

DESIGN OF A UV-C ASSISTED DISINFECTING DEVICE FOR DENTAL EQUIPMENT

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ABSTRACT

Owing to the current situation of the corona outbreak, the need for hygiene reaches its peak. Moreover, the medical field requires more hygiene in comparison to others because they are dealing directly with the patients thus having high chances of getting infected. Dentistry is one such field which also requires proper cleaning and sanitization of equipment's. As the majority of the instruments gets direct contact with the patients therefore, these instrument's need to be adequately sanitized. Generally, the method adopted by dentist in rural and semi-urban areas are cleaning their instruments simply with water or detergent. Liquid disinfection is also used such as alcohols under high pressure, which may damage the instrument. Therefore, there is a need to develop a system for sanitizing the dental equipment's effectively with ease. UV Radiation which is a chemical-free process and highly effective in killing the microbes and quicker than other methods. In this regard, an attempt has been made to develop a sanitizing system to be used by dentists employing ultra-violet (UV-C) rays. The proposed design will resolve the issue of the hectic sterilization process. It will provide medium level sterilization of the dentistry equipment. The ease of use has been taken into consideration, along with the economical cost. The system will provide highly efficient output (complete killing of germs, microbes etc.) in short duration of time, a safety mesh has been provided to avoid human body collision with the UV setup. The proposed system can be a viable solution for easily and effectively cleaning and sanitizing the dental equipment.

Keywords: Disinfection, Sanitization of surgical, Sterilization, UV disinfection, UV Sterilization for dentistry.

1. INTRODUCTION

A dentist's equipment comes in direct contact with the saliva, tongue, or enamel of the tooth of the patient. If the equipment is to be used again for some other patient without proper sanitization it's quite harmful and infectious. The sterilization or disinfection process nowadays is more important because of the communicable diseases we have seen recently such as COVID-19, Hantavirus, Ebola, etc. Communicable diseases are diseases that can be spread from one person to another and cause a large number of people to get sick. They are caused by germs like bacteria, viruses, fungi, parasites, or toxins. The main gap or loophole observed in the existing dentistry disinfectant technique used in the clinics and dental hospitals from the surveys and other internet sources is that they are not that sufficient and progressive. In addition to it, the ease of usability of the techniques is not easy/simple and not that effective. Cleanliness and hygiene are not up to the mark. As seen in the reports and reviews many of the general equipment are being used after cleaning with frequently used disinfectant or most of the time is being used anyways without even cleansing.

Generally, the method adopted for disinfectant techniques incorporates the following steps:

Step1- Cleaning.

Cleaning is a process which is performed before disinfection of the dental instruments or tools. Generally cleaning is performed with water or detergents.

Step2- disinfection.

Disinfection is a process which is done after the cleaning, such that all the microbes, debris, solid dust are removed. Disinfection of the tools is done with the liquid disinfectants.

Other types of Disinfectant models are:

1. Disinfection using steam:
 - i. This is the most used technique in hospitals for disinfecting the surfaces of various tools. This process is done by supplying high saturated steam under pressure.
 - ii. The heat from the steam helps in killing the microorganisms in a easy way.
 - iii. Specific temperatures should be used to kill the microorganisms. The common steam temperatures are 121°C and 132°C.⁶
 - iv. These temperatures are required for a minimal time to kill the bacteria present on the tools or instruments.
2. Chemical vapor disinfection:
 - i. This process uses mixtures of chemicals such as alcohol, formaldehyde, ketone, acetone, that are heated under high pressure.
 - ii. Disinfection occurs at 270°F with 20psi with a minimum time of 10 to 12 minutes following the manufactures instructions.

Ultraviolet (UV) light is a form of light which is invisible to human eye, but it can be used to disinfect the microorganisms.⁷ UV Sanitization provides fast and efficient sterilization also it can be used anywhere and is affordable to all levels of society. It provides an energy-efficient solution. It can be used commercially or for household purposes as it is durable and long-lasting also. UV sanitization works in the following ways:

- I. Unlike the chemical and water disinfection, UV provides a rapid and effective killing of microorganisms through physical process.⁷
- II. When bacteria, viruses are exposed to the wavelengths of UV light, then they are incapable of reproducing and infecting.⁷
- III. In addition, UV also destroy the chemical contaminants such as pesticides and pharmaceuticals through a process called UV-oxidation.⁸

Scientific research has proven UV light has ability to inactivate the power of bacteria, viruses and harmful pathogens.⁹ The present paper will provide a solution for effectively disinfecting the dental equipment's with ease. The paper discusses the problem identified, concept generation, Pugh's matrix, 2D CAD projections, exploded view of the model, bill of material & working of the device, and outcomes. The Pugh matrix helps determine which items or potential solutions are more important or 'better' than others. The Pugh matrix is a tool used to facilitate a disciplined, team-based process for concept generation and selection. Several concepts are evaluated according to their strengths and weaknesses against a reference concept called the datum (base concept).² Definitions used in the matrix are as follows:

Management: Tool management provided in the product to segregate or to provide ease in use.

Portability: The ease and provision provided in the model to locate from one place to another.

User safety: The safety provided in the model to protect the user from any danger or medical hazards.

Energy-efficient: How much power consumption is there in operating the model.

Assisting tasks: Additional assistance provides to enhance the functionality of the product.

Cost: The approximate cost that is going to made the product.

In most of the dental clinics, the equipment is not sterilized often properly, which leads to the infection of the patients. The sterilization of equipment takes time (both chemical and autoclaving techniques that uses pressurized steam). The major limitations and shortcoming of the available methods are time consumed in sterilization, expenses of consumable items i.e. Dettol, Savlon, ethanol, etc. and ease of portability. The present research work presents a solution to the above mentioned limitations.

2. CONCEPT GENERATION

2.1. Mid-mesh UV-c chamber.

In this concept model, the disinfection is supposed to be done with the help of UV-c light using UV lamps. These lamps have to be installed on the sidewalls of the box which will emit light and that light will eventually sterilize the surgical tools which are placed on a mesh-like structure. The structure allows the light to cover up most of the area of the tools.

2.2. Vertical UV-c & bath.

In this concept model, the disinfection is supposed to be done with the help of UV-c light using UV lamps and with liquid disinfectants. Here a cylindrical type of vessel is designed which will hold the tools straight vertically and a liquid mist of disinfectant will be sprayed on it for better disinfection.

2.3. Hanger with mist.

In this concept model, disinfection is done with the help of liquid disinfectants only. Here hangar-like structure will be provided in a cylindrical vessel which will rotate the pole hanger from the bottom with a specified RPM motor and the liquid will be sprayed on the tools so that the tools will get fully covered with it and provide good disinfection result.

2.4. UV-c reflection assisted.

In this concept model, a box is designed with an internally covered polished silver coating which reflects the UV light emitted from the lamps installed on the lid of the box. The tools are placed in a transparent tray for full light exposure. Light will turn on when the lid closes and vice-versa. A drawer is provided at the bottom to store wet wipes or tissues for cleaning purposes.

2.5. Horizontal spin with bath.

In this concept model, the vessel is provided with a liquid disinfectant that will clean the tools when placed in a mould horizontally. The setup will be rotated with the help of a motor. When the tools are partially immersed in the liquid, they will get multiple baths while going in and coming out of the liquid flow.

3. CONCEPT SELECTION USING PUGH'S MATRIX

Table 1 shows the concept selection using pugh matrix. The generated concepts were evaluated on the basis of six factors identified by voluntary survey conducted. Management, portability, safety, energy efficiency and cost. Among the five developed concepts, mid-mesh UVc chamber and UVc reflection assisted concept were found to be most efficient. Therefore, concept number 4 was selected.

Concept No.	Concept name	Management	Portability	Safety	Energy efficient	Task-assisting	Cost	Total
1	Mid-mesh UVc chamber	2	3	4	3	4	4	20
2	Vertical UVc & bath	4	2	2	2	1	2	13
3	Hanger with mist	1	1	1	4	3	4	14
4	UVc reflection assisted	4	4	4	3	5	4	24
5	Horizontal spin with bath	1	3	2	1	3	1	11

Table 1. Pugh's matrix selection (The concepts had been rated according to factors provided to pick the suitable one)

4. DETAILED DESIGN OF COMPONENTS

The following section discusses about the details of design with its dimensions

4.1 Lid with a safety mesh.

The lid of the box is designed in a rectangular shape. Having ($l*b=300*150$ mm) taking the dimensions of the commonly used tools and equipment in consideration with the tool (mouth mirror) having higher dimension is of 6 inch= 152.7mm.³ A safety mesh is provided at the top covering the UV lamps for user safety, because after long period of utilization will heat up the lamps and may be dangerous for the user if left uncovered. The mesh is made up of very thin wires of stainless steel which will not restrict the light from lamp to reach the tools and to provide effective functionality (refer figure 1).

4.2 Transparent tray.

A tray of tough glass is provided in the body case of the box that is used to place the equipment in it for disinfection purpose. The dimensioning of the tray is ($l*b=280*130$ mm) because of the tool sizing 152.7 mm highest dimension in commonly used tools.³ The transparency is decided due to the need of tools to be fully covered in the light so there should be no obstruction of light (refer figure 2).

4.3 Polished silver Mylar coated body-case.

The body case that is provided with reflective silver coating on the inner walls of the box that is used to reflect the UV light inside the box for full spread of light in each and every corner of the box for better performance and to the mark disinfection of the tools and equipment because silver mylar has the highest reflective percentage in all materials.⁴

Here on the lower side of the box a vent is provided for the placement of the drawer which can be used for additional works.

Figure 3 and 4 shows the pin used for joint and body case.

4.4 Drawer.

The drawer of material PVC is provided at the bottom of the box which can be used for additional works associated with cleaning and wiping tasks, like the placement of cotton or disinfectant liquid wet wipes can be place over there for post and preprocess tasks to be done with ease (refer figure 5).

4.5 Manual push power button.

A manually operated power button is provided at the right side of the box which will be helpful for the power operation of turning on and off of the product. It is provided for emergency (in case any sensor stops responding) power off or can be used usually.

An exploded three-dimensional view of the device is illustrated in figure 6.

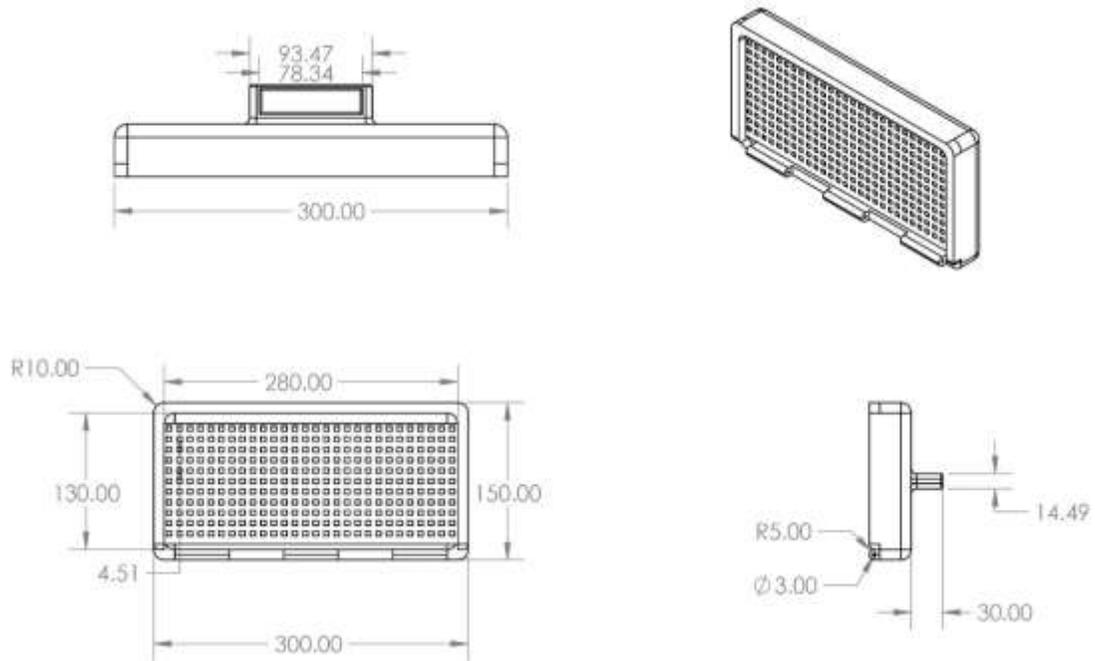


Figure 1.Lid of the box

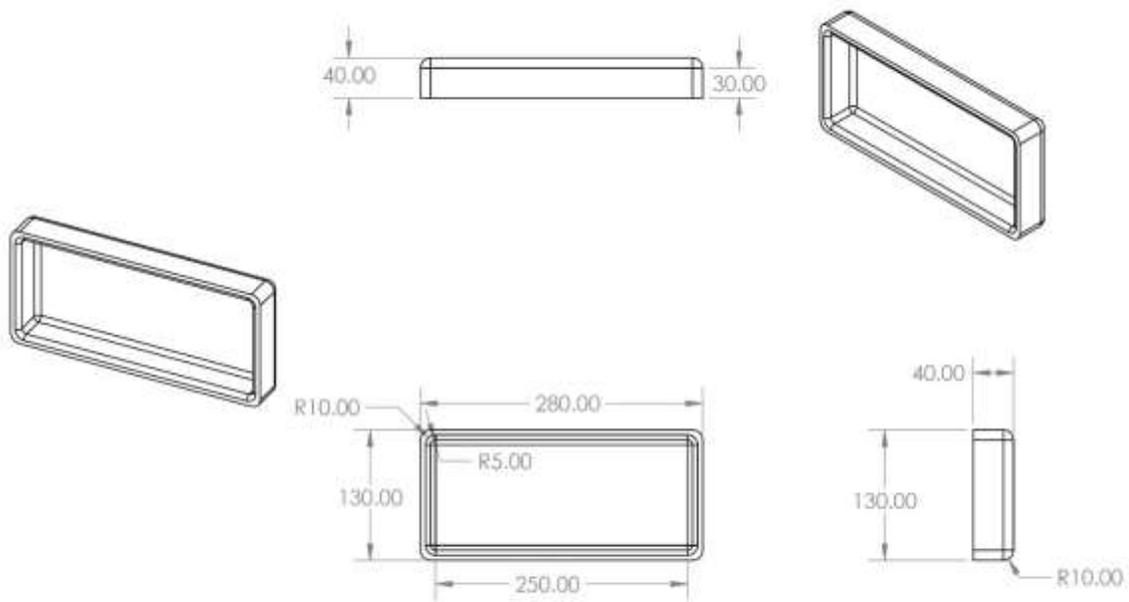


Figure 2.Transparent tool holding tray

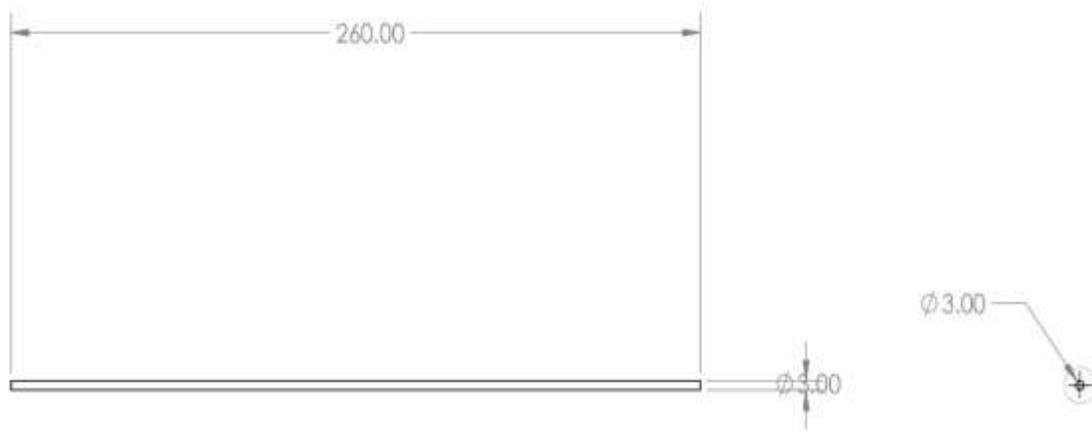


Figure 3.Pin for hinge joint

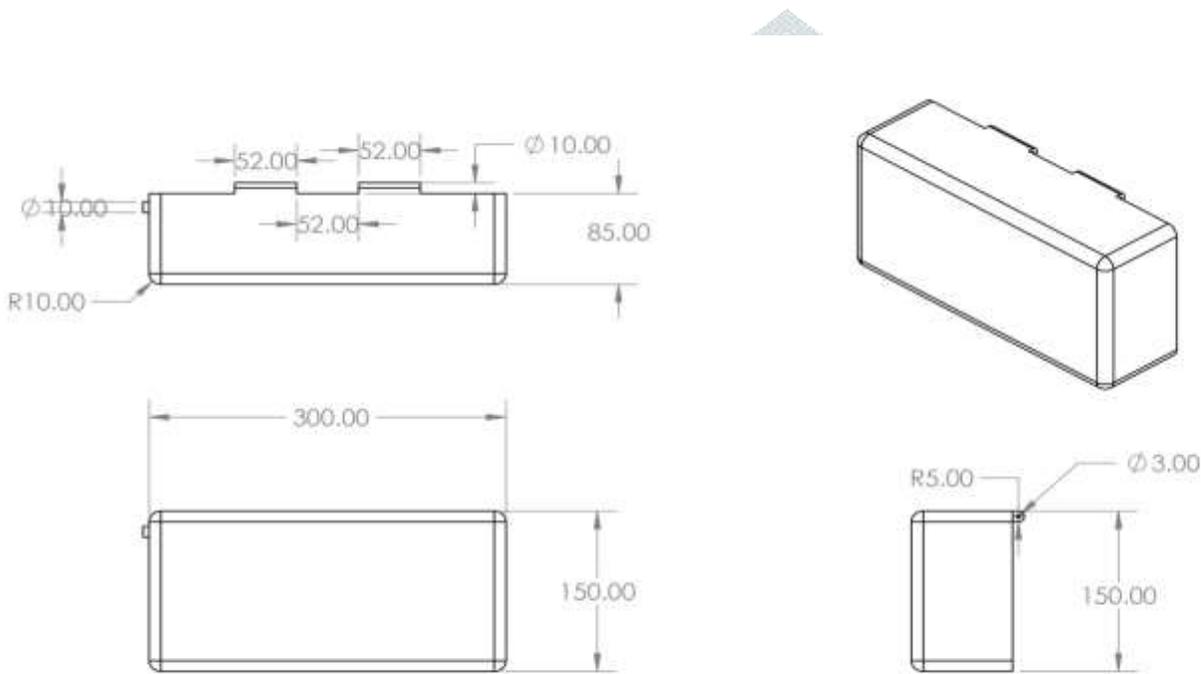


Figure 4.Body case

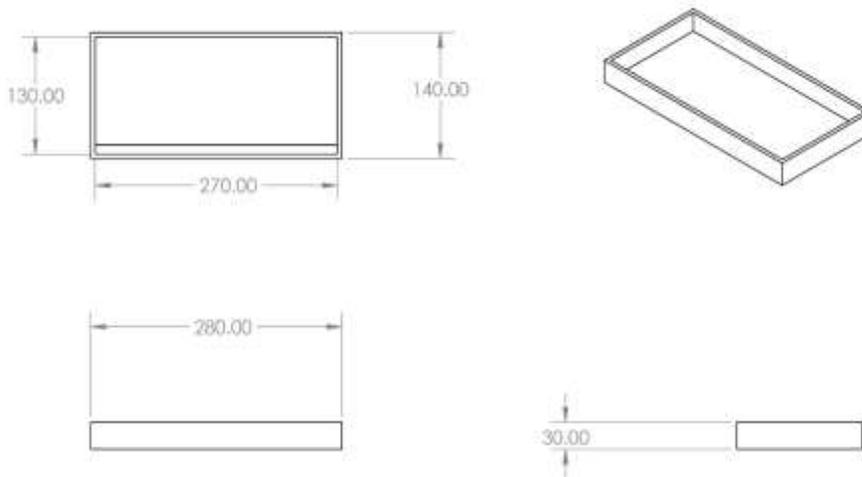


Figure 5. Multipurpose Drawer

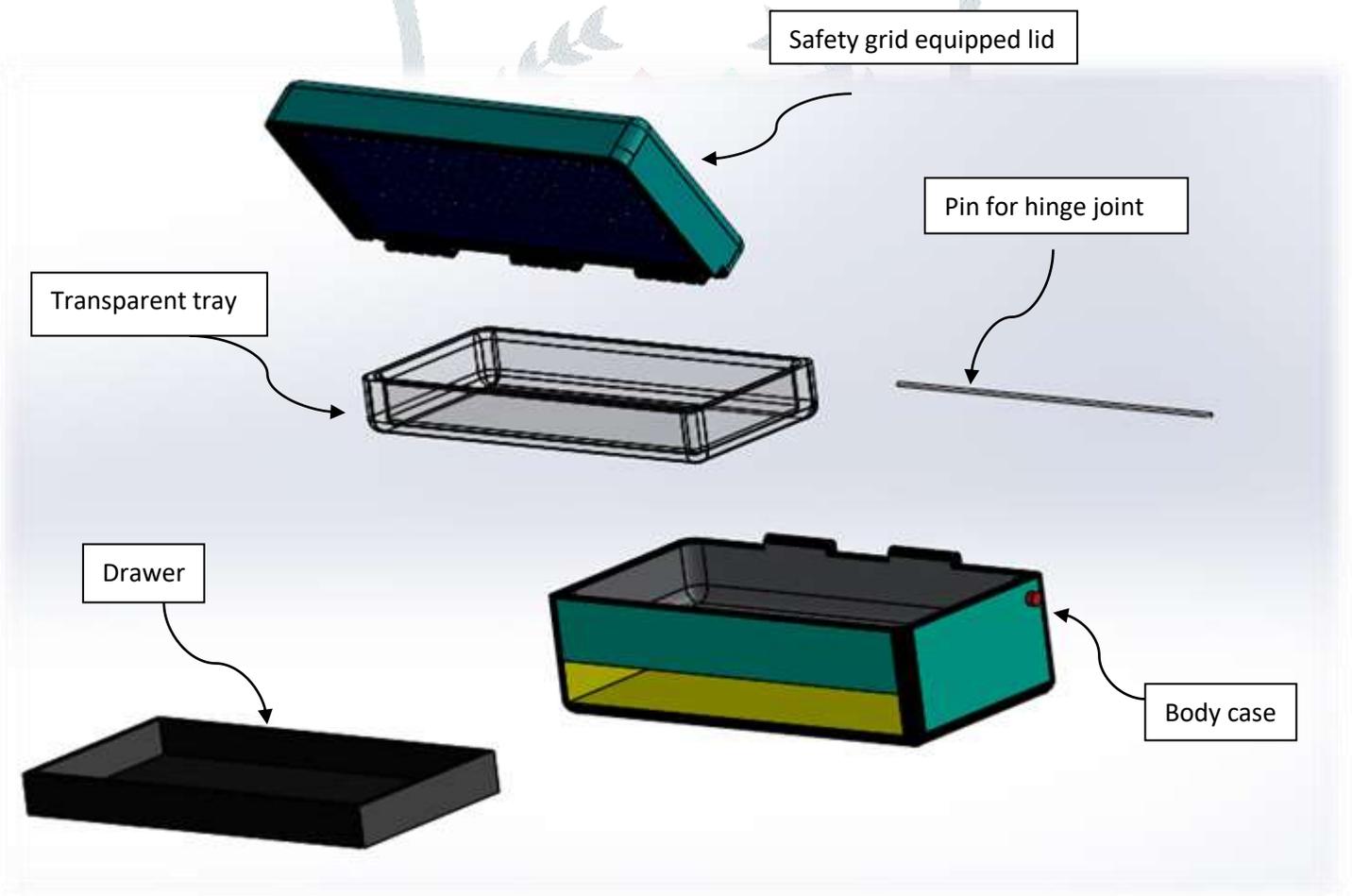


Figure 6 Exploded view of the product (for depiction of all the parts at a time).

Table 2 shows the bill of materials for the proposed design.

Table 2: Bill of material (Depicting the required material and equipment)

S.no.	Component	Material	Quantity	Form
1	Body	Aluminum	2 Kg	Sheet 2.5mm
2	Tray	Glass	~350 gm	moulded
3	Handle	plastic	~150 gm	moulded
4	Drawer	PVC	~300 gm	moulded
5	Mesh/Net	Stainless Steel	350*170 mm	Sheet 1mm
6	Pin	Plain carbon Steel	270 mm*dia 3mm	Rod
7	UV lamps		2 Pcs.	Tubes
8	Cable	copper	2 metres	wire
9	LDR		1 pc.	
10	Spray paint	Plastic paint	2 cans(200ml)	liquid
11	Push button		1 pc.	
12	Body case	silver mylar	1 metre*600 cm	sheet 0.5 mm
13	Assembly	Adhesive glue	100ml	liquid
14	Body	Rubber	~2.5 metre	tape 2mm

5. WORKING PRINCIPLE

The proposed dentistry disinfectant set up consists of the various components as listed below: -

- I. A disinfectant Chamber with reflective silver mylar coating
- II. 8w UV lamp⁵
- III. An equipment (to be disinfected) holding tray
- IV. LDR
- V. A tray outside the chamber (to store cotton/napkin wipes)
- VI. Power supply

The working of the setup is simple but effective. The disinfectant chamber has an equipment holding tray at the center of its base, where the equipment to be disinfected is placed. The UV lamps are fitted on the upper lid of the chamber, so as the UV rays can directly fall on the equipment placed in the tray. The disinfectant chamber is also equipped with a LDR, whose role is to complete or break the circuit of power supply to the UV lamps. The LDR will complete the circuit between power supply and UV lamps when the upper lid of the disinfectant chamber is closed. And it will break the circuit when the upper lid of the disinfectant chamber is open and shut the UV lamps. So, when power is supplied to the disinfectant chamber and the upper lid of the disinfectant chamber is closed, the circuit is completed and the UV lamp starts working. The UV rays of the UV lamps are directed towards the equipment to be disinfected placed in the equipment holding tray. The equipment is left in direct contact with UV rays in the disinfectant chamber for 10 minutes. The UV radiation kills all kinds of viruses and germs present on the equipment and make them safe for further use. After the process is done, when upper lid of the disinfectant chamber is opened, the LDR breaks the circuit between power supply and the UV lamps. The disinfected equipment can be taken out by holding it with napkins provided at the outside of chamber in a tray.

The use of the dentistry disinfectant set up is quite easy that anyone could operate it. It is less time consuming and fully optimized.

Step by step instructions to use: -

1. Place the equipment to be disinfected in the equipment holding tray.
2. Close the upper lid of the disinfectant chamber.
3. Let the equipment to be disinfected by UV rays.
4. Open the upper lid of the disinfectant chamber.
5. Take out the disinfected equipment from the disinfectant chamber by holding it with napkin to prevent contamination.
6. The provision to keep wipes/napkins is provided at the bottom of the chamber i.e. multipurpose drawer.

6. CONCLUSION

A UV-C assisted disinfecting device for dental equipment is designed. The proposed design incorporates ultraviolet lamps and a focusing arrangement to expose all the surfaces of the dental equipment thereby increasing the effectiveness of the device. A storing section is also provided to keep the equipment after disinfecting. Pugh matrix was used to evaluate the conceptual designs. Moreover, a comparative analysis was also performed to evaluate the proposed design with the existing methods for disinfecting of dental equipment. The proposed design can be utilized for effectively and quickly sanitizing the equipment with ease.

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