Chapter One

Thesis Overview

1.1 Introduction

Health is a crown on head of healthy people. Everyone is interested in his or her health, specially about teeth to have a nice smile. But teeth and gum may be affected by diseases, bacteria and rot. Because of less care, people all over the time tried to treat disease of teeth and gum, beginning from taking them off ending with surgical therapy. So this project concerns in people who need health teeth by a modern technology using a portable dental unit.

1.2 Project Objectives

In order to treat the diseases and inflammations of teeth and gum by modern technology which reduces the effort and time for both dentist and patient. This project is looking forward to designing a portable dental unit which can be moved and carried easily by reducing dental unit components. This design can do the same job of a dental unit, which includes the function of high speed turbine, low speed turbine, and triple syringe.

As medical books and resources give only rough idea about the dental chair, this project aims to support the biomedical engineering discipline in the university with a complete documentation about the dental unit. Hence, providing the students with a valuable knowledge gained from advanced training courses and experts.

1.3 Project Importance

As the dental chair is relatively expensive, and it needs a special clinic with special specifications like site, light, dimensions, conditioning, and other circumstances, the idea of designing a portable dental unit is occurred, especially in critical situations. This design aims to reduce both patient's and doctor's time, with less effort from dentist, since it can be moved, carried, repaired and constructed easily. The best feature of this design that it can be used in any place, either inside or outside of the clinic, like open days, also in critical circumstances, like wars, emergency and other conditions. In addition; this project acts an important task in the modern hospitals, because some children and patients refuse or not able to be treated in the clinic, so they are forced to be treated under sterilization in the operating room. In other hand, by minimizing dental unit components, system cost will be minimized.

1.4 Historical Background

1.4.1 Ancient

The pain of teeth was known all over the civilizations. They began to take off the infected tooth. Then in the medium civilization the dentistry was an occupation like any other career. In 1728 a book entitled "Dentist Surgeon" by Dr. Beer fisher was established, he described the dental instruments and ways of treatment. This book was considered as a historical point in dentistry.[1]

1.4.2 Modern

In 1850s, the dentistry became an exclusive job for the dentist, then at the beginning of 20th century turbines and filling teeth were discovered and used to treat teeth's pain, after that in 1895 the dental x-ray was discovered, these developments caused a revolution in dentistry.[1]

1.5 Project Content

This project discusses several important points in designing a portable dental unit; it is divided into six chapters as follows:

Chapter one contains an introduction about the project, project objectives and importance, economical study, abbreviations, and time plan.

Chapter two talks about a physiological background of teeth and gums.

Chapter three discusses the complete construction of the treatment unit in dental chair and the way of operations for each part and preventive maintenance for them.

Chapter four discusses the complete construction of the service unit in dental chair and the way of operations for each part and preventive maintenance for them.

Chapter five contains the designed block diagrams, the system implementation, and the specifications of the system components.

Chapter six contains the results, challenges, and recommendations.

1.6 List of Abbreviations

Several abbreviations have been used in the project such as:

1. RPM: Round per Minute.
2. Psi: Pascal pressure.
3. DC: Direct Current.
4. AC: Alternate Current.

5. UV: Ultra Violet.
6. HST: High Speed Turbine.
7. LST: Low Speed Turbine.
8. SV: Solenoid Valve.
9. LCD: Liquid Cristal Display.

1.7 Economical Study

The following table represents the prices of the main components of the the project.

Table 1.1 Economical Study

NO.	Material	Quantity	Price
1	Air motor	1	150 $
2	High speed turbine	1	100 $
3	Three way syringe	1	80 $
4	Contra angle	1	80 $
5	Solenoid valves	4	200 $
6	Footswitch	1	100 $
7	Micro switches	4	40 $
8	Air valve regulator	1	50 $
9	Internal air regulators	2	70 $
10	Internal water regulator	1	30 $
11	Tubes for turbines	3	30 $
12	Internal tubes	15 m	30 $
13	Holders	3	30 $
14	Other materials	---	200 $

From the preceding table, the total cost of the project is about 1200 $, which is relatively economical cost.

1.8 Time Schedule

The time plan views the stages of establishing the project with its components, divided into two semesters as shown in the following tables

Table 1.2 Time Schedule of the First Semester

Week / Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Project Determination	■	■	■												
Data Gathering				■	■	■	■	■	■	■	■	■			
Documentation									■	■	■	■	■	■	■

Table 1.3 Time Schedule of the Second Semester

Week / Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Design of Block Diagrams		■	■	■	■										
Purchasing the Components				■	■	■	■	■							
System Implementation						■	■	■	■	■	■	■	■	■	■
Documentation									■	■	■	■	■	■	

Chapter Two

Physiological Background

2.1 Introduction

Teeth are a grace of God that we have to look for them. They are affected by several particular diseases. Hence, we must wary about them. In order to design a system which can treat teeth's diseases, the physiological structure of tooth, gum, and diseases which may affect on teeth must be known. In this chapter the structure of teeth, the most common diseases of gum and teeth, the diagnostic methods (naked eye, X-ray, panoramic X-ray), the treatment methods (either cosmetic treatment or therapy treatment), and the ways to prevent these diseases starting with personal care, ending with surgical therapy will be discussed.

2.2 Tooth Structure

Tooth consists of a crown and one or more root, the crown is the visible part in the mouth, and the root is hidden part inside the jaw, the junction of crown and root is called the neck, and the end of the root is called the apex. Tooth consists of four layers; Enamel, Dentine, Cementum and pulp, as shown in figure 2.1

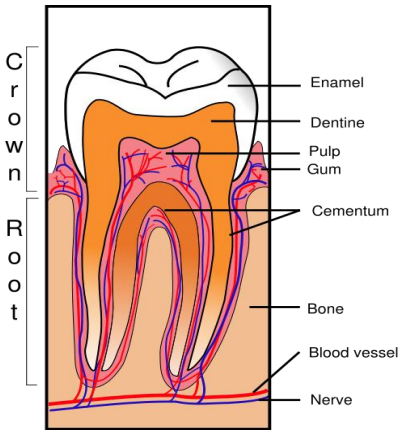

Figure 2.1 Structure of Teeth[2]

2.2.1 Enamel

Enamel is the protective outer covering of the crown and it is the hardest substance in the body. It does not contain any nerves or blood vessels; therefore it is insensitive to pain. Unlike most other body tissue it cannot regenerate so the damage caused by progressive decay or injury is permanent.

2.2.2 Cementum

Cementum is the protective layer of the root and it is similar in structure to bone. Cementum meets enamel at the neck of the tooth the thickness of cementum may varies at different parts of the root.

2.2.3 Dentine

Dentine forms the main bulk of a tooth the occupies the interior of a crown and root, it is very sensitive to pain but normally is sheltered from pain stimuli such as extremes of temperature or chemical irritation by it is outer coating which acts as a protective layer of insulation. Dentine is harder than the bone but less solid than enamel.

2.2.4 Pulp

The pulp is purely soft tissue; it contains blood vessels and nerves, and occupies the center of the dentine. Vessels and nerves of the pulp enter the root apex through the apical foramen and pass in the root canal into the crown.

2.2.5 Supporting Structure

Tooth fits into a socket (alveolus) in the jaw, the part of the jaw containing the teeth is a ridge of bone, and it contains the entire tooth socket and is covered with

a soft tissue called gum. The jaw bones consist of dense outer layer known as compact bone and a softer interior called spongy bone.

2.2.5.1 Gum

The anatomical term for gum is gingival; it is soft tissue that immediately surrounds the root of teeth, and bone.

2.2.5.2 Periodontal Membrane

It consists of thousands of fibers which fasten the cementum to the body socket. These fibers anchor the tooth to the jaw bone and acts as shock absorbers for the tooth which is subjected to heavy forces during chewing. The periodontal membrane contains nerves and blood vessels, but consists mainly of bundles of fibers which pass obliquely form bone to cementum.[3]

2.3 Dental and Gum Diseases

Our mouth is wonderfully designed machine with many different parts that is full of bacteria which causes dental and gum diseases.

2.3.1 Dental Diseases

There are many kinds of dental diseases which caused by microorganisms that produce toxic chemicals which destroy dental tissues. When the oral cavity is dominated by pathogenic bacteria a dental disease will appear. Some of bacteria living in the plaque can change sugar into acid which dissolves enamel to produce caries. Figure 2.2 summarizes the dental diseases.

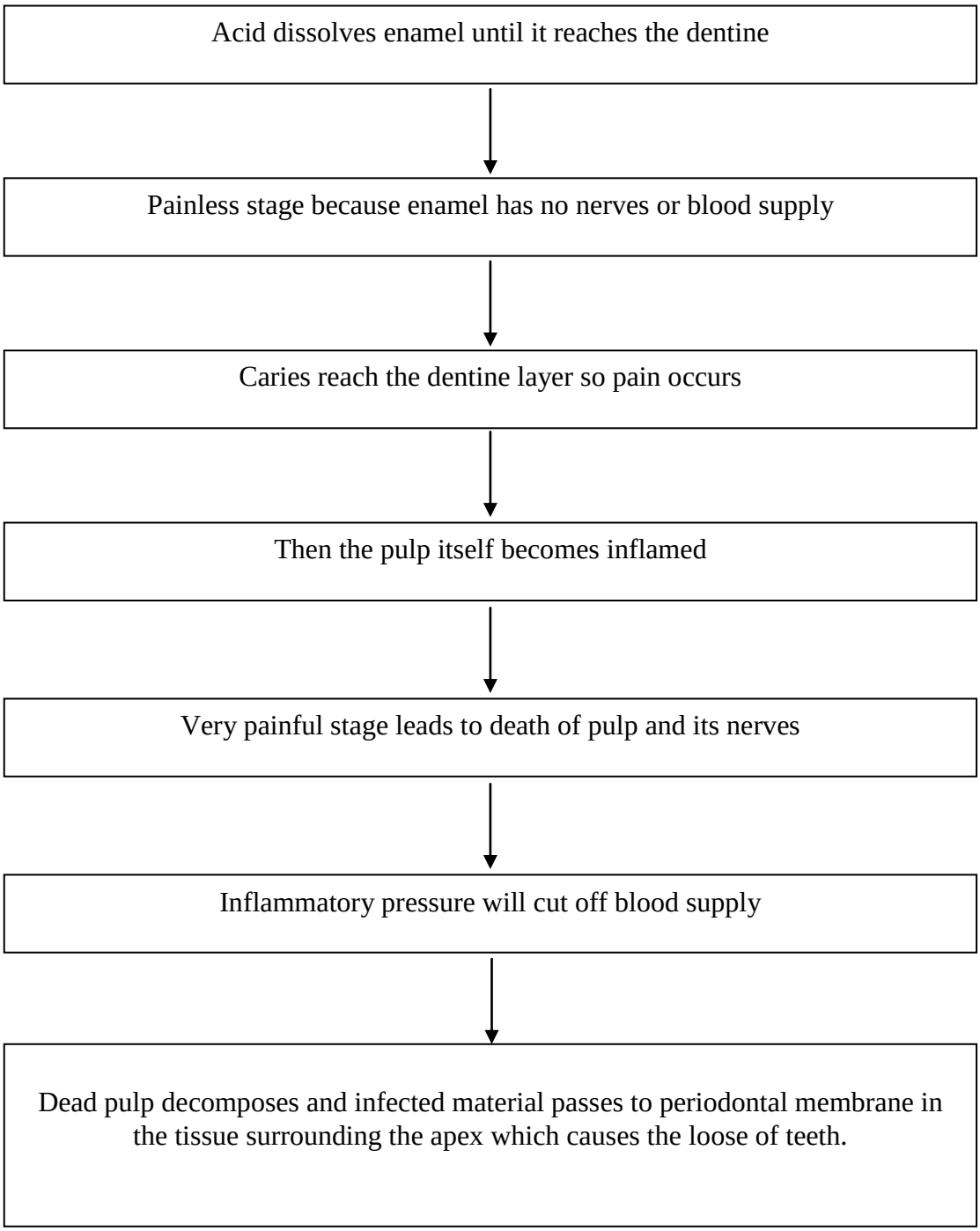

Figure 2.2 Caries Effects [4]

2.3.2 Gum Disease

Gum disease describes bacterial growth and production of factors that gradually destroy the tissue surrounding and supporting the teeth . The block diagram that illustrates the steps of the gum disease is shown in figure 2.3

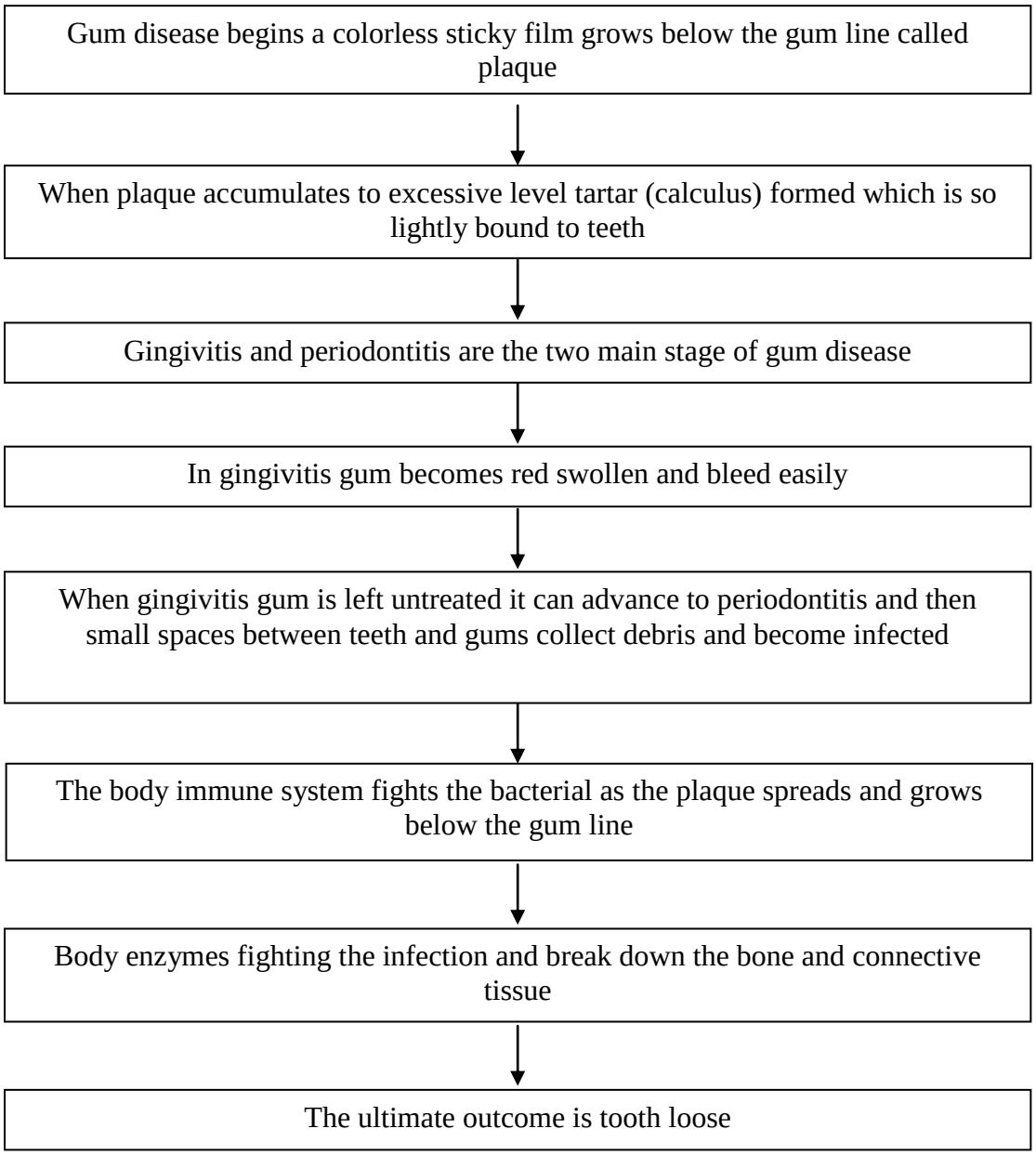

Figure 2.3 Steps of Gum Disease[4]

2.3.3 Causes of Periodontal Disease

The main cause of periodontal disease is bacterial plaque, which causes sticky and colorless tooth layer. However, factors like the following also affect the gum health:

1. Smoking (tobacco use)
2. Genetics
3. Pregnancy and puberty
4. Stress
5. Medication and some drugs
6. Clenching or grinding teeth
7. Diabetes
8. Poor nutrition

2.4 Signs and Symptoms

Periodontal disease may progress painlessly, producing few obvious signs, even in the late stages of the disease. Comparison between healthy and disease periodontal are illustrated in figure 2.4

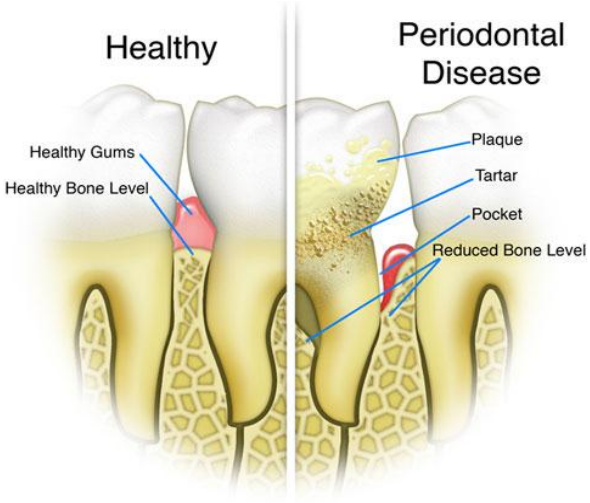

Figure 2.4 Healthy Vs Periodontal Diseases Tooth[5]

Despite the periodontal disease symptoms are subtle; it is not entirely without warning signs. Hence, Teeth diseases can be diagnosed according to the following symptoms:

1. Gums that bleed during and after tooth brushing.
2. Red or swollen gums.
3. Persistent bad breath or bad taste in the mouth.
4. Receding gums.
5. Formation of deep pockets between teeth gums.
6. Loose or shifting teeth.

2.5 Dental Treatment

2.5.1 Introduction

The evolution of dentistry appeared with the past civilization when the human starts to search for the method that can stop the tooth pain. As mentioned in the preceding references, the tooth pain is defined as a destroying of teeth structure caused by flukes that cut the structure of teeth. The critical solution was to extract the damaged teeth.

With the developments of science, the dental treatment is developed to give a multi choices and options. The treatment of toothache depends on the reasons of the pain. Dental disease treatment is divided into two categories; therapy treatment and cosmetic treatment.

2.5.2 Therapy Treatment

The most common dental disease is the caries, which is a tooth decay caused by acid that dissolve the enamel and dentine layers. This caries produces a black cavity in tooth structure.

2.5.3 Tooth Diagnosis

Diagnosis is the examination of tooth to detect the presence of caries; there are several diagnostic methods.

1. Naked eyes; to detect the large cavities.
2. Using probe; probe is blunt pointed instrument that is passed over teeth and it clasps with holes.
3. X-ray film; the formed image used to detect the cavity and caries before it can be seen by any other method.
4. Transillumination; a bright fiber-optic light is placed against the crown and the cavity shows up as a dark shadow.
5. X-ray panoramic; it is a modern method that has much less radiation than traditional X-ray and more comfortable. It shows more detailed information, because it images the entire jaw, tooth and surrounding bone. It also shows the entire mandible details that the traditional x-ray can't do, it can also show the impacted teeth and it can detect any small cavities that could be found there and give accurate location of these cavities.[6]

2.5.4 Treatment Procedures

If caries is allowed to progress untreated, it will cause toothache, followed by pulp destroy. The aim of the treatment is to have a good tooth by stopping caries progressing. The type of treatment depends on the health of the pulp. If it is still vital and not affected by caries, the tooth can be filled. But if the pulp is inflamed, or already dead, treatment can be done by tooth extraction or root canal therapy.

2.5.4.1 Restorative Filling

This treatment is applied when the pulp is vital, since the carries cannot be treated by drug, and nothing can be used to regenerate the lost tooth structure, so the

restorative filling is the best choice. The caries and damaged structure of tooth is removed, and missing structure of it is rebuilt with filling materials.

Restorative filling has the following steps:

A) Cavity Preparation

The caries is cut with burs fitted in a hand pieces; after removing the carious surface the cavity is formed. Figure 2.5shows the use of hand piece in cavity preparation.

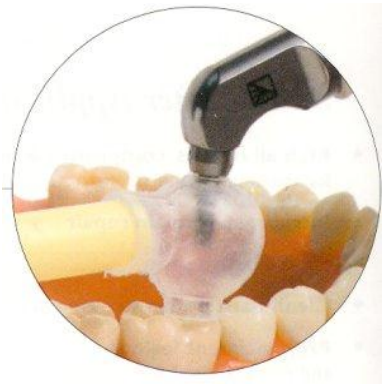

Figure 2.5 Using of the Hand Piece In Cavity Preparation[7]

B) Cavity Lining

Before a permanent filling is inserted, temporary filling is used to make insulating layer of cement to protect the pulp against conducting heat or cold, and it gives time to the berserk nerves to be clam.

C) Insertion

The technique of inserting the filling varies with the type of cavity, used filling material and the chewing load should be handled. Cavity must be dry during insertion of the fillings, so the saliva should be controlled by "saliva ejector" by using absorbent materials or suction hand piece.

D) Polishing

After inserting the permanent filling, it is necessary to smooth and remove any high spots or proud edges and make it more comfortable by using polishing instrument.

2.5.4.2 Dental Fillings

There are two types of dental fillings according to the duration that it kept in teeth; temporary fillings and permanent fillings.

A) Temporary Fillings

Temporary fillings are too soft, soluble and don't stay for long time in the teeth, it is used to calm the nervous system and to relieve the pain. It is basically used in "cavity lining" step. The temporary fillings consist of zinc oxide, eugenol cement, zinc phosphate cement, poly carboxylate, and Gutta—percha.

B) Permanent Fillings

Permanent fillings are put after removing of the temporary filling. They are indelible and steady that are kept in the teeth structure. The main functions of permanent filling can be listed as follows:

1. Restoration of part lost by caries.
2. Conservation of proper function of teeth.
3. Preventions of pain.
4. Prevention of further caries.

5. Restoration of appearance of front teeth.

Several factors influence the performance, durability and expense of dental restorative filling. These factors include the material components of the fillings, where and how the filling is placed, and the chewing load that tooth can handle.

Restorative fillings are placed immediately into prepared cavity after removing of temporary filling.[8]

2.5.4.3 Extraction

Extraction means that the dentist removes all the structure of teeth because the pulp is inflamed or dead and the pain cannot be stopped by filling of teeth, in other hand there is a periodontal disease that can't be treated.

The extraction of teeth is done by using of "forceps" which is an instrument that can hold the teeth tightly and extract it.

2.5.4.4 Root Canal Therapy (endodontics)

The basic object of endodontic treatment is to remove the inflamed or dead pulp and replace it with a permanent root filling. This will seal each end of the root canal, and remove the source of irritation which causes destroying of the root. The root filling restores the function of teeth.

The steps of endodontics are:

a) Removing infected pulp.
b) Enlarging and clean the root canal.
c) Disinfecting root canal.
d) Filling root canal.

2.5.4.5 Cosmetic Treatment

Cosmetic treatment is the other type of dental treatment which is used to enhance the appearance of teeth.

2.5.4.6 Teeth Whitening

It is the simplest technique in cosmetic dentistry treatments, which aims to get white and clean teeth to have a nice smile by putting a plastic tray over the patient teeth, and then a whitening gel is placed into these trays.

2.5.4.7 Dental Bonding

Dental bonding is used to improve the appearance of the surface of a tooth, to replace tooth structure that has broken, or to repair damage caused by tooth decay. This technique is inexpensive and does not take long time.

2.5.4.8 Dental Crowns

Dental crowns use porcelain to cover the front sides of teeth which lies above the gum line. Dental crowns are strong and durable, but it is an expensive technique.

2.6 Preventions

Prevention that keep the teeth, and periodontal healthy includes healthy eating, oral hygiene, fluoride, scaling and root planning, antibiotic treatments.

a) Healthy eating: Everyone should take care about the kinds of eating by minimizing snacking, sugary drink or frequent sucking of candy and mints, because it creates a constant supply of acid in mouth.

b) Oral hygiene: it consists of brushing and proper flossing. Brushing eliminates only the plaque from surfaces of the teeth, but flossing removes plaque between the teeth and under the gum line.
c) Fluoride: Fluoride incorporates into structure of the enamel, it protects the teeth against the action of acids. The fluoride can be found as tooth paste or mouth wash.
d) Scaling and root planning (SRP): Scaling scrapes the plaque and tartar from tooth and gum line. Root planning smoothes rough spots on the tooth, where bacteria arc being collected.
e) Antibiotic treatments: Antibiotic treatments can be used either in combination with surgery and other therapies, or alone, to reduce or temporarily eliminate the bacteria associated with periodontal disease, antibiotic drugs have the ability to fight infections.[8]

Chapter Three

Dental Unit

3.1 Introduction

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 3.1 to work efficiently.

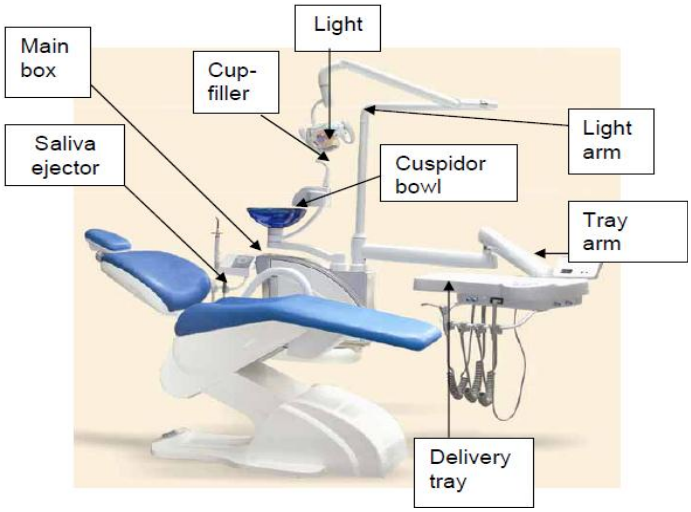

Figure 3.1 Dental Unit Components[9]

The complete understanding of dental unit construction will pave the way to design a potable dental unit, which can do the same functions of the normal one.

Figure 3.2 depicts the block diagram of dental unit components. This chapter talks about the complete construction of treatment unit components, including its parts, composition, principle of operation, troubleshooting, and maintenance, whereas the service unit will be discussed next chapter.

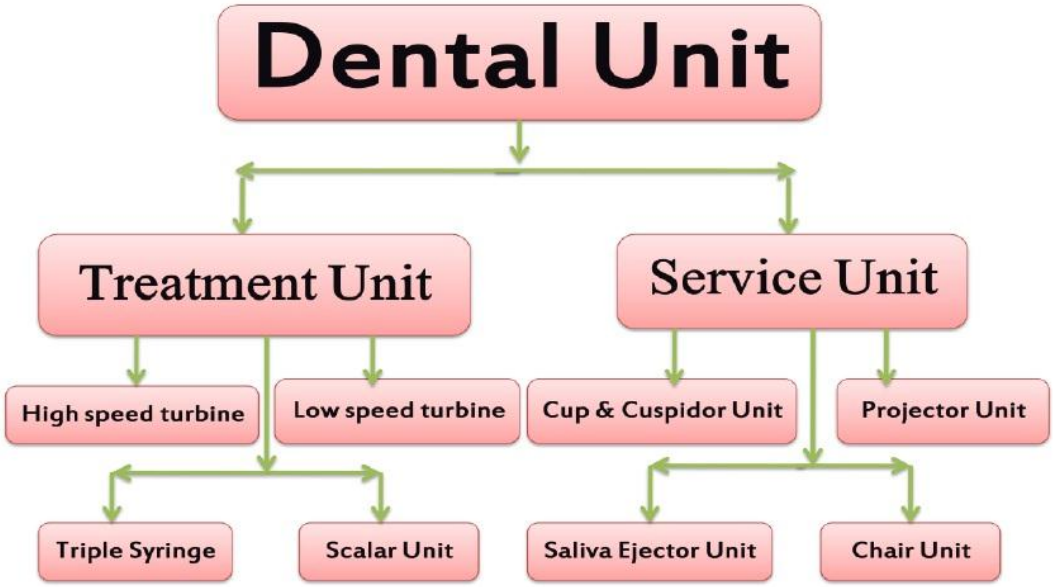

Figure 3.2 Block Diagram of Dental Unit Components

Despite dental unit consists of subsystems, all of them operate as a complete single system, in other words, the operation of all units in dental chair is integrated.

3.2 Treatment Unit

The main part of dental unit is treatment unit. It provides all treatment features to the dentist to perform the therapy operations. It consists of hand pieces that provide the treatment process, as shown in figure 3.3.It is designed to be flexible to move in every direction in a large range. Dental hand pieces are a precision built

mechanical designed for use with rotary instrument such as burs, stones, wheels and disks. It may be electric or compressed air driven.

Hand pieces are handle devices, which makes several important tasks, such as cutting, cleaning or polishing the teeth. It can be driven pneumatically or electrically. Hand pieces can be classified - according to the revolution per minute, or a speed at which they operate - to low speed and high speed turbine.

When the turbine or the micro motor is lifted from the holder, the switch is turned on, and the circuit is now on standby position. To activate the turbine or micro motor the foot switch should be pushed. The turbine or the micro motor works at 2.2atmospheric pressure. It contains adjustable switches for both water and air pressure.

Figure 3.3 Treatment Unit[10]

3.2.1 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 figure3.4

Figure 3.4 High Speed Turbine[11]

3.2.1.1 High Speed Turbine Components

High speed turbines have the same basic principle of operation and the same main components. High speed turbine consists of:

1) **Bur (Rotary Instrument):**

It is used to remove caries which appear on the surface of the decayed teeth. It can be made of steel carbide or diamond coated material, it is inserted into a shuck, and rotated when air comes into the head of the hand piece through air turbine. It consists of three basic parts: head, neck and the shank, as shown in the figure 3.5

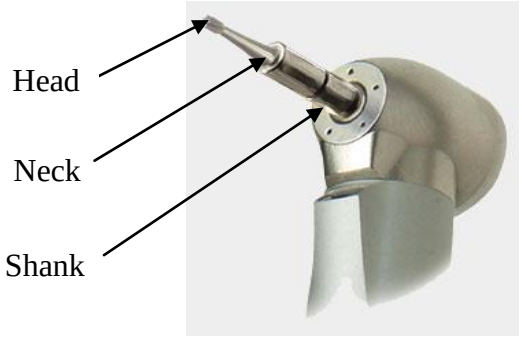

Figure 3.5 Parts of Bur[12]

The head of the bur is the cutting portion which is constructed in many sizes and shapes. The neck, which is the narrow portion of the bur, connects the shank with the head. The shank is designed with a fit shape that allows it to inter in the head of the hand piece easily, the length of the shank depends on the specific use of the bur.

2) Chuck:

It is a plastic or metallic frictional parts, they are used to hold the cutting or polishing tool, the bur is held straightly by either manual tightening or a power level lock. A chucking mechanism depends on that the chuck has slots, which are closed on the bur.

3) Bearing:

A high precision tool which is used to support rotating part with a very low friction, there are two types of bearings:

a) Ball bearing turbine (oil).

b) Air bearing turbine (oil less).

The following table shows the difference between ball and air bearings:

Table 3.1 Comparison Between Ball and Air Bearings[13]

Ball Bearing	Air Bearing
The needed pressure is (2-2.5)bar	The needed pressure is (3-3.5) bar
Speed (300,000-360,000)rpm	Speed (450,000-500,000)rpm
Easy and fast starting	Low starting (friction)
Good connection between the rotor and the ball bearing	No fixed connection between the rotor and the air bearing

4) Canister:

A closed cylinder which houses a rotating turbine assembly.

5) Rotor (Impeller):

It provides rotation for the cutting tool (bur). It is held by the bearing which is housed by canister, as shown in the figure 3.6

Figure 3.6 Rotor Components[14]

6) Turbine:

It is located in the head of the high speed hand pieces (canister), it rotates by the use of the compressed air.

7) Three Channels:

Inlet air channel, inlet water channel and outlet air channel.

3.2.1.2 High Speed Turbine Principle of Operation

High speed turbine is used to dig the hardest outer shell of the tooth (enamel), this digging needs a high speed rotation reaches to 400,000rpm.

Previously, this speed of rotation was achieved by using electrical motor with 220V. However, the high speed produces heat. Hence, water is used to keep operation area cool. Because of the presence of water and electric lines together, this technique is too dangerous.

A modern technology uses compressed air to have the same speed without danger. High speed turbine basically contains three holes (inlet air channel, outlet air

channel, and inlet water channel). Compressed air reaches the rotor –which located inside the chuck- via an inlet air channel. Rotor rotation will be accompanied by chuck rotation. Consequently, the bur will rotate. The rotor is fixed by two bearings; to facilitate its motion. The excess air will return via a wide whole (outlet air channel) to form a closed loop system which increases the efficiency, and get rid of the air quickly.

High speed hand piece uses a water system to keep operation aria cool. The water comes from water inlet channel, then it will be splashed on the surface of drilling from outlet hole at the head of the hand piece as illustrated in the figure 3.7

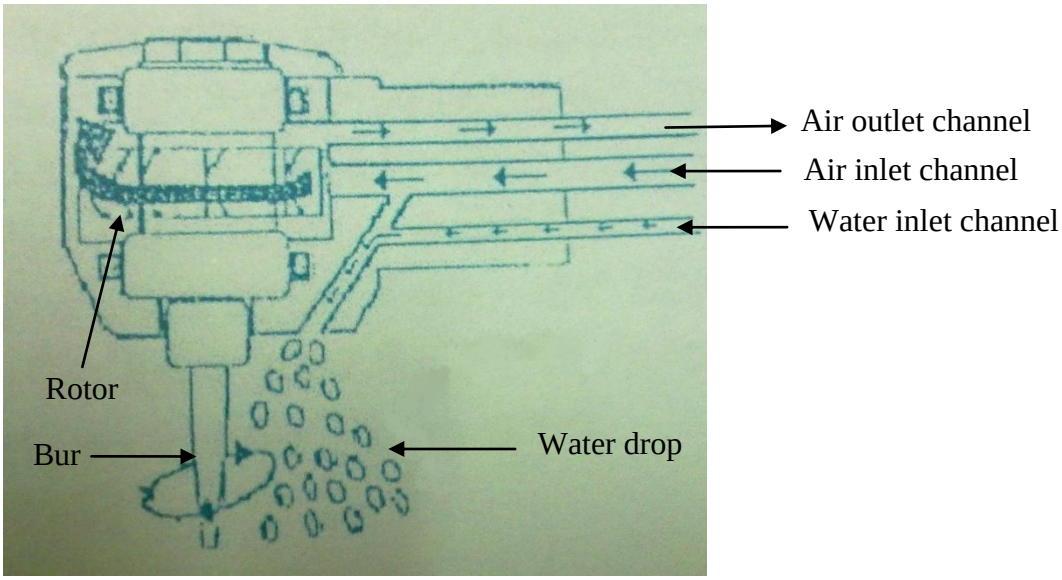

Figure 3.7 HST Principle of Operation[15]

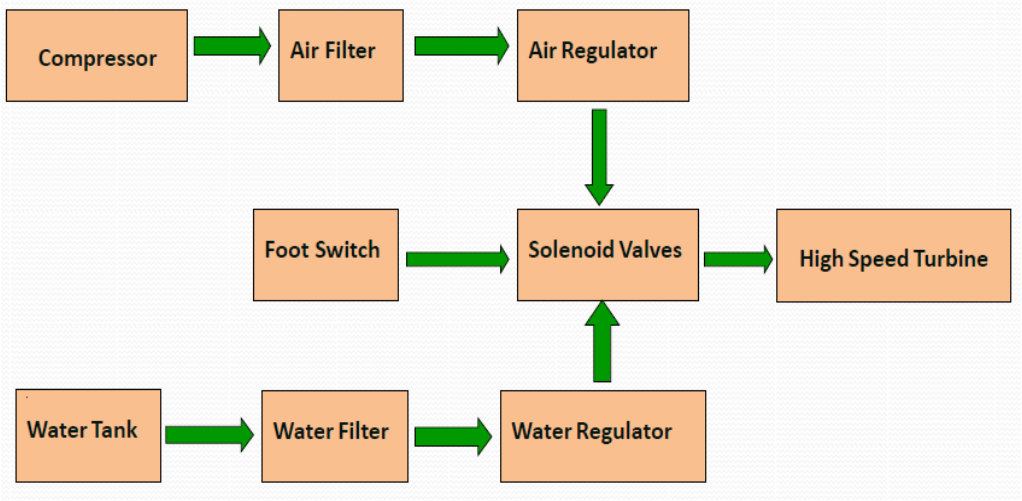

Figure 3.8 Block Diagram of Principle Operation of HST[13]

3.2.1.3 Troubleshooting of the High Speed Turbine

High speed hand piece faces many troubles, the table 3.2 summarizes the troubles, reasons, and the solutions for high speed turbine:

Table 3.2 Troubleshooting of High Speed Turbine[13]

Problem	Possible Reasons	Solution
No outlet water to cool the teeth	No water in the main tank	It must be filled
	A large hole in the pipe	It must be replaced
	Block in the way of water	it must be cleaned either by chemical acid or inserting a wire in the pipe
Noisy sound in the head of turbine	Broken parts in the rotor	It must be replaced
	Problems in the bearing	It must be lubricated or changed
Slow motion of the hand piece	Low pressure level	the O-ring, filters and pipes must be checked
	Leakage in the main pipe	it must be replaced
	Broken burs	it must be replaced

3.2.2 Low Speed Hand Piece

Low speed hand piece (figure 3.9) 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 3.9 Low Speed Turbines[15]

3.2.3 Low Speed Turbine Components

Low speed turbine consists of three components; motor, attachment, and the head. The motor is used to generate mechanical motion. The attachment tool is used to translate the mechanical motion generated by the motor to the head of the hand piece via mechanical translators. This may accompanied with heat, in this case, cooling by water should be implemented externally or internally.

3.2.3.1 The Motor

The motor is the lower part of the Low speed hand pieces. The first idea was to generate low speed motion from the high speed turbine, by reducing the air pressure. This idea failed after being experimented, because it generates a rotation with low torque, which causes stopping of the bur during drilling. Then the low speed hand piece was developed to contain mechanical motion generator. After translating of motion from the lower part of the motor to the upper part -through shaft and gears-, the bur will rotate with the specific speed and torque.

There are three types of motors which are used in low speed hand pieces; electric motor, air motor, and micro electric motor. Figure 3.10 shows the motors of the low speed turbine.

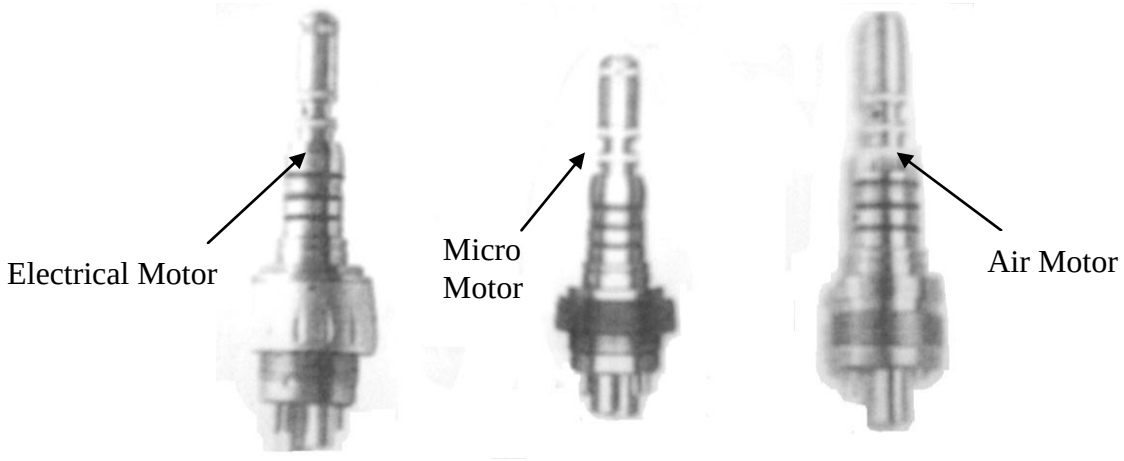

Figure 3.10 Motors of the Low Speed Turbine[15]

1) Electric Motor

Electric motor is the oldest type, it was used to generate a rotational motion in two directions; clockwise and counter clockwise. Its speed in range (12,000-18,000)rpm, it works at 220Vac and produces a relatively high torque, but it was not safe as high voltage is required.

2) Air Motor

Air motor consists of blades and rotor, it works by compressed air with a pressure reaches to 3.5 bar. This pressure must be broken down to reach 1.8 bar at the outlet of the blades, then the gears of the rotor will break down the pressure again to reach 1.3 bar, by doing this, the rotation speed will reach to 30,000 rpm with a high torque, but still less than in electric motor. The direction of rotation is controlled by change the direction of the entrance air to the motor, by using footswitch. Figure 3.11 shows the block diagram of principle of operation of the air motor.

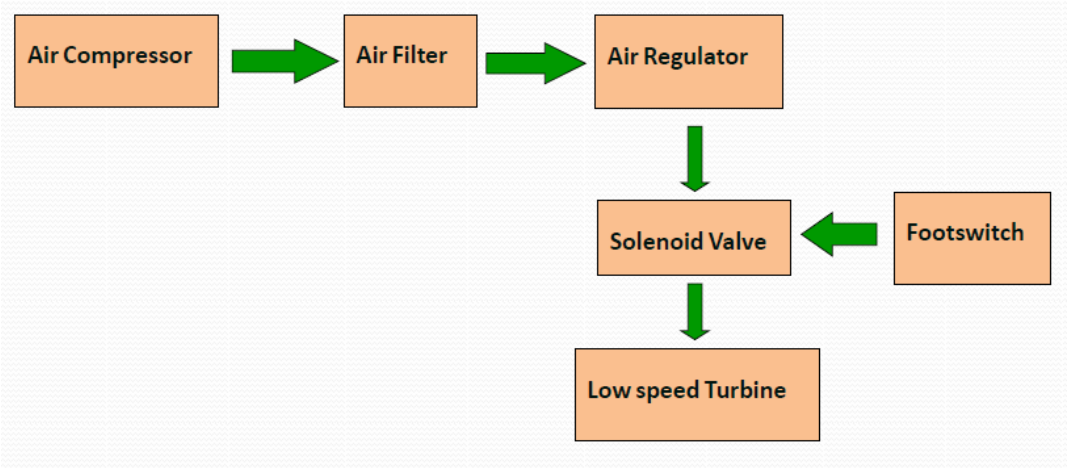

Figure 3.11 Block Diagram of Principle of Operation of the Air Motor[13]

3) Micro Electric Motor

Micro motor is an electric motor works with direct current, and voltage in the range (12-24)Vdc, which is safe for the patient. It is distinguished by the small volume, the range of its speed (25000-50000) rpm, and it has high torque. The direction of rotation is controlled by changing the polarity of the voltage across the brushes.

3.2.3.2 Attachment

Many units and models have some methods of quick connecting or disconnecting of the head and attachments, where they have a bottom to depress, the disconnecting gives the ability to sterilize the head after every use.

The main function of the attachment is to make a bridge between the motor and the head, to translate the mechanical action from the motor to the bur. It consists of a house of motor and nosecone.

The nosecone is connected to the head and to the motor. It consists of gears that translate the mechanical rotation from motor to the head.Figure3.12 shows the attachment and the nosecone.

Figure 3.12 Attachment and Nosecone [15]

3.2.3.3 The Head

The Head of the hand piece contains a chuck. This chuck is designed in a way that can be connected to a bur or other rotary instruments easily. Most heads contain a latch ring, from which the speed and direction of bur rotation can be controlled.

There are two shapes of the head; straight and contra angle as shown in figure3.13. The desired head is selected according to the medical application. For example contra angle is used to reach areas in the oral cavity which is difficult to be accessed via straight hand.

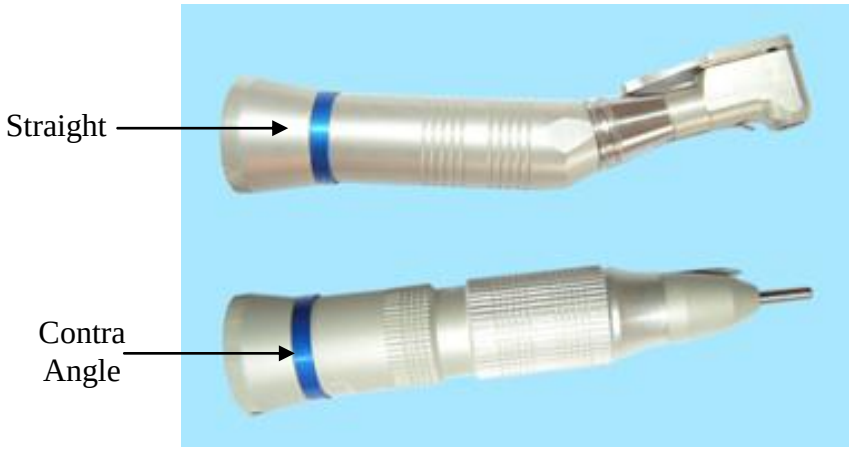

Figure 3.13 Types of Low Speed Turbine[16]

The nosecone is inserted at the center of the head, so the gear at the end of the nosecone is connected to the other complement gears at the head, the translation mechanism of rotation from the motor to the head is achieved by this combination.

3.2.4 Troubleshooting of the Low Speed Turbine

Low speed hand piece faces many troubles. Table 3.3 summarizes the troubles, and the solutions for low speed turbine:

Table 3.3 Troubleshooting of Low Speed Turbine[13]

Problem	Solution
Oil less bearing is defected	It must be replaced
Broken part in mechanical translator bur	It must be replaced
Slow motion in the hand piece	Increase the air pressure

3.2.5 Triple Syringe

Basically dental unit has one triple syringe (shown in figure3.14), 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 3.14 Triple Syringe[16]

By pressing specific button on the syringe hand piece the operator of the unit can choose the water only, air only, or spray. Many syringes have a quick disconnect that allows the syringe tip to be changed and autoclaved after each treatment. Two channels are connected to the hand piece; air inlet and water inlet channel.

The spray will be produced at the output by pressing both air and water buttons where the air scatters the water to small drops (spray). The cross section of the output end of the triple syringe is illustrated in the figure 3.10

Figure 3.15 Output of the Triple Syringe[11]

Figure 3.16 shows the block diagram of triple syringe system.

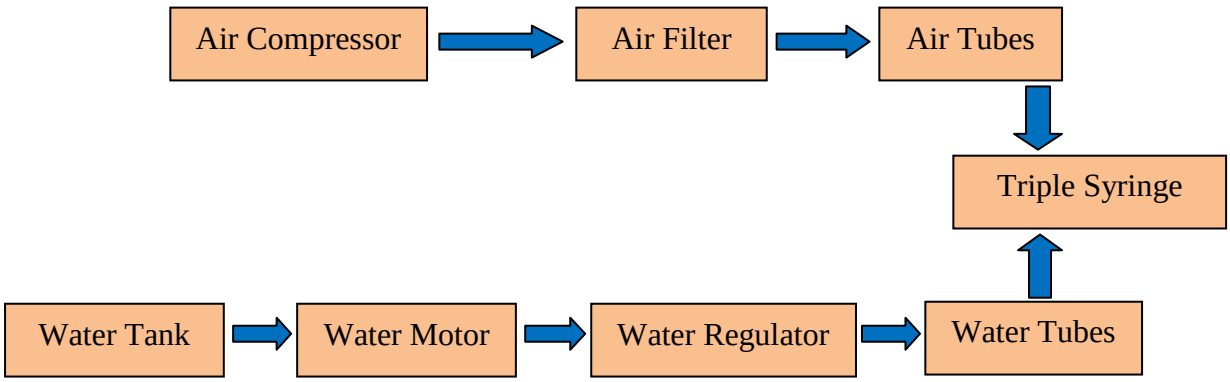

Figure 3.16 Block Diagram of Triple Syringe System[13]

3.2.6 Scalar Unit

Scalar unit (see figure 3.17) is used to remove scales layer on teeth which forms from bacterial secretion. It is recommended to make scalar cleaning every six months.

Figure 3.17Scalar Hand Piece[11]

Scalar hand pieces defer from other hand pieces; they generate a head vibration motion instead of rotational motion. There are many methods to generate vibrations at the head plate of the hand piece:

A) **Electric Motor**: it generates a rotational motion, which is converted into vibration motion using special mechanical pieces.

B) **Magnetic Field**: it is composed of a very thin plate which fixed at one terminal, while the other terminal is connected to blades. The plate is located between two magnets with opposite polarity as shown in the figure 3.17(a). When AC current passes through the magnet, the positive current signal will activate one of magnet, so it will attract the plate to its direction as shown in the figure 3.17(b). Then the negative current signal will activate the other magnet, so the plate will be attracted to the other direction as shown in the figure 3.17(c). The vibration is applied by the continuous operation of this plate movement.[11]

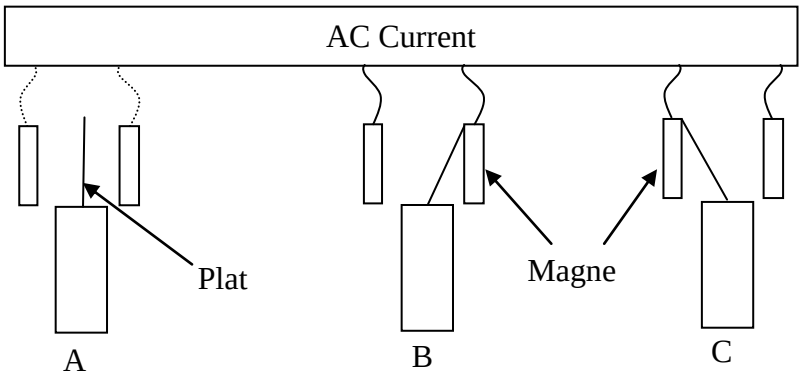

Figure 3.18 Scalar Operation Using Magnetic Field[13]

C) **Compressed Air**: it generates the vibration of the plate via compressed air. The used air pressure is 3.5bar.

3.2.7 Additional Options

Additional options can be added to the hand pieces or it can be implemented directly to the hand piece via the designer; to improve the efficiency, flexibility and facility. Such options include fiber optic, heater, endo-oral camera, and other options.

3.2.7.1 Fiber Optic

Dental hand pieces may contain fiber optics (figure 3.18)to provide the operator with the source of artificial illumination. The clinical applications of the fiber optic hand pieces are almost limitless. It is used- in general inspection of the oral cavity and tooth structure-to help, identify, and diagnose caries, stains, decay, and calculus. Many systems have a light controller-that permit adjustment of the light intensity- to fit individual reference and needs.

Fiber optic technology involves the transmission of light through long, thin fibers of glass or transparent material. The light travels(non electrically) through the

fiber by reflecting from wall to wall without transmitting or generating heat. This makes fiber optic completely safe for use in the oral cavity.[13]

Figure 3.19 Fiber Optic Hand Piece[11]

3.2.7.2 Heater

Heater is added to the hand piece to provide warm air and water.

3.2.7.3 Endo-oral Camera

Endo-oral camera is used to provide a macro view, or a view inside the mouth. This digital technology gives the ability to communicate with the patient to improve the quality of dental care, and display information and documents on a screen.

3.2.7.4 Additional High Speed Turbine

Another high speed turbine can be added to the treatment unit, as alternative hand piece to the dentist, if any problem in the original high speed turbine is happened during treatment.[13]

Chapter Four

Service Unit

4.1 Introduction

Dental unit consists of two main units, treatment unit and service unit. As said before, the treatment unit is the main unit in dental chair, which was discussed briefly in the previous chapter. This chapter talks about the second unit in dental chair, which provides additional services for both dentist and patient during treatment operation, this unit is called service unit. The complete construction and principle of operation for all components of this unit will be discussed in this chapter.

Service unit consists of four main parts (figure 4.1); projector unit, cup and cuspidor unit, suction unit, and chair unit.

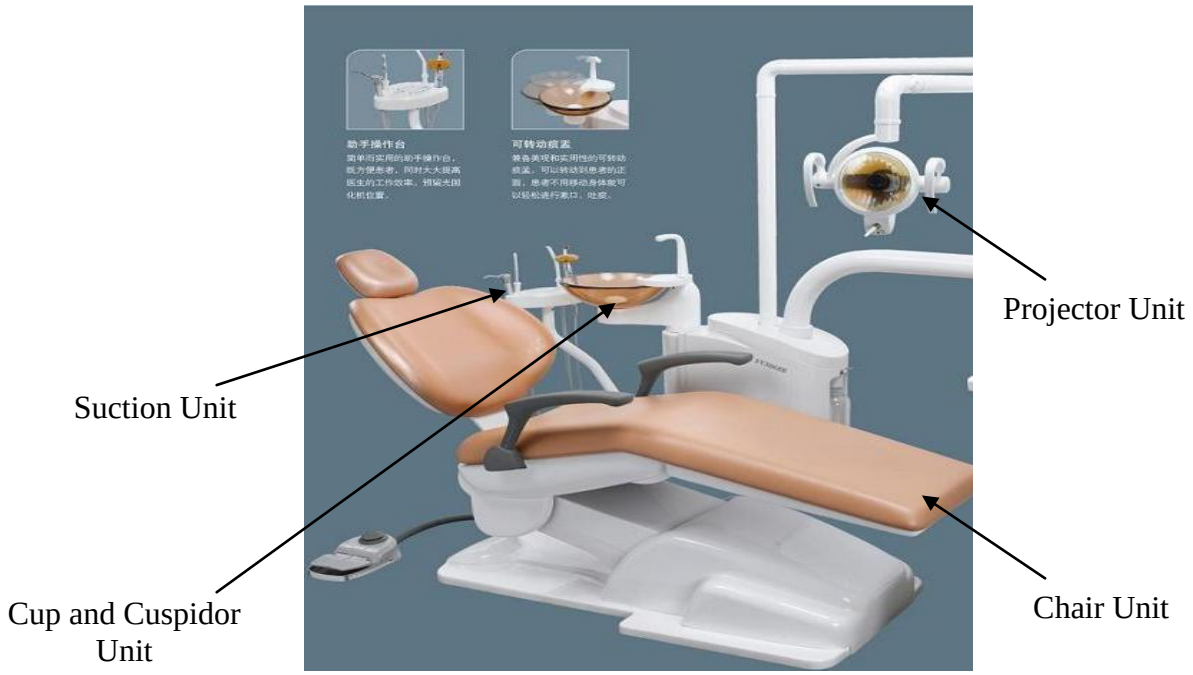

Figure 4.1 Service Unit Components[17]

4.2 Projector Unit

Projector unit (figure 4.2) is used to enhance illumination inside patient's mouth, the lighting system in dental unit differs from other lighting system, because it needs to direct the illumination on the patient mouth only, and keeping the light far away from patient face. This can be done by using two curved light reflectors, these reflectors will also reduce the heat on patient mouth. In projector unit there are two ceramic bases connected to each reflector, to protect the projector unit from high temperature which is caused from the lamp. The arm connects the lamp with dental chair contains an electric wires in order to provide the lamp with power.

Figure 4.2 Projector Unit[17]

The lamps which are used in projector unit are of two types:

1) Tungsten Lamp: it was used in old dental units, it works on AC voltage, which provides a power of 100W.

2) Halogen Lamp: it works at (12-24)Vdc, providing a high power of 150W. Halogen lamp is more commonly used, because its default age and output power are greater than tungsten lamp. [13]

4.3 Cup and Cuspidor Unit

The cup provides the patient with water, while the cuspidor used to take away the residual filling saliva, and blood which are produced inside the mouth during the treatment. Cup and cuspidor is shown in figure 4.3.Cuspidor has two filters to trap any impurities and particles through the pipe, then it will be collected in a container to participate the impurities, then the collected fluid passes to the drain. The cup is put over sensitive base with a switch that opens the water valve, if the cup is empty, the switch becomes on, after the cup is filled, the valve switch off. The switch is controlled by two ways; timer or weight sensor. Figure 4.4 shows the block diagram of cup and cuspidor unit.

Figure 4.3 Cup and Cuspidor Unit[18]

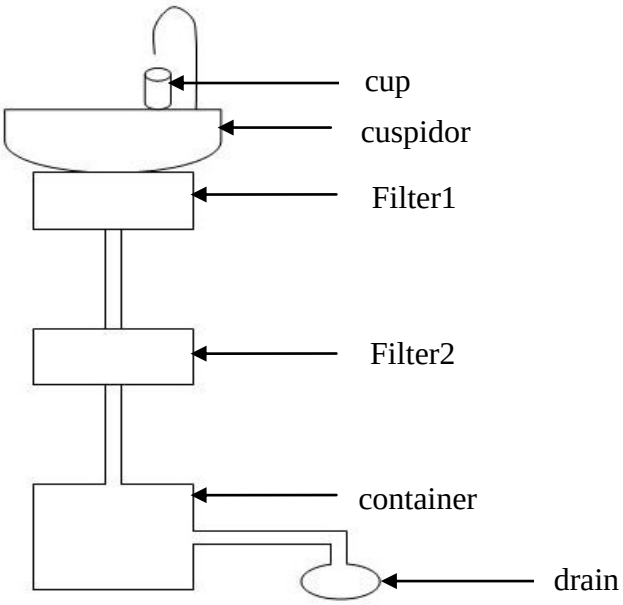

Figure 4.4 Block Diagram of Cup and Cuspidor Unit[13]

4.4 Suction Unit

Suction unit (figure 4.5) 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 4.5 Suction Hand Pieces[18]

The principle of operation is based on pressure difference which enforces the fluid to trans from the high pressure regions to low pressure regions according to venture principle.

The operation of suction depends on vacuum that is created in the container by suction motor, this container has another open terminal that is connected to the suction hand piece. After the vacuum is produced in the container, external fluid will be sipped and collected into a container due to pressure difference.

There are three sensors at different levels in the container, two of them at lower level and separated by small distance, when the water reaches to these sensors, they become connected (by conducting of the electrical signal between them), as a result the valve at the bottom of the container will be opened to trans the fluid to the drain. The third sensor is at higher level, when the fluid reaches to that level, the container is full and cannot receive more fluid, so the sensor sends a signal to stop the suction motor, and prevent the over flow in container by terminating the suction of the fluid, and gives time to empty the container.

For the vacuum source it can be either central for the whole dental clinic, or it can be individual for every unit. In the case of central suction unit there are a non-return valve (one way valve) at the terminal of each dental unit, this valve stops the suction of that unit when it is unusable. The block diagram of Suction unit is shown in figure 4.6[13]

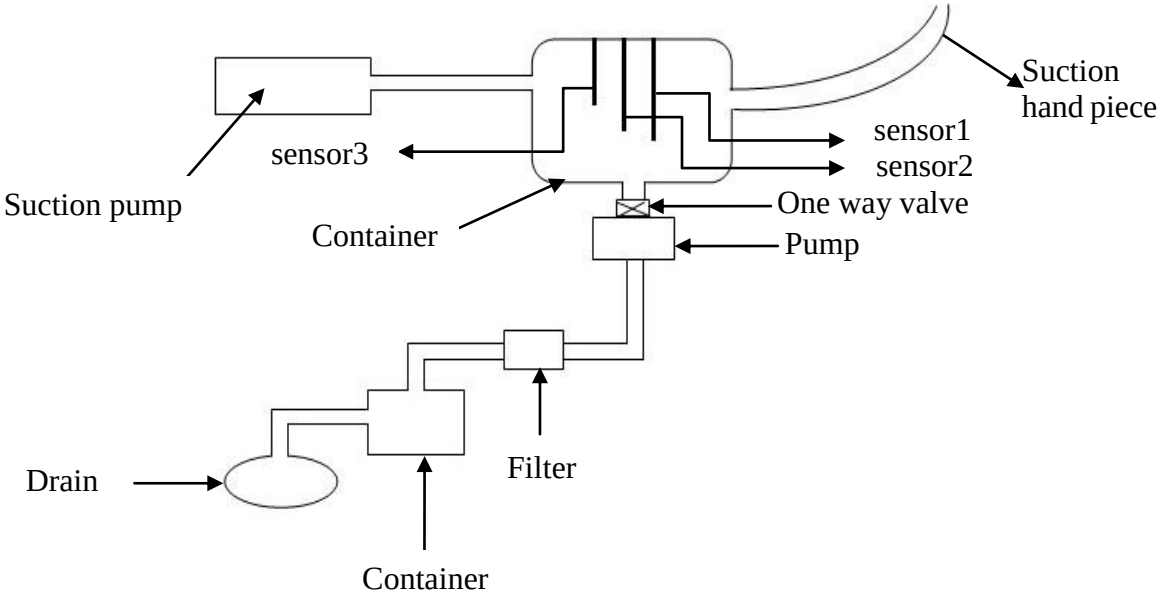

Figure 4.6 Block Diagram of Suction Unit[13]

4.5 Chair unit

Chair unit (figure 4.7) is an important part in dental unit, which provides the dentist with all equipments and all necessary items during patient treatment, it also provides flexibility and comfort for patient positioning, specially the head. Therefore it is expected to perform two main states; one is to lift or to lower the seat, and the other is to change inclination of the patient back.

Figure 4.7 Chair Unit[13]

The movement of the chair is controlled by three different system :

1) Hydraulic System.
2) Electric System.
3) Voice System.

4.5.1 Hydraulic System

The overall principle of hydraulic system depends on oil pressure. In the first generation the oil is kept in the tank and blocked between two pistons, the upper piston is connected with the chair and the lower one is controlled by mechanical switch (foot switch). In the second generation the hydraulic oil pump is activated electrically, once the pumping starts, the oil would be directed in the desired route according to function key pressed. Every route is completely controlled by solenoid valves. The valves prevent back flow of oil, and control the flow rate of it, second generation principle is illustrated in the figure 4.8

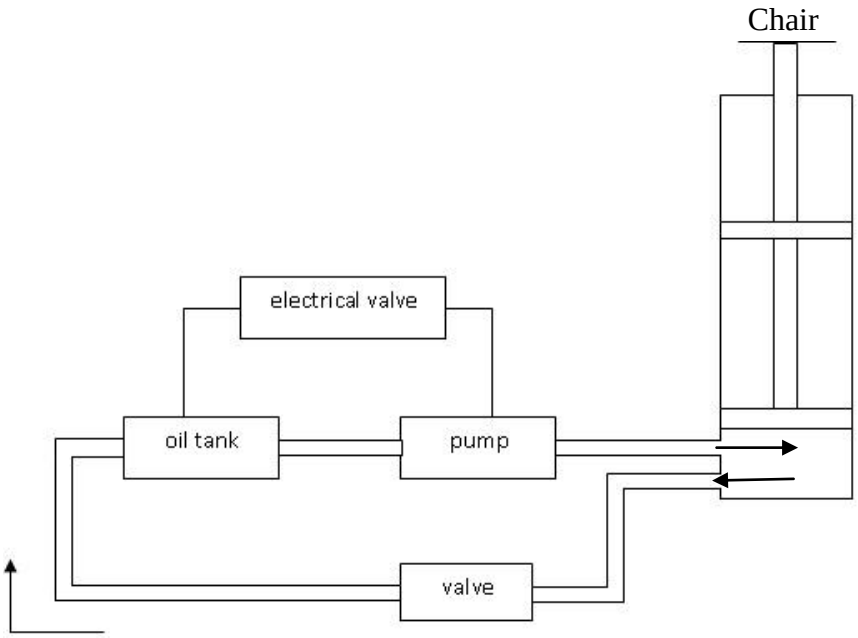

Figure 4.8 Chair Hydraulic System[13]

Rising chair operation is done by pushing the appropriate button. The pump and the concerned solenoid valve are activated, and this allows oil to run from the oil tank into the jack or piston. The resulting oil pressure causes expansion of piston, which would result in lifting of the seat. The piston is hinged at the bottom with the chair base. Therefore, the result achieved is an upward motion of the seat.

On the other hand, to lower the seat another button is to be pressed, then certain solenoid valves will be opened allowing oil flow back into the tank, a point to notice here is that lowering the seat needs no pump action, because the weight of seat with the patient weight are the only forces acting on the seat during the lowering process. There also exists a foot-operated brake that enables the dentist to stop the seat, while being lowered, at any desired position.

The second possible state is changing the back piece inclination, to lower the back piece, a certain button is pressed, upon doing so, certain solenoid valve will become open, and thus allowing oil to flow out of the back piece jack, this will cause the jack to fall in, since the jack is connected to the bottom of the back piece. Its collapse result in increasing the inclination of the back piece, the active force here is the weight component into the back piece, to reverse the mechanism. i.e. to lift the back piece up, an appropriate button is pressed, upon pressing the button, the pump and the concerned solenoid valves are activated causing oil flow into the back piece jack. The jack will expand pushing at the bottom of the back piece and thus resulting in lifting the seat back.[13]

4.5.2 Electric System

It’s the most commonly used in dental unit. It consists of electric motor that runs a set of gears and spindles. To raise the seat the electric motors rotates causing a drive gear to rotate. The drive gear is engaged to a vertical column with teeth, the circular motion of the drive gear is transmitted into linear motion at the column. The

column is fitted under the seat and therefore the motion of the column will cause the seat to move up.

To lower the seat the direction of rotation of the drive gear is reversed and the seat is lowered, for that a DC motor is used with the gears in order to be able to reverse the rotation direction.

The system used for the back piece is not different. Another drive gear or drive spindle can be used and the direction of motion can be changing the direction of rotation of the DC motor.[13]

4.5.3 Voice System

It is the most modern system which controls the all movements of the dental by voice commands by the dentist, which are converted to signals to move the chair.

4.6 Additional Parts

Additional options can be added to the service unit ; to improve the efficiency, flexibility and facility. These options are dental light cure, compressor, junction box, and control foot switch.

4.6.1 Dental Light Cure

Light cure is used to dry the filling after putting in the teeth. The first generation consists of heater, fan to cool it, and reflectors to focus the thermal heat on the filling. Figure 4.9 shows the light cure.

Figure 4.9 Light Cure[18]

Second generation depends on using of light as a heat generator. Since the ultra violet (UV) has high energy that is required to dry fillings. A filter is used at the front of halogen lamp to pass UV only and focus it up on the desired position, and then the UV is translating via fiber optic. Figure 4.10 shows the block diagram of light cure.[13]

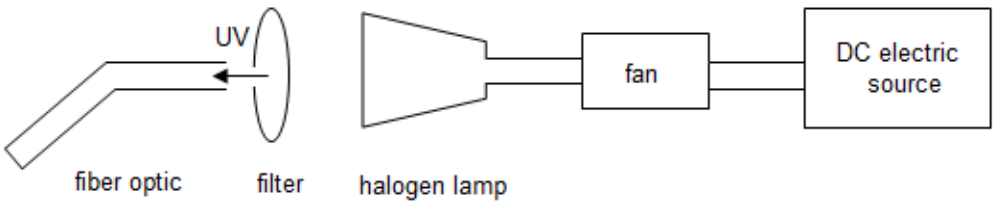

Figure 4.10 Block Diagram of Light Cure[13]

The third generation replaces halogen lamp by light emitting diode which does not need to be cooled so fan is eliminated.

4.6.2 Compressor

A large central air compressor in the clinic 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 outside of the patient treatment area for the safety and conformability reasons. Most dental hand pieces operate on air pressure within (20-80) psi, with a specific pressure recommended for each hand piece. Compressor is shown in figure (4.11).

Figure 4.11Air Compressor[19]

The block diagram of the air compressor is shown in figure 4.12.

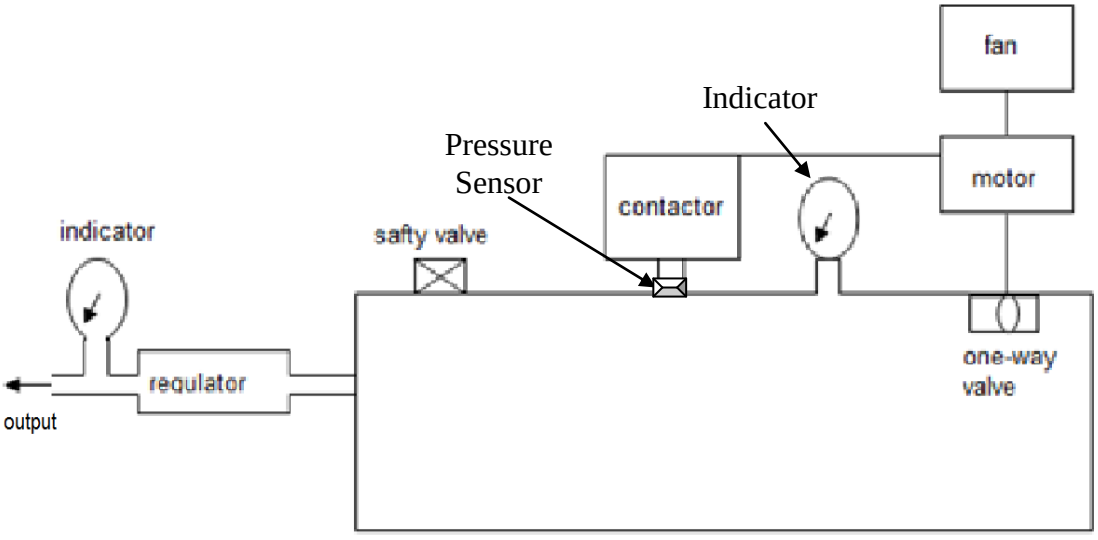

Figure 4.12 Block Diagram of Air Compressor[13]

The air compressor consists of:

1) Fan connected with motor to sip the air, then force it to the tank where the air is collected with a specific pressure.
2) One way valves which are located at the inlet of the compressor to prevent air from returning back.
3) Pressure indicator on the surface of the tank to give an indication about the pressure level in the tank.
4) Contactor (pressure switch) which consists of platen plates, this switch can sense the pressure in the tank and if it reaches to the recommended pressure, the contactor will disconnect the motor; when the tank is full.
5) Safety valve, when the pressure inside the tank exceed allowable limit, safety valve will leak excess air.
6) Regulator and indicator at the outlet of the tank to control the output air pressure.[20]

4.6.3 Junction Box

A junction box contains the main lines and regulation for air, water, and vacuum. Each of these three parameters has its own pipe, filters, and regulators. The junction box is used to provide the spittoon and treatment unit with required amount of water, air and vacuum.[13]

4.6.4 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. Foot control is available in two versions: foot operates by moving a level side way,

and foot control operates by pressing down. The dentists operate all hand pieces through the use of a foot control device.[13]

A valve inside the foot control regulates the hand piece speed, and provides an electric signal that activates air and water flow.[21]

The foot control is operated by light foot pressure applied to any part of the disk as shown in figure (4.13). Some foot controls may also be equipped with a wet/dry toggle switch and a chip blower. The wet/dry toggle switch can shut off the water coolant to the hand pieces without moving the hands from the treatment area.

Figure 4.13 Footswitch[21]

Chapter Five

System Implementation

5.1 Introduction

In the preceding chapters, the complete construction and principle of operation for each part in dental unit were briefly discussed; this will help to achieve the main goal of this project that is to design a portable dental unit which can perform the main tasks as the normal dental unit.

This chapter talks about the complete design of the portable dental unit. The designing has passed through several stages such as: designing an electric and pneumatic block diagrams, purchasing the parts, designing an external frame, studying the specifications of the required parts, and testing.

5.2 Project Conceptual Design

Designing of the portable dental unit consists of two main parts; electric and pneumatic systems. The electrical system talks about all electrical connections which are necessary to supply the electrical components of the system with the required voltage, while the pneumatic system talks about air and water connections required to supply the hand pieces and the bottle with the required pressure.

5.2.1 Electric System Design

As discussed before, the electrical system of the portable dental unit feeds the dental system controllers (switches, valves, and micro-switches) with the required DC voltage. A power supply circuit and the electrical connections of the system will be discussed in this section.

5.2.1.1 Power Supply Circuit Design

As all dental system components operate at 24 Vdc, a complete power supply circuit, shown in Figure 5.1, is designed to provide the dental unit with the required voltage (Vcc = 24Vdc) from the 50Hz, 220Vac line voltage.

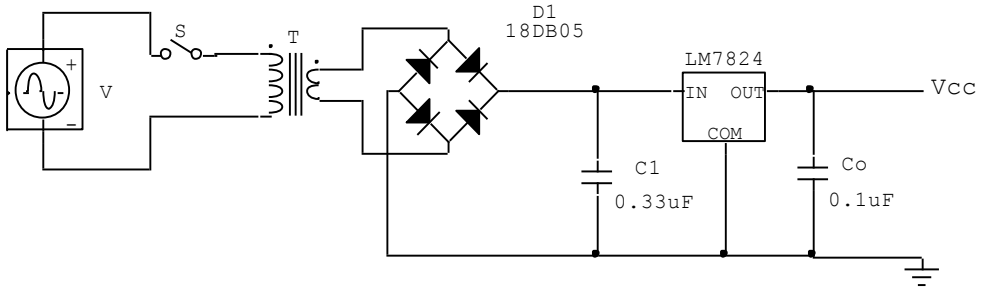

Figure 5.1 Power Supply Circuit

The main switch is implemented to facilitate controlling the system power. The output of the switch and the neutral line are connected to (1:9) step down transformer to decrease the source voltage to 24 Vac. This voltage is converted to pulsating DC by a full-wave rectifier[22]. LM7824 voltage regulator is connected to the output of a filtered regulator and maintains a constant output voltage (24Vdc) despite changes in the input voltage. The capacitors C_1, Co values were chosen according to the regulator datasheet for optimum stability.

5.2.1.2 System Electrical Connection

The DC voltage (Vcc) obtained from the power supply circuit designed in the previous section is connected to the dental system controllers as shown in figure 5.2

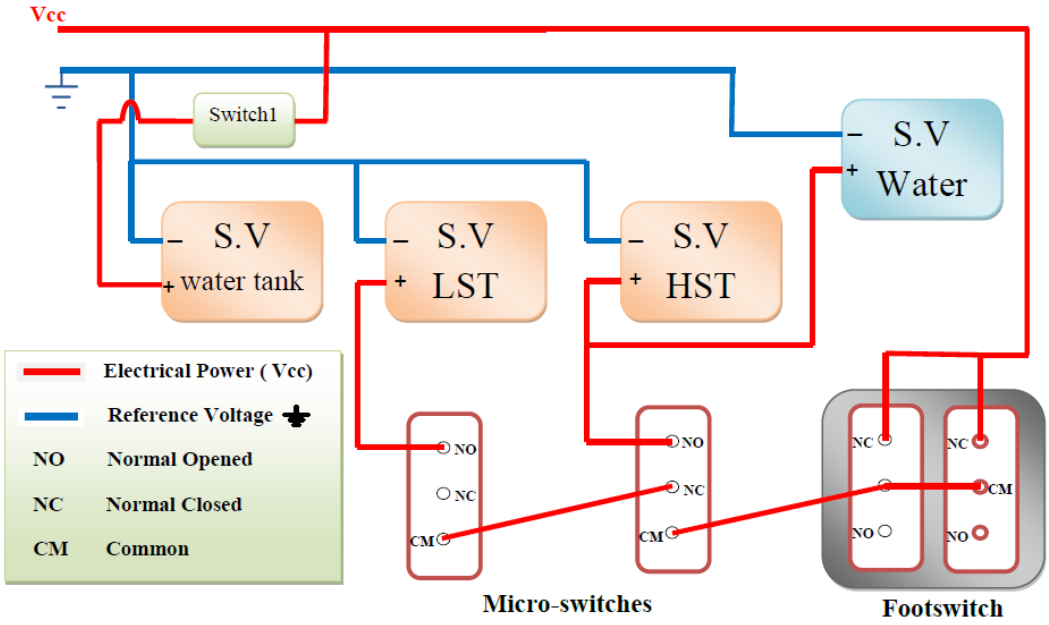

Figure 5.2 Block Diagram of Electric Connections

From the previous figure, Vcc is connected to the positive pin of the water tank's solenoid valve through a switch. The idea of implementing the switch is to control air passing to the water tank. Also Vcc is connected to a normal closed pin in micro-switch which is placed in the footswitch.

Figure 5.3, depicts the micro-switch connections, taking into account that switch positions for a footswitch are always shown with no load (pressure) to the switch, and when the user press on the switch, the switch will have the position indicated by the dashed line.

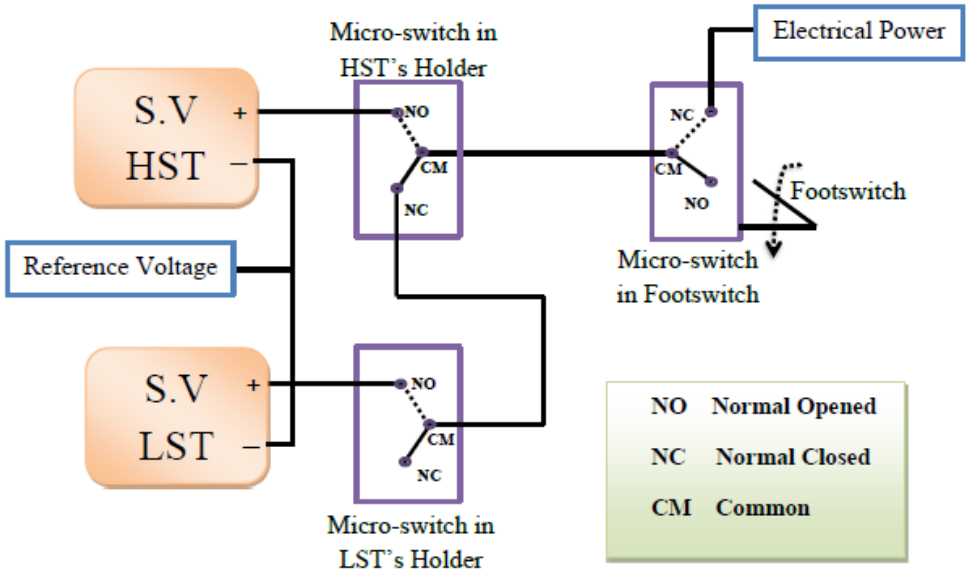

Figure 5.3 Micro-switches Connections

Switch positions for a micro-switch in HST's and LST's holder are always shown when the micro-switch corresponding turbine is fixed on its holder. Hence, when the user pull one of the turbine, the corresponding switch will have the position indicated by the dashed line.

According to the schematic shown in figure 5.3, it is obvious that neither HST nor LST has electrical power when the footswitch is not pressed.

When the user press on the footswitch, electrical power will arrive to HST micro-switch. If the HST is connected to its holder, no electrical power will exist on the HST solenoid valve, and the electrical power arrives LST micro switch. If the user pulls HST, the contact will be made with the NO position of the HST micro-switch. This action will complete the circuit for the HST valve, and no electrical

power will arrive LST micro-switch. Hence if the user pulls LST during this stage it will not be able to work.

If the user pulls LST, when the user press on the footswitch, (and the HST is connected to its holder), the contact will be made with the NO position of the LST micro-switch. This action will complete the circuit for LST valve.

Finally, in order to complete the circuits of the previous connection, all negative pins of solenoid valves are connected to the reference voltage.

5.2.2 Pneumatic System Design

Pneumatic system design consists of two main stages: Air lines connections, and water line connections. These lines are made from plastic tubes.

5.2.2.1 Air Lines Connections

As discussed in chapter three, air lines should be connected to high and low speed turbines, triple syringe, and water tank. As shown in figure 5.4

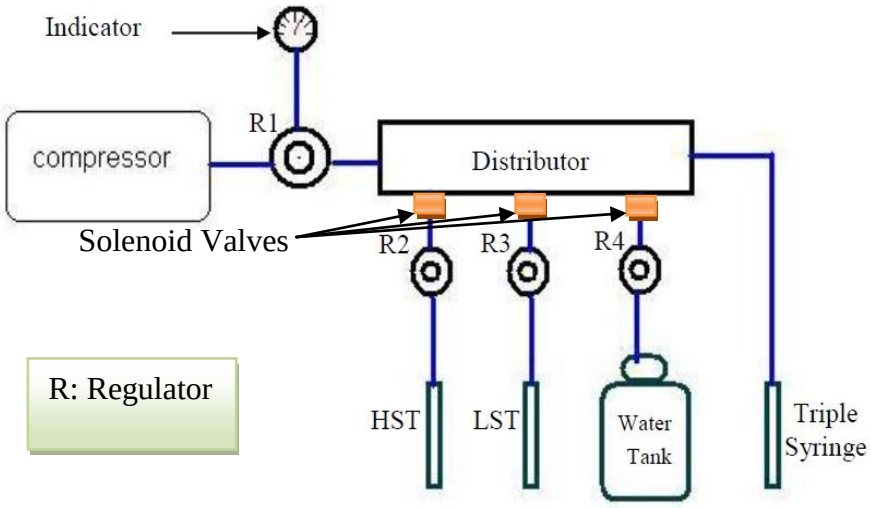

Figure 5.4 Air lines Connections

From the preceding figure:

1. Air is collected from surrounding, and filled into the compressor to give the total output air pressure which should not exceed 7 bar.
2. A regulator R_1, shown in figure 5.5, is placed after the compressor to reduce the pressure to (4.5-5) bar.

Figure 5.5 Regulator[23]

3. The regulated air reaches distributer, which supplies the HST, LST, and water tank solenoid valves shown in figure 5.6. The solenoid valves act an important task in the design; they control the air reaching HST, LST, and water tank, by allowing it to pass into one direction.
4. As shown in figure 5.4, HST, LST, and water tank solenoid valves are connected to the regulators R2, R3, and R4 respectively. These regulators calibrate the pressure value that must be applied to HST, LST, and water tank as follows:

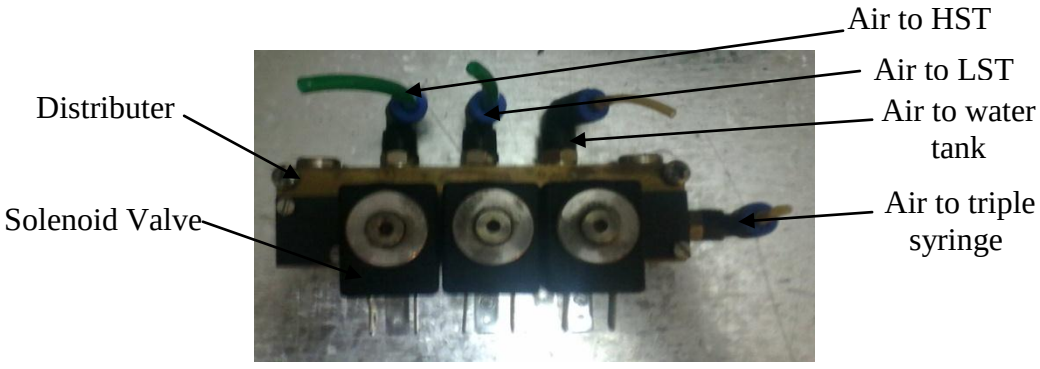

Figure 5.6 Distributer and Solenoid Valves

A) High speed turbine needs (1.8-2.2) bar to rotate in a fixed speed (400,000)rpm.
B) Low speed turbine needs 3.3 bar in order to rotate in required speed (30,000)rpm.
C) Triple syringe operates at any pressure of air in order to get the needed function, whereas water tank needs 1 bar air pressure, to push water to the system.

5.2.2.2 Water Lines Connections

A 1.5 litter water tank, shown in figure 5.7, is used to supply the high speed turbine and triple syringe with water, via a tube connected with a filter at the head.

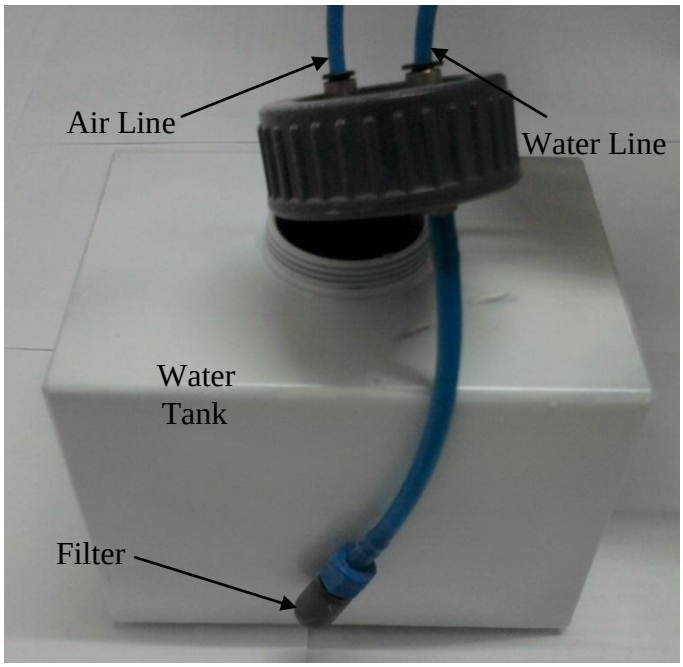

Figure 5.7 Water Tank and Filter

The complete block diagram of the pneumatic system is shown in figure 5.8 From the figure, one can observe the following:

1. A direct water line is connected to the triple syringe without valve because it has a push bottom on the head. Also no regulator needed because it can operate at any air and water pressure.
2. Another water line is connected to the HST, passing through a solenoid valve. A regulator R_5 is placed just before the hand piece to control the pressure of the water.

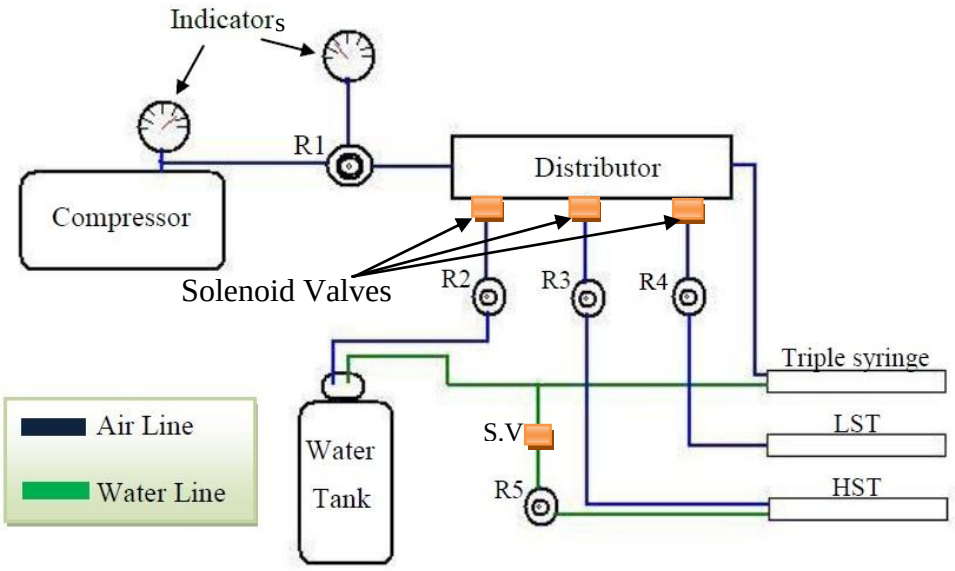

Figure 5.8 Pneumatic System Connections

Figure 5.9 depicts the pneumatic and electric connections of the designed portable dental unit.

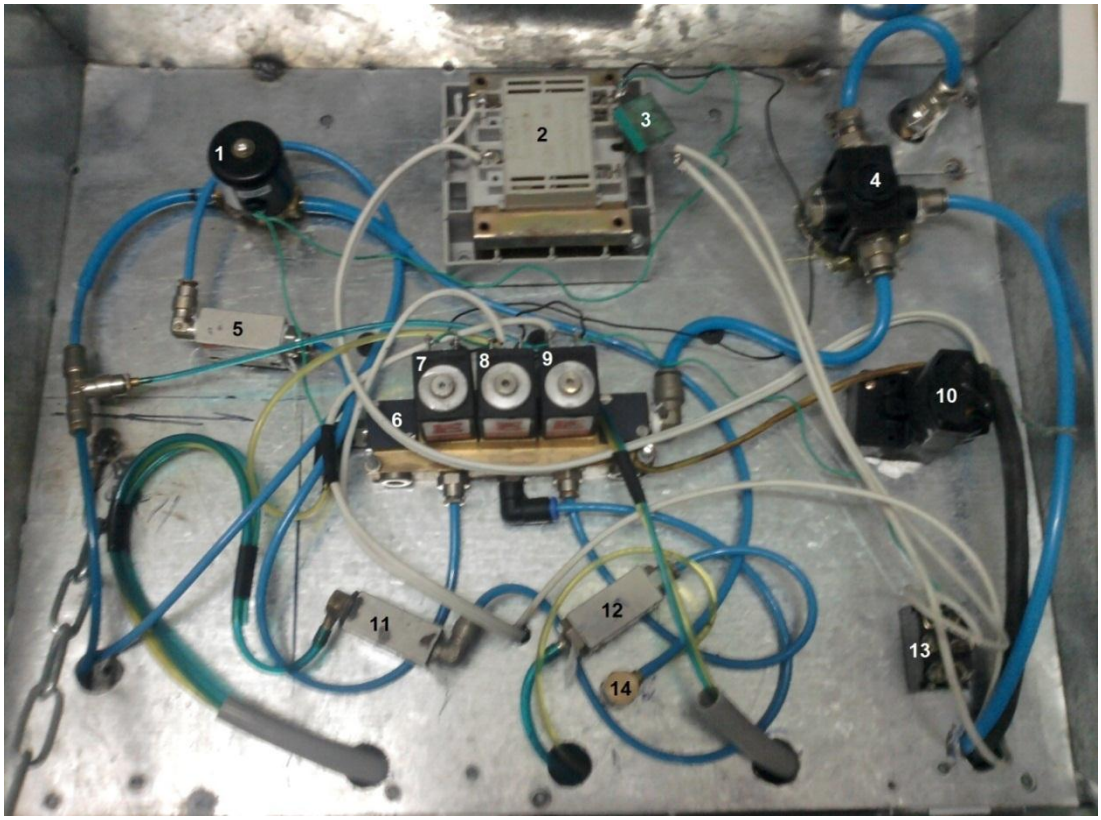

Figure 5.9 The Complete Connections of the System

1. Solenoid valve for water
2. Transformer
3. Bridge diode
4. Main regulator
5. Air regulator for water tank
6. Distributer
7. Air solenoid valve for water tank
8. Air solenoid valve for LST
9. Air solenoid valve for HST
10. Main switch
11. Air regulator for LST
12. Air regulator for HST
13. Switch for SV of water tank
14. Water regulator for HST

5.3 Purchasing the Parts

Because of the high cost of the required parts for the design in Palestine; the parts were purchased from Jordan with suitable cost, taking into account high quality, good efficiency, and long life time features.

5.4 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 steel, to resist the stress and the rust.

The external frame, shown in figure 5.10, has cuboid shape, with dimensions about (45*55*20) cm^3, and about 15 Kg weight. These features allow the user to carry the system easily, perform maintenance when it is needed, and put all needed parts inside it.

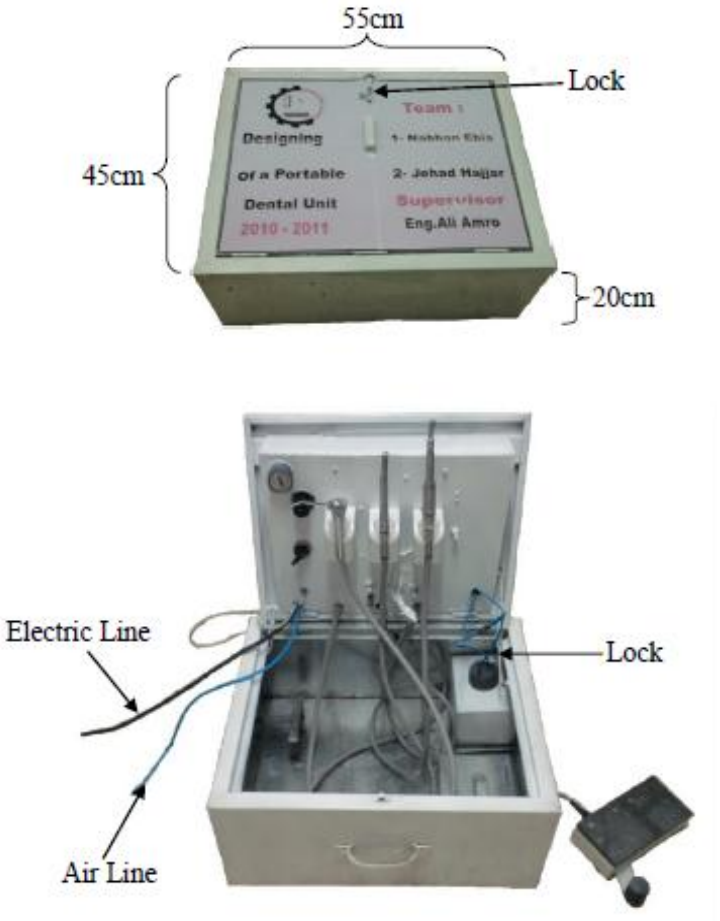

Figure 5.10 External Frame Layout

In order to control opening and closing the system easily, a small lock is put on the upper side, and other locks are put inside the system at the needed positions, as shown in figure 5.10

The internal structure of the system, shown in figure 5.11, is divided into several places; each place is designed to be connected easily with the corresponding part of the project. From the figure, there are special places for fixing water tank, foot switch, and a box for other materials. Hence, all these components will not be defected during carrying the system.

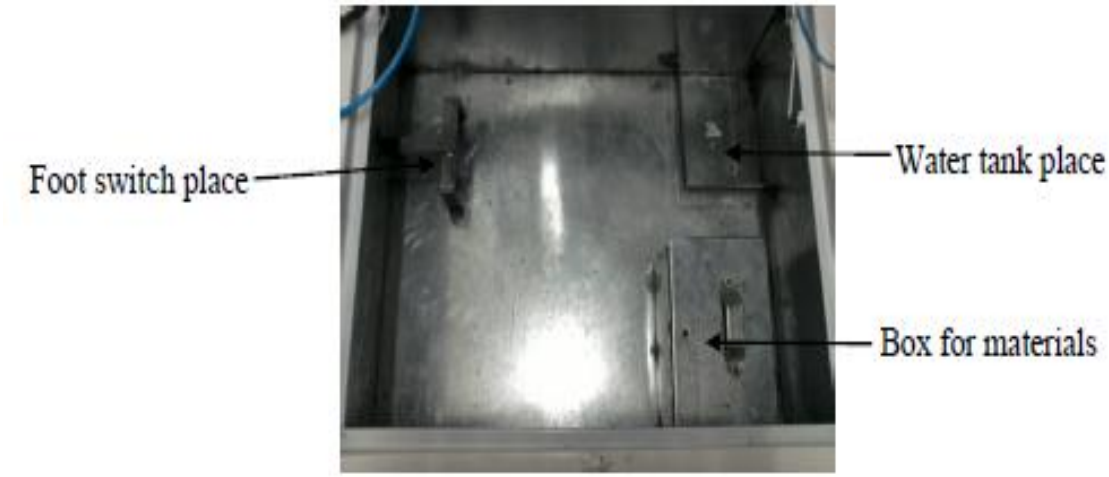

Figure 5.11 Internal Structure of the Frame

The system is painted with white color to avoid corrosion, and to have a beautiful shape.

5.5 Specifications of the Parts

In order to get optimal results from the designed system, portable dental unit components that fulfill the standard specifications were chosen. The main specifications of each part are discussed in this section.

5.5.1 High Speed Turbine

A PANA Air (NSK) high speed turbine, shown in figure 5.12, is chosen in this project as it has the following specifications:

Figure 5.12 High Speed Turbine[24]

1. Rotational speed is (300,000-400,000) rpm.
2. Recommended air pressure 1.8-2.2 bar.
3. Recommended water pressure is 1 bar.
4. Best visibility angulation.
5. Low noise.
6. Two holes.
7. Can be autoclaved.
8. Good quality (Made in Japan).
9. Push bottom.

5.5.2 Low Speed Turbine

A SUPER ME-20B Low speed turbine, shown in figure 5.13, is chosen in this project as it has the following specifications:

Figure 5.13 Low Speed Turbine[24]

1. Rotational speed is (30,000-40,000) rpm.
2. Recommended air pressure 5bar.
3. Best visibility angulation.
4. Low noise.
5. Three holes.
6. Can be autoclaved.
7. Good quality (Made in Japan).

5.5.3 Triple Syringe

A PL_010_A Triple syringe, shown in figure 5.14, is chosen in this project as it has the following specifications:

Figure 5.14 Triple Syringe[24]

1. Can handle 5 bar air pressure.
2. Can handle 1 bar water pressure.
3. Two holes.

4. Durability.
5. Can be autoclaved.
6. Good quality (Made in Japan).

5.5.4 Solenoid Valves

Solenoid valves shown in figure 5.15, are chosen according to the following specifications[24]:

Figure 5.15 Solenoid Valves

1. Small solenoid valve 24Vdc, 5watt.
2. Medium: water, air, and oil.
3. Function type: Normally closed.
4. Body material: Copper.
5. Sealed product.

5.5.5 Water Tank

A water tank, shown in Fig 5.7, is designed to fulfill the main required features; a stainless steel material is chosen to resist the air pressure that will be applied to it, and to resist corrosion. About 1.5 liter (13*12*11 cm^3) volume is chosen to fulfill the portability requirement.

5.5.6 Footswitch

A footswitch with two micro-switches is chosen in this project, the idea of adding the second micro-switch is to work as backup. A relatively heavy base is chosen to give durability during operation.

5.5.7 Distributer

The chosen distributer is made from copper. It can handle 8bar air pressure. It has one input with six outputs; four of them are used to the hand pieces and water tank, while the residual two outputs can be connected to another hand pieces.

Chapter Six

Results and Future Works

6.1 Introduction

After implementing the system hardware in the preceding chapter, the results obtained during the system testing are discussed in this chapter. The main challenges occurred during the design process, and important recommendations are mentioned in this chapter.

6.2 Results

The designed system was tested after connecting all the pneumatic and electric system components. A dummy tooth was used to test the HST and LST efficiencies, the following results were obtained.

1. HST operates with the required speed (300,000-400,000) rpm.
2. LST operates with the required speed (30,000-40,000) rpm and with a required high torque.
3. Triple syringe gives water and air at the needed pressures.

Comparing the resulted values with the required (which are mentioned in the preceding chapters), it is obvious that the system fulfills all the required specifications.

6.3 Challenges

While designing the system, there are many challenges were faced, such as:

1. Not all the required parts for the project were available in the Palestinian market. As a result the main parts were purchased from Jordan.
2. The project components are expensive.
3. Medical books and resources give only rough idea of dental chair system. This pushed us to study the system via training courses and asking the experts in this field, and writing the thesis in our own words.
4. As the system constructed from electrohydraulic subsystems, it wasn't an easy issue to combine them together and get the optimal results that we reached at the end.

6.4 Recommendations

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 LCD which can show some readings about the system, such as: the hand piece which is pulled, temperature, alarms …etc.
3. Adding suction unit into the system.
4. Adding fiber optic to give the light through the hand pieces during operation.
5. In marketing field, this project can be sailed or marketed for many interested companies or hospitals …etc.