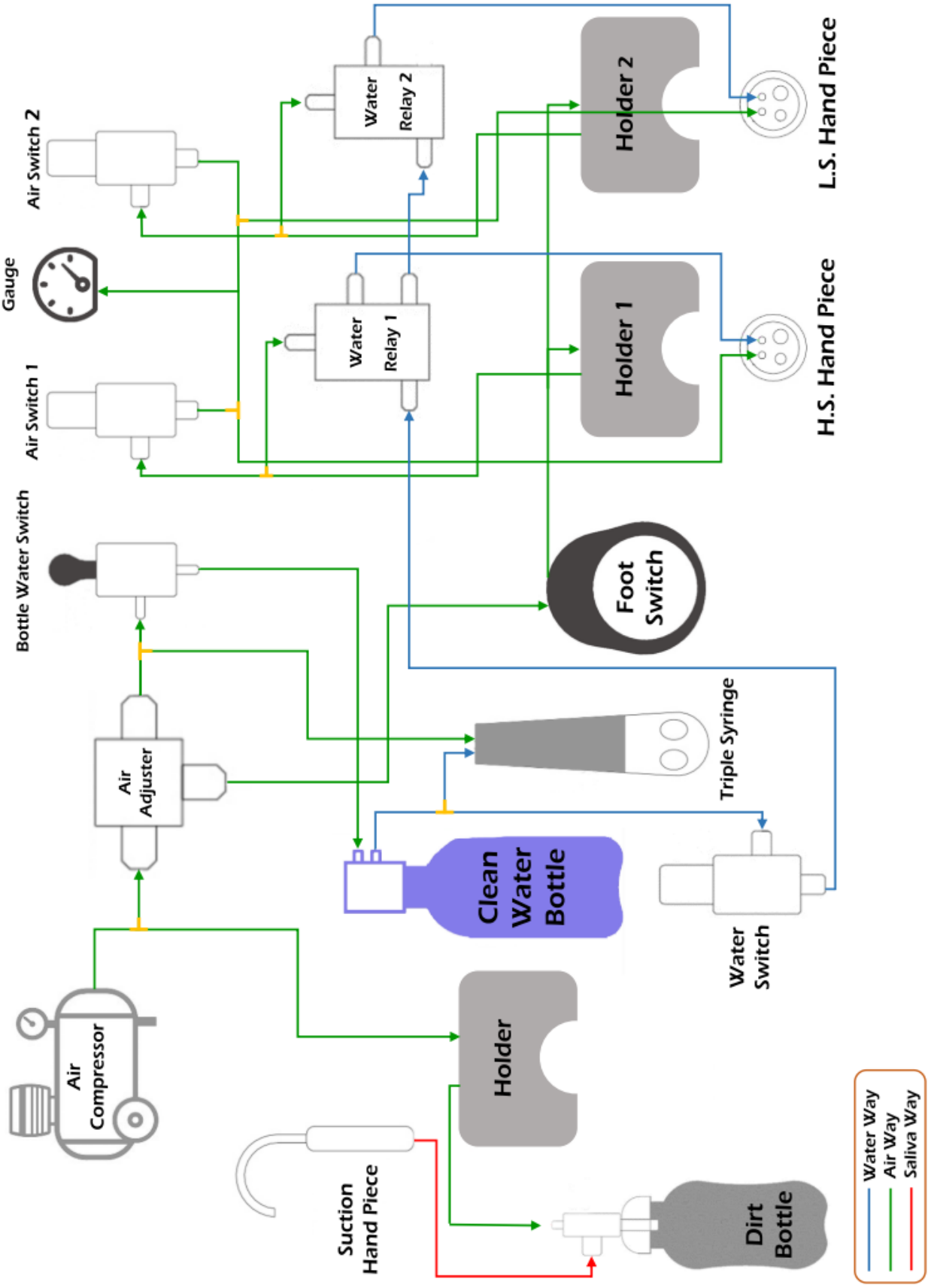

Figure 0–26: A visual representation of the water and air connection circuit.

Chapter 4. Conclusion and recommendations for future work

4.1 Conclusion

In conclusion, this project aimed to investigate and optimize various aspects of dental unit design and operation, with a focus on improving patient comfort, infection control, and overall efficiency. Through a review of the relevant literature and analysis of current dental unit designs, several areas for improvement were identified, including the integration of ergonomic features, the implementation of effective infection control measures, and the optimization of workflow and instrumentation.

Based on these findings, a new dental unit design was proposed that incorporated these key improvements, including adjustable patient positioning, streamlined instrument arrangement, and advanced infection control features such as a closed water system and anti-microbial surfaces. The proposed design was evaluated through a series of simulations and user tests, which indicated that the new design was highly effective in improving patient comfort and reducing the risk of infection, while also enhancing the workflow and overall efficiency of dental procedures.

Overall, this project has provided valuable insights into the complex and multi-faceted nature of dental unit design and operation, highlighting the importance of considering not only the technical aspects of equipment and instrumentation, but also the human factors that contribute to the success of dental procedures. Through further research and development in this area, it is hoped that future dental units can be designed and optimized to maximize patient outcomes and improve the overall quality of dental care.

4.2 Recommendations for future work:

After completing the design, and fulfilling the objectives of the project. The following points can be implemented in the future to give further development to the system:

1. Adding a scalar unit to the system.
2. Adding a sensor to the suction unit that detects blockage of the bottle and automatically shuts down the unit.
3. Adding additional air and water filters.
4. Adding solar panels to power the device using solar energy in areas where there is no access to electricity.
5. Working on downsizing the air compressor while maintaining the required specifications.
6. Working towards fulfilling the requirements of ISO 13485 International Standard for Medical Devices to obtain certification for this device after registering it with the Central Agency for Standardization and Quality Control in Iraq and acquiring a patent.

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