MODERN MEDICINE AND PRACTICE
https://inovatus.es/index.php/ejmmp

EUROPEAN JOURNAL OF MODERN MEDICINE AND PRACTICE
Vol. 4 No. 7 (Jul - 2024) EJMMP ISSN: 2795-921X

EXPERIMENTAL BASED STATISTICAL ANALYSIS FOR DENTAL CHAIR FAILURES

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Abstract: With the improvement of people's living standards and the enhancement of oral health awareness, oral health has been paid more and more attention. The dental clinic of most domestic hospitals is often overcrowded, and the number of patients treated every day is much higher than in some foreign hospitals. The dental unit is a piece of essential medical equipment in the clinic. The need to improve the dental unit, as the dental chair is an important vital tool in modern dentistry. The purpose of this research is to provide therapeutic solutions, to discuss the main common malfunctions and the development of the dental unit, and to find the most appropriate solutions available to it. In this project, the hand piece was developed and the user's performance was improved by developing lighting. A dental unit malfunction survey was conducted and a dentists requirements survey was conducted that will enhance the unit's performance. Collected from surveys and found the most common malfunctions. The lighting unit was chosen for development. Most of the questionnaire items could affect the overall satisfaction with the dental unit chair. Additionally, because the design and appearance quality, maintenance, and overall satisfaction with the water fountain and cuspidor may have the greatest impact on the overall satisfaction with the dental unit chair, the improvement of these elements may bring about the enhancement of the overall satisfaction.

Introduction:

Dental chairs are a vital tool in modern dentistry. Their design paved the way for further improvement in dental treatment. The developments, there are many problems facing dental chair users, Since the twentieth century, the design of the dental chair has evolved continuously and turned from manual-operated mechanisms to an automated mechanism recently. In dental clinics, it is important to have the quality of lighting that helps illuminate the patient's mouth to clean and other procedures that help the dentist's work. [1] the use of a dental unit chair is essential for the diagnosis and treatment of patients. Dentists spend most of their office hours in the dental unit chair space for patient care. In addition to dentists, patients and dental hygienists also use the dental unit chair. The dental unit chair consists of the following components: the light, patient seat, foot controller, water fountain and cuspidor, monitor, bracket table and controller, and dentist chair (Figure1-1).[2]



Figure 1.1. Dental unit chair system. (**a**) Light, (**b**) patient seat, (**c**) foot controller, (**d**) water fountain and cuspidor, (**e**) monitor, and (**f**) bracket table and controller.[2]

1.2 Classifications of dental unit malfunction

- **Electric**

Include malfunctions like : wire of power in junction unit, ,motor for up-down in box unit, motor backrest returned or recline backrest in box unit, cable of power card in box unit, operation light is not shine or meets other problem in light unit, hot water cup cannot heat up or the water temperature is too high, ,curing light lamp is off in light unit, ,coils of air generator in dental compressor, ,there is no electricity in the unit, ,power regulator for scalar problem in frequency in dentists tray, ,treatment machine set a dysfunction, ,the high and low suction cannot work, the low suction have little power after a period time using and micro switch for scalar hand piece,

- **Mechanical**

Include malfunctions like : Doctor's chair or assistant chair, ,converter in junction unit, ,filters of water in junction unit, ,pressure of regulator in junction unit, ,main switch in junction unit, ,head for back rest, ,adjustments for head of back rest, ,distributor solenoid valve in dentists tray, ,screw for solenoid valve in dentist's tray, ,membrane (diagram for solenoid) in dentist's tray, ,distributer for air in dentist's tray, distributer for water in dentists tray, valve for instrument of water hand piece or angle for air motor, 6%,valve for instrument of water for turbine, valve for scalar of water, gage for air adjustment, adjustment for tray air, adjustment for tray water, hole for hose of the arm, hinger for turbine (valve) in dentists tray, finger for rest of turbine in dentists tray ,base for turbine or angle or scalar in dentists tray, a crack occurs tray in the hose or tube which transfer air from compressor to the hinger in dentists tray, A crack in tube of air for triple syringe, A crack in tube of water of triple syringe, control or adjustment press water in dentists tray, control or adjustment press air in dentists tray, ,closed of syringe in dentists tray, scaler cannot work normally, during the hand piece operating, the hydrosphere meet some problem, waste block the pipeline, no water for gargling in pipeline, leaking pipes leakage in pipeline, ,pipeline interface is not tight or is a litter loose, ,electromagnets valve problem, ,water bottle burst, ,water tube in bottle have blocked, Dental air compressor valve air filter regulator pressure, ,Thread BSp pneumatic air compressor pressure regulator, ,Tube connection to turbine, ,Ac single phase oil free dental air generator compressor, no water in unit in compressor, ,no air in unit, ,the lack of air in the modules, absence of water in the modules, ,the hand piece comes out some water drops after finishing work with it, no air in the syringe, and no water in the syringe,

- **Electronic: - Include malfunctions like:** Fuse in junction unit, and bottom for control panel,

Logical: - Include malfunctions like: Circuit board problem, card control supply in box unit, card control supply of relay, and card of control panel.

Literature review

Alshorman et al., 2002 [1], found Dental unit water lines harbor considerable amounts of bacteria, they derived from the biofilm on their inner surfaces. The authors Improved the Unit Design Independent Systems by using Bottled Water, these systems have been available as optional accessories to the dental unit for many years. Their main advantage is they bypass the municipal water supply, drawing fluids from the reservoir bottle(s) holding either sterile or distilled water or a dilute aqueous biocide solution. However, use of such systems alone cannot reliably improve the quality of treatment water, as biofilms will form within the bottles unless carefully managed. Regular cleaning of the inside of the bottles and flushing of the water lines with a disinfectant is required to reduce adherent microbial biofilms. The rustle showed the only way to lower bacterial counts in the DUWL to acceptable levels is to eliminate the biofilm inside the tubes permanently and prevent biofilm formation in new units.

Coleman1et al., 2008, [2] studied the problem of the DUAL output waters are often contaminated by high densities of microorganisms, heterotrophic aerobic Gram-negative environmental bacteria. The authors reported how practical developments and innovations in specific areas can contribute to effective DUWL biofilm control. These included the use of effective DUWL treatment agents, improvements to DCU supply water quality, DCU design changes. These solutions are safe for patients and staff, and which do not cause deterioration of DCU components following prolonged use.

O'Donnell et al., 2011[3], studied DUWLs are universally prone to microbial biofilm contamination seeded predominantly from microorganisms in supply water. Consequently, DUWL output water invariably becomes contaminated by high densities of microorganisms as in (figure 2), they authors propose a variety of approaches, many of them unsuccessful, to control DUWL biofilm. They found that advances in biofilm science, DUWL chemical biofilm treatment agents, DCU design, water treatment supply, and development of automated DUWL biofilm control systems offer effective long-term solutions for DUWL biofilm control.

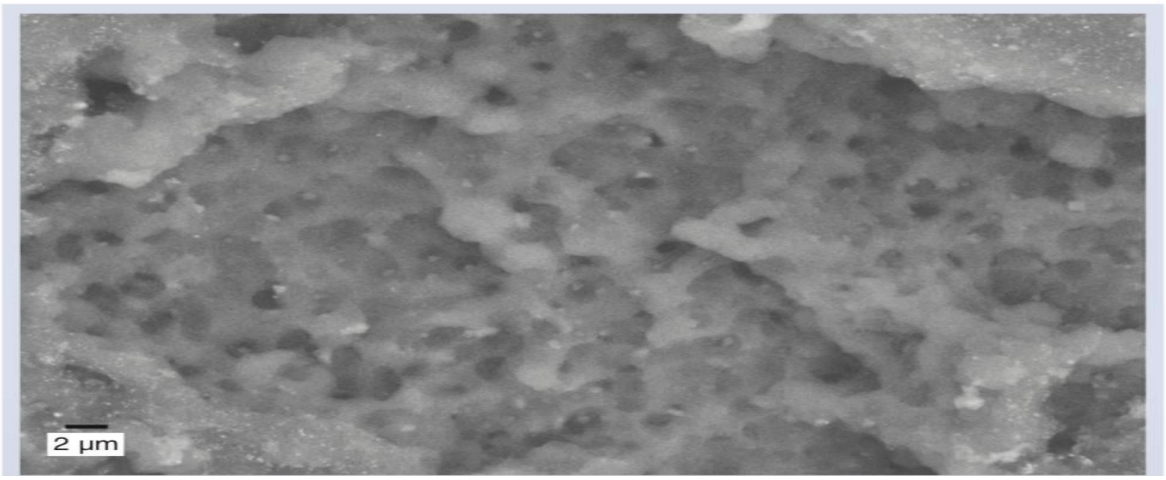


Figure (2.1). Electron micrograph of 4-week-old biofilm formed on the internal surface of a dental unit waterline taken from a dental chair unit supplied with potable quality mains water. The biofilm reached a thickness of 30 µm after 4 weeks growth.

Danijela et al., 2011[4], studied design requirements for (therapeutic) dental chairs, survey methods, and observing, photographing and recording the realistic situations and needs of dental therapists in their offices. The authors suggest that the therapeutic chair should be designed in such a way as to enable maximum

freedom of movement with as few unnecessary movements as possible and that educating users about possible solution applications is essential. They found that the paper provides guidelines for further multidisciplinary research as in (figure 3), thus making an important contribution to maintaining and improving dentists' health. The new findings allow entry into the fields of science and applied research at the European and global level, helping the timber sector.

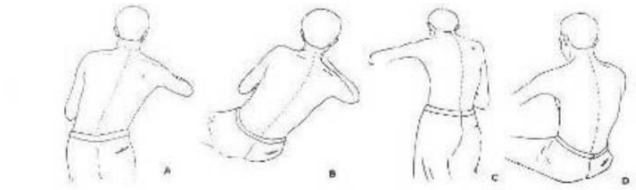


Figure2.2A) by standing "directly" over the lying patient; B) by sitting "directly" over the lying patient; C) by standillbvtmmung "indirectly " over lying patent; D) by sitting"indirectily" over the lying patient . (Njemirovskij 1971)

Nilchian et al., 2013 [5], found that portable dental units allow the underprivileged and the elderly to get the care they deserve in more areas. The researchers conducted semi-structured interviews by one person, seven dentists, two specialists, and 11 final year dental students who participated in their cosmetic dental units in Isfahan, Iran. The qualitative research method was chosen firstly because of the paucity of readily available information on the units and secondly because of the specialization. They find portable units very useful for community outreach programs, with two subcategories of serviceability and oral health access. Other factors mentioned were the efficiency of the portable dental unit and factors affecting each individual patient.

Pareek et al., 2013[6], calculated water flowing down the biofilm coated waterlines will contribute to microbial load in the water as it exits the tubing. Frequent periods of water stagnation in DUWLs and the properties of the plastics used in DUWLs construction can promote the attachment and colonization of biofilm forming microorganisms Three disinfectants were diluted with distilled water to achieve 1: 100, 1: dilution and their effect in reducing the microbial contamination in the dental unit waterlines was studied. The result of this research the output water from the disinfected dental chair units showed a high reduction in bacterial.

Wirthlin 2015[7], the authors' research demonstrated that simply flushing the DUWLs and leaving them dry when not in use is an ineffective and inconsistent method of treating the contamination issue. Alkaline peroxide treatments require no more time for treatment than simply flushing, but have been found to be equally ineffective and inconsistent in reducing contamination and were among the more expensive treatment options available, the chlorine dioxide products such as DioxiClear and MicroCLEAR were the most effective in treating the contamination, with MicroCLEAR consistently reducing bacterial counts to 0 after initial shock treatment.

CATALDI et al., 2017 [8], collected systematic studies of the incoming and outgoing dental unit, focusing on the problem of wastewater pollution and its regulations. A systematic review of the literature for the past 17 years on the subject of the dental unit was conducted. Italian and English were the two languages chosen for the research papers. Studies in PubMed, Medline and Cochrane were searched, with respect to the inclusion criteria. Investigation and analysis of the two set of papers revealed that there were many scientific information and studies on contamination of incoming dental unit water, in contrast to not much in the literature on dental unit wastewater. The authors conclude that dental unit wastewater is a problem that the scientific community underestimates, with the exception of dental amalgam waster.

Puviarasi et al., 2017 [9], sometimes the chair will not function properly due to piston rust and over weighted patient and the dentist may have pain in the legs due to continuous operation of the chair, this project describes the design of a smart, motorized, voice controlled dental chair, This system was designed and developed to avoid wasting the energy and time of the doctor.

Smith et al., 2017[10], the internal mechanisms of dental handpieces contain narrow lumens(0·8-2·3mm) which can impede the removal of air and ingress of saturated steam required to achieve sterilization conditions, Non-vacuum downward/gravity displacement, type-N steam sterilizers are an unreliable method for sterilization of dental handpieces in general dental practice. The handpiece most likely to fail sterilization is the type most frequently used for surgical interventions.

Cuny 2017 [11], control practices regarding dental unit waterline (DUWL) treatment, biofilm formation in DUWL tubing, minimum standards for safety, and various methods for DUWL treatment, Crosstex International manufactures a wide array of infection prevention and control products for the health care industry.

Bruyne et al., 2019 [12], this study investigated the influence of different stool types on muscle activity and lumbar posture, The latter stool comprises a seat pan consisting of a horizontal rear part for the pelvis and an inclinable sloping down front part for the upper legs, with a vertically and horizontally adjustable back rest, To maintain neutral posture during dental screening, the Gropes is considered the most suitable design for the tasks undertaken.

Albertin 2020[13], found Bracket bonding failures have multiple causes, one of which is the light-curing failures of the adhesive (5). Usually, bonding failures occur at one of the two bonding interfaces: between the adhesive and the enamel or between the adhesive and the bracket base the present investigation demonstrated that there is no significant difference between the effects of the two LED lights tested on direct bonding of the orthodontic brackets during the first 6 months of treatment. No previous attempt analyzing the clinical performance of high-intensity LED light-curing units has been identified in the literature.

Fajrin et al., 2020 [14], studied design an electric dental chair using a pneumatic as an up and down drive and a linear actuator as a back drive for upright and lying down position using a remote control. As well as dental light as a light source for dental examination. The authors used a SHARP 2Y0A21 infrared sensor as a switch for four conditions, namely low, medium, high, and off. The results of testing showed that remote can function as planned with an accuracy value of 100%, pneumatic can lift loads up to 120 kg with a load resistance error of 5 minutes at a height of 25 cm by 0.1% and at a height of 15 cm by 25%. In the actuator voltage testing, the average value of the voltage when it dropped was 11.80 VDC and when it rose was 11.20 VDC, the lowest error was 0.6% and the highest error was 3.5%. The light intensity testing obtained an average result at low condition of 2032 lux, in medium condition of 8435 lux, and in high condition of 20280. In testing, the SHARP 2Y0A21 sensor function worked well with an accuracy value of 100%.

Keunbada Son et al., 2021 [15], studied survey users' satisfaction with a dental unit chair in order to highlight the elements affecting the dentist's satisfaction. The authors placed the questionnaire items into seven constituent components as a dental unit, including, patient seat, foot control device, water fountain and spittoon, screen, easel table and console, and dental chair as in (figure 1). Using these questionnaire items, a pilot experiment was conducted for Amed and Winter. Check the reliability of the alpha scale used. The Bartlett test for sphericity, the Kaiser-Meyer-Olkin (KMO) scale, and analysis of factors that were factors that would form a questionnaire were appropriate for the survey. They found most of the questionnaire items could affect the overall satisfaction with the dental unit chair. Additionally, because the design and appearance quality, maintenance, and overall satisfaction with the water fountain and cuspidor

may have the greatest impact on the overall satisfaction with the dental unit chair, the improvement of these elements may bring about the enhancement of the overall satisfaction Occupational nonspecific granulomatous osteomyelitis of third metacarpal bone as a sequel to percutaneous injury.

Crawford MA et al., 2020 [16] , found possibility of mechanically to overcome the retracting bacteria from the mouth into the water line used to provide a spray of water to cool high-speed burs during treatments. This was demonstrated by results obtained after clinical use and after use in simulated, worst case test conditions using a red tempera indicator solution and indicator bacteria. In addition, the dental air turbine gains torque by applying compressed air to the rotor; the rotor spins for a while after air outflow because of the inertial force [8, 9]. This freewheeling creates negative pressure within the turbine, resulting in uptake of contaminants (e.g. saliva and blood), and the so-called suckback effect.

Jin et al., 2022 [17], found A water leakage problem is one of the most common malfunctions of the dental unit. At the initial installation stage, the manufacture equipped each unit with a water heater to heat the internal waterways. The structure of the heater was simple, the appearance of the heater was made of stainless steel, it was supplied by 24V power, and the material of the inlet and outlet water pipes was brittle. Therefore, it was common to see cracks that can lead to water leakage after 2-3 years of use. This phenomenon had a high failure rate. Engineers assessed the situation and determined that the water leakage problem was caused by unapproved material supplied by the manufacturer. So the engineer comprehensively checked all the pipes inside all the dental chairs, recorded the pipe diameter and length details, purchased approved water pipes, and replaced the water pipes at potential leakage risk one by one to prevent the occurrence,. These solutions reduced the failure rate for dental units and improved they found understanding of the importance of using and maintaining the equipment correct.

Methods

Cause Analysis and Solution of Common Failures

Two surveys will be performed to collect the data that represent the common malfunctions and the requirements to improve the performance of the dentist and reduce the effort he pays during his work. The first survey includes a direct contact with a number of biomedical and technician engineers that deals with the problems of the dental units. The information that are collected from them focuses on the type of fault, Location of the fault, number of times, Possible solution, Failure percent and cost of each one. The collected data classified into mechanical, electrical, electronically and programmatically.

Elements of the Survey of Dental Unit Chair User Satisfaction

The second survey consists of asking the dentists about the requirements they would suggest improving their performance. An online questioner form will be produced and separate it between them to collect the data.

Results

The first survey was conducted for the dentist’s requirements about the dental chair. Six questions were asked about the dental chair, and 25 responses were obtained, the second survey about the dental chair lighting unit. Four questions we asked the dentist about the problems he suffers from and how they can be developed. 30 responses were obtained by dentists.

Elements of the Survey of Dental Unit Chair User Satisfaction results:

Do you need to adjust your light continually, your setup is likely not optimal?

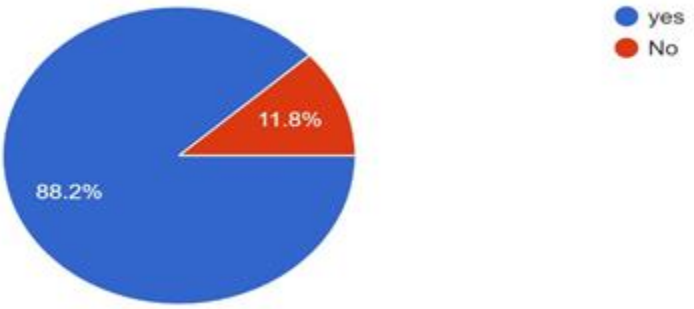


Figure (4.1) 88.2% of the dentists answered that they need to constantly adjust the lights, and 11.8% answered that they do not need to do so.

Have you ever faced a leaking in the hydraulic fluid?

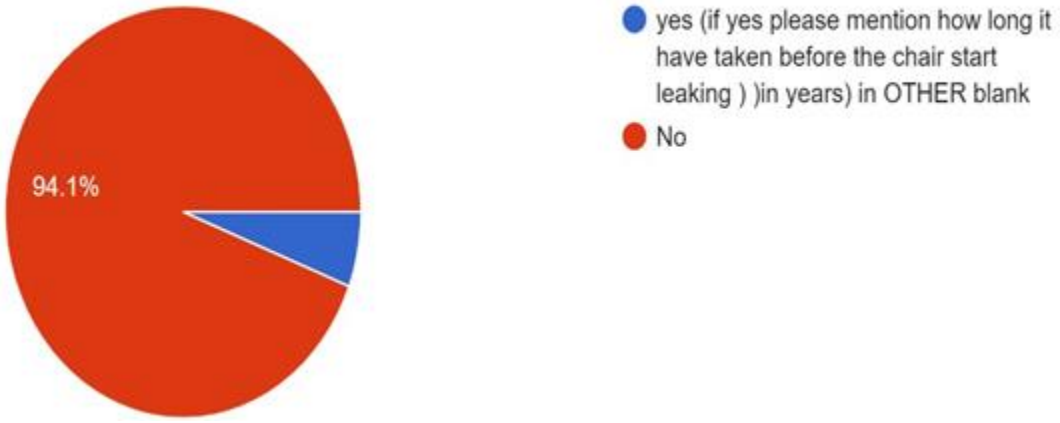


Figure (4.2) 94.1% of the dentists answered that they encountered a leak in the hydraulic fluid.

Is there a FAILING UPHOLSTERY and FOAM

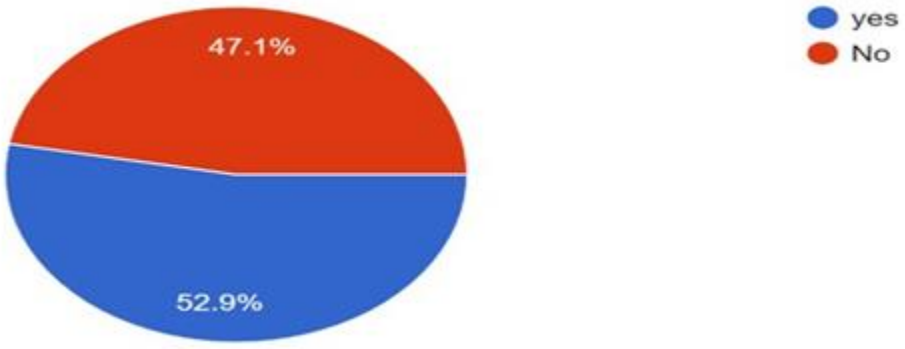


Figure (4.3) 58.8% of the dentists answered that they yes to this question and 41.2% answered no.

Is the chair base worn?

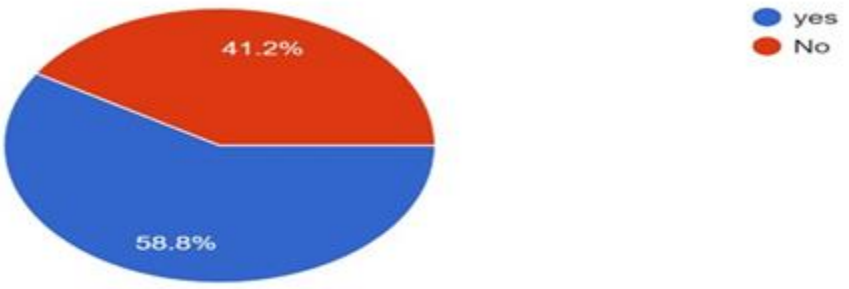


Figure (4.4) the chair base is worn out, according to 58% of dentists.

Newer chairs sport the newest and most up-to-date bacteria-resistant materials.

Do you think you need this new feature?

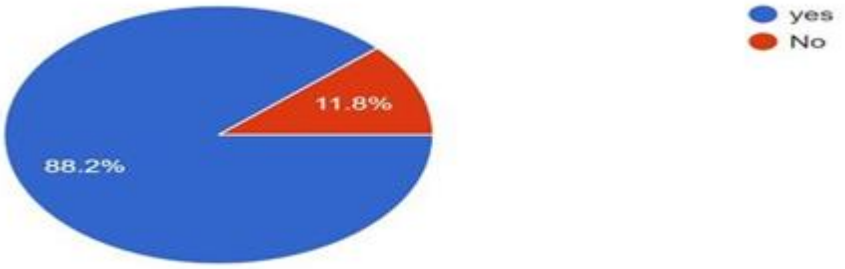


Figure (4.5) most dentists need materials that resist bacteria in the dental chair to avoid infection.

Do you think Doctor's chair or assistant chair need to be improved?



Figure (4.6) dentists confirmed that the dental chair needs to be improved and developed.

Elements of the Survey of Dental Lighting Unit Chair.

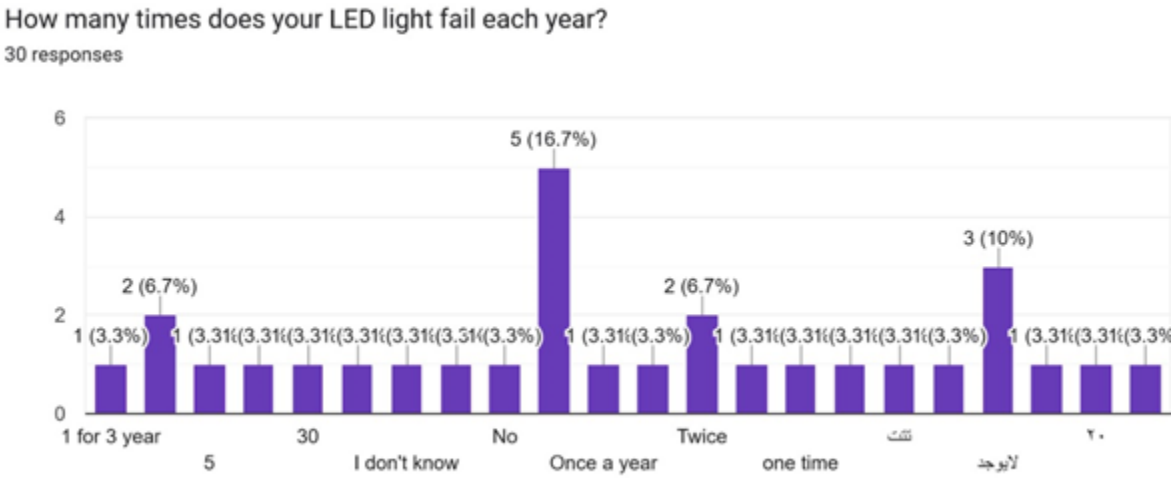


Figure (4.7) the dentists answered about the duration of the failure of the lighting, most of which was a year and a half, so we worked on the lighting to help the dentist reduce the number of malfunctions that occur in the device.

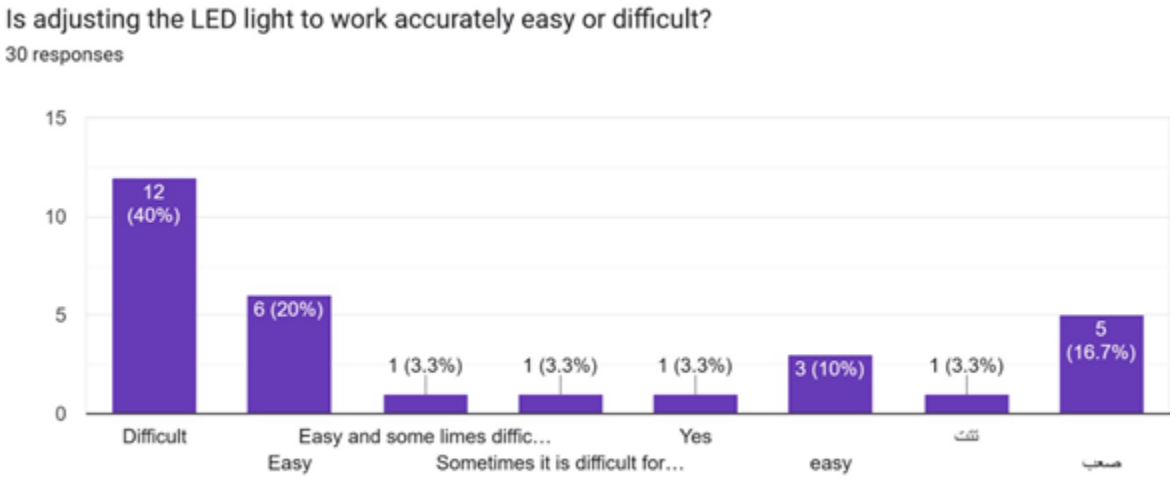


Figure (4.8) When we asked the doctors whether adjusting the lighting during work was easy or difficult, most of the answers were difficult to adjust during work because it works and at the same time adjustment is required so it is difficult for him.

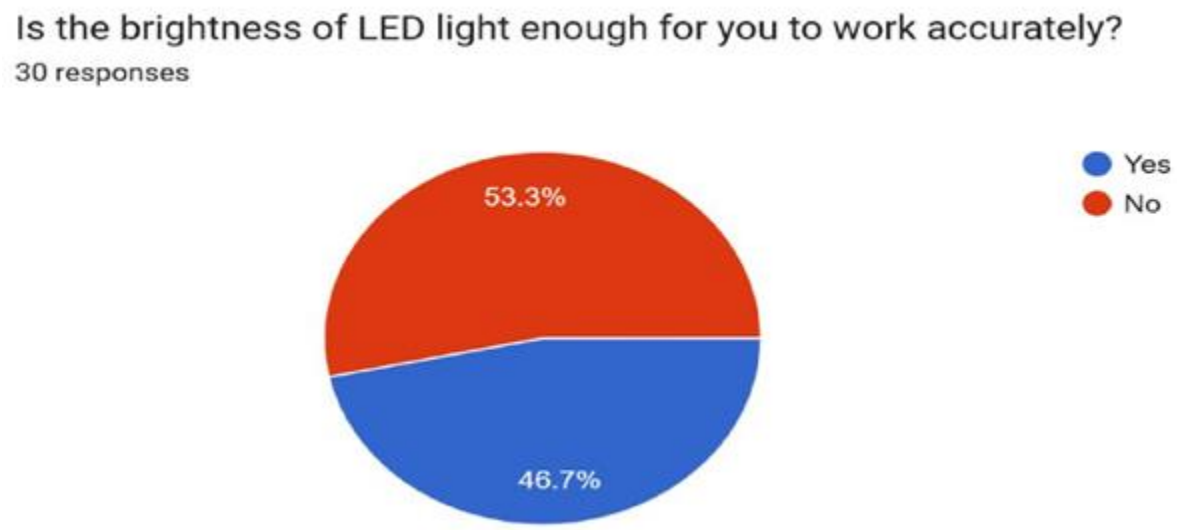


Figure (4.9) lighting is not enough for dentists because it may be far from it, so it is not enough.

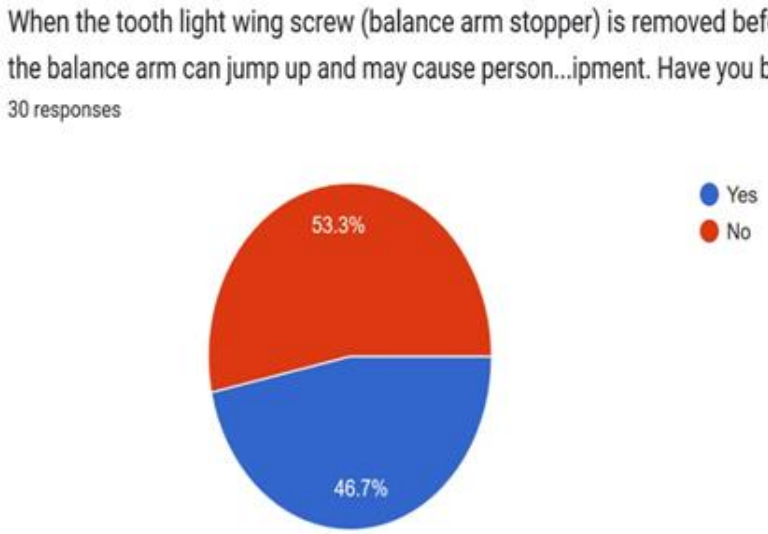


Figure (4.10) When the tooth light wing screw (balance arm stopper) is removed before the light head is attached the balance arm can jump up It may cause danger to the patient or harm the patient, so the answer was no from most dentists.

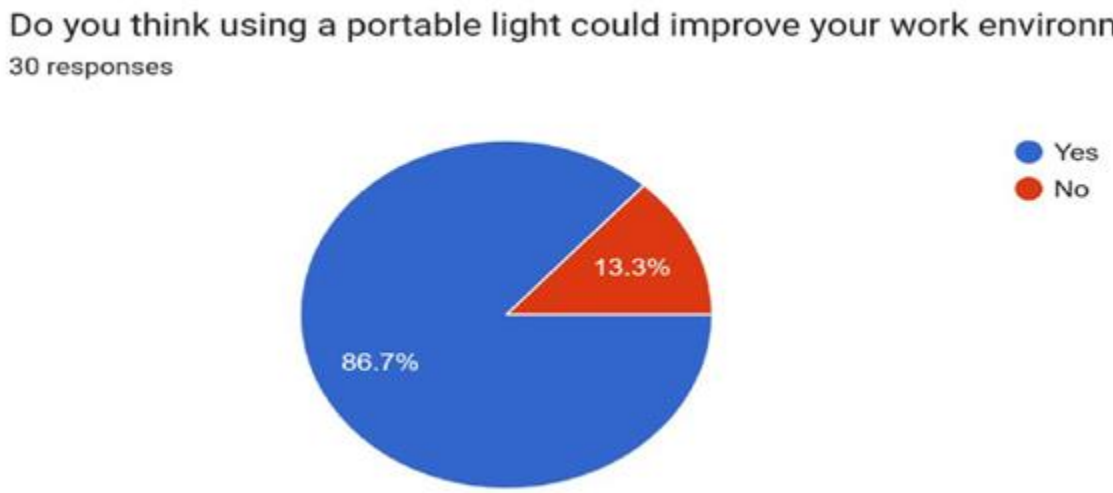


Figure (4.11) Making portable lighting helps improve the work environment, and most of the answers were yes, because it reduces the size of the device, reduces breakdowns, and reduces costs when malfunctioning

Discussions

According to the collected data regarding the requirements by the dentists, 88 % of them need to adjust the lighting many times during the operation. Furthermore, the Light unit has number of faults happens to it, which also cost about 165$. Therefore, in this work a new method of lighting is suggested

The step of development

Materials:

1-lithium battery 3.7 2-led 5mm 3-Wires 4-lithium battery charger board 5v. 5- Portable PAL filament hand piece with LED

We made an LED holder that moves right and left so that the doctor can be more comfortable in his work because when he uses the normal lighting it is difficult for him to move because he may be working and needs to move the angle of the lighting and therefore it is difficult for him to move. As for the LED holder that we worked on it is easy to move and change the angle and be it is connected to the battery so that it is easier for the doctor also more than other means as shown in figure 6. Also, these materials are less expensive than the lighting in the device, and also reduce the size of the device, so it is better than the regular lighting in the device. When there is a malfunction in the device, spare parts are easier and less expensive

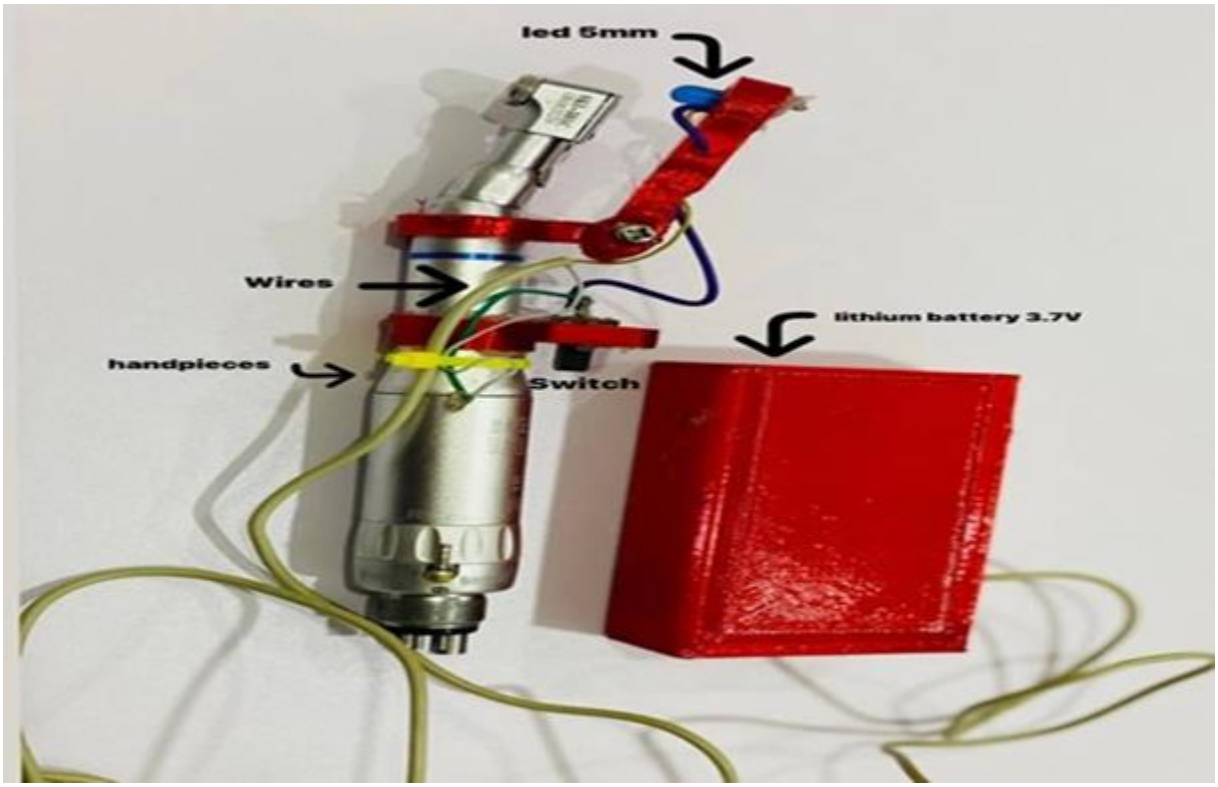


Figure (4-1). Portable PAL filament hand piece with LED

Conclusions

- An extensive literature review has been performed
- The common faults, the cost to fix them and the possible solutions have been identified
- The clinicians have been asked about what they most wanted to adjust in order to work better for patient well-being.
- Most of the answers were on the lighting, which is always uncomfortable in the doctor's work.
- It was decided to modify the lighting system of the unit
- A tool was designed with the addition of a moving LED with an LED holder.
- We used a 3D printer to design a simple tool that enhances the work of the dental unit.

Maintenance engineers not only need to deal with daily failures but also need to deeply analyze the causes of failures and how to prevent similar failures. Medical engineers and technicians should use their professional knowledge to make appropriate innovations and feasible improvements to the existing equipment to solve the current problems

Recommendations

To the best of our knowledge, in several previous studies on the dental unit chair, there were no studies providing quantitative information regarding the factors to consider while purchasing a dental unit chair. Thus, an appropriate comparison with previous studies is difficult. However, quantitative information on factors to consider when purchasing a dental unit chair can help the dentist in their decision, as it can confirm what items to consider when choosing a dental unit chair. In addition, this information will be

important information for dental unit chair manufacturers, as they can check the design preferred by dentists and the factors that are important to them when developing or improving the chair unit. And In the context of the current advanced management of medical equipment, engineers should improve their maintenance concepts, transform their experience into practical maintenance practices, and use information technology and quality management methods to improve medical equipment maintenance

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