Novel Design, Control and Fabrication of Automated Paste Polishing System

Vida Kargar¹, H. Golestane², S. A. Mousavi³

1-Department of Dentistry, Islamic Azad University, Khorasgan Branch, Iran, Email: vidakargar_89@yahoo.com
2-Department of Dentistry, Islamic Azad University,Khorasgan Branch, Iran, Email: golestaneh@dnt.mui.ac.ir
3-Department of mechanical engineering, Islamic Azad University, Najafabad Branch,Iran, Email: sa.mousavi@pmc.iaun.ac.ir

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ABSTRACT
Periodontal polishing is the act of smoothing the tooth surface and performed by hand-piece device and addition of prophylaxis paste onto the bristle brush by the dentist. Disadvantages of this technique include non-uniform cleaning of tooth surface and removal of dental deposits including dental plaque and long duration of head substitution due to paste running out and other factors. To solve this problem, a new machine was designed capable of adding the prophylaxis paste to the hand-piece apparatus head automatically. This setting injects the prophylaxy paste into the target point with pneumatic automatic control system. This paper deals with design and fabrication of pneumatically operated automatic paste machine. The pulse and pressure system control for pneumatic system were designed and implemented. The manually operated machine is converted into a pneumatically operated machine by applying proper ergonomically design procedure. Findings support the use of automatic pneumatic paste injection instrumentation over the traditional hand paste polishing.

KEYWORDS: Design, Polishing, Pneumatic, Prophylaxis paste, Automatic control

1. INTRODUCTION
Polishing is an integral dental procedure [1-2].Microbial plaque is the primary etiological factor in caries and periodontal disease [3-4].Although it may be possible to smooth dental surface to inhibit plaque accumulation , many patients do not have the motive or skill to maintain a plaque-free state for extended periods of time [5].
During the early treatment or supportive periodontal procedures, polishing operation is developed by using instruments such as air powder polishing apparatus mainly for removing supragingival staines and dental surface hardness.[6-8].Failure to uniformly clean the tooth surface and long duration of head substitution due to paste running out and other factors are among the disadvantages of this operation. Prophylaxis paste is suitable for cleaning the teeth because of containing stain and trace remover with little damage to enamel and dental tissues. This cream is prepared in the form of paste and has the following features: excellent segregation and physical attributes and in addition, mouth sensory and consistency characteristics, acceptable to consumers, influence in spread of hygiene in dental caries, and useful impact on parts of teeth structures. [9-11]. This is depend on the speed of the hand-piece, the abrasiveness of the past, and the amount of time spent on cleaning the tooth. [12-15]. For these reasons, one requires an apparatus that enables dentist, hygienic specialist and/or periodontist aid to apply controlled amount of dental substances for a patient in a hygienic and effective manner. In novel proposed system injection operation is done with the help of compressed air. It is cheaper than air powder polishing machine and more efficient as compared to manual machine. This apparatus must be designed and produced in a way that patient’s or dentist’s immunity and safety is not endangered if used under the respective circumstances and for achieving certain targets. The apparatus shall be designed to eliminate any risk related to its application and to provide a high level of protection, safety, and immunity besides
maintaining its capabilities. These problems are solved in pneumatic machine by using an automatic cylinder injector. The main components are developed using Solid work software. The advantage of this machine is, productivity is increased as compared to manual machine.

2. DESCRIPTION
The pneumatically operated polishing injection machine is fabricated with using various components. The components are pneumatic cylinders, upper cylinder (100×100mm) and pressure regulator, 2/2 direction control valve, flow and pulse control system, Compressor, injector, bolts and fixture. The upper cylinder is used for reciprocating motion of the piston which injects the prophylaxis paste in to injector. The compressor provides compressed air to both the cylinders, which causes movement of the plunger. Air filter removes all foreign materials and allow dry, clean air to flow without restriction. Once the compressor air has been properly cleaned, it is necessary to regulate it to the required level of pressure regardless of fluctuations in compressed air main line. Different pneumatic systems work efficiently at different operating pressure. Hence selection of pressure regulator of right range is important for efficient working of pneumatic system. Pneumatic automation components extensively use sealing material made out of rubber compounds. Pulse and pressure control system is used to control the direction and the amount of the air inserted to automated system. This invention is totally connectable to all dentistry hand-pieces, and in particular, features a removable and connectable mechanism for polishing patients teeth. It was attempted in this design to cover the parameters like portability, automatic injection force, and light weight.

3. APPARATUS DESIGN
There should be some design consideration for ergo-mechanical design and biocompatibility of a system that mentioned below. This apparatus must be designed, manufactured, and packed so as to minimize the risk of personnel and patients’ exposure to contaminating substances during transportation, storage, and application of the equipment. A great deal of care and precision must be devoted on non-exposure of tissues and their duration and sequences. The device must be designed and manufactured to minimize the risk of exposure to leakage of hazardous substances from instruments. If the device is intended to be used in combination with other instruments or equipment, the total combination comprising the connective systems is supposed to be safe and shall not disturb function of instruments. The equipment need to be designed and produced so as to minimize damage to patient and user; from mechanical risks for instance, the strength stability, and removable parts related to the equipment shall be designed optimally. Bio-compatible Stainless steel with autoclave ability was used for designing framework of the apparatus. In the case of portable device, it can be separated from hand-piece setting when not required. Another advantage of portability is the fact that if the hand-piece instrument encounters a problem and needs to be replaced, charging system and container of prophylaxis storage can be easily dismantled since it and mounted on a new instrument.

A. List of components
Upper cylinder, Control system, Input and output hose, Relief valve, pedal, Pressure Regulator, Injector, fixture, Hexagonal nuts & bolts

A. Design of Cylinder
Following points are needed to be considered while selecting a pneumatic cylinder. Cylinder thrust, Air consumption and Type of mounting. The cylinder thrust is a function of piston diameter, operating air pressure and the frictional resistance (though in the case of static thrust, the frictional resistance is zero). The air consumption data for cylinder is required in order to estimate the compressor capacity. The calculations include air consumption during forward as well as return stroke. Air consumption in liters for forward stroke: Free air consumption in liters for return stroke. Material selection is important and Material Used = High strength Steel Density of Steel = 7.82708e-09 ton/mm³ Poisson’s ratio = 0.27 Young’s Modula’s = 19.98 Mpa. The figure 2 shows the CAD model of designing cylinder.
Output of the cylinder is complete with injector part that shows on fig.3. Design of Hexagonal bolt & nut for mounting the cylinders 8 hexagonal nuts and bolts are used. Hexagonal nut and bolt is designed using the appropriate design procedure. (Fig3)

**Pulse and pressure control unit**
This Pneumatic Control Unit is an integrated unit featuring all control components necessary to set up and run pneumatics easily from a computer. It consists of several parts that mentioned in following.

**Layout of the Control System Front Panel**
The Front Panel provides LCD, touch panel, pressure gage, an LED to indicate valid system power, and a Reset button as it is shown in Fig. 5.

**Back Panel**
The Back Panel provides a 24V power inlet connection, a USB connector, a power switch (not shown in Fig.6), and a 4mm 2-way connectors for air input/outputs an air port for the compressed air supply as it is shown in Fig. 6.
Micro Controller Unit
The MCU (Micro Controller Unit) is the heart of the control system. It handles timed switching of the Valves, reading values from the Inputs, controlling the Valves and communications over the Serial Port to the host computer. The MCU has both volatile and non-volatile storage. The non-volatile storage makes it possible to configure how the system will behave following power-up.

Valves
Two on-off pneumatic Valves are installed in the system. They are set up to allow an Actuator Port to fill, leave inflated and empty the attached actuator. The Valves are driven from the MCU, either using Pressure a pulse control or timed commands from the host.

Inputs
A foot pedal is connected to the control system. The foot pedal key input provides 5V DC power to operate. The Input is read by the ADC, and the results are fed to the controller.

Serial Port
A standard RS232 Serial Port is fitted to the control system so it can be conveniently run from a wide range of host computers. Commands can be sent over the Serial Port to modify the software-based valve control, Switch valves and read input.

Reset Button
The Reset Button allows the MCU to be reset into the “Power-On” state. When the Reset Button is pressed, the MCU will return to any settings that are stored internally.

Power Input
24V DC is fed into the Power Input. This is used to power the Valves and the MCU as well as providing 5V DC on the pedal Inputs.

Power Switch
The Power Switch turns on and off the electronic circuits of the control system. When power is off, the valves will be turned off, and so cannot fill or empty an output port.

Valve control
Each output valve can be driven by state setting commands, controller outputs and timed pulse operations. These operate in the order listed, so that if a controller is running, the controller output takes priority After the timed pulse operations, and if a state setting command is used, it takes priority over the controller and the timed pulse operations.

Pulse Valves
Each valve has time interval that is in the range 0.15. The corresponding valves are turned on for as many milliseconds so a pulse of 1 will hardly operate the valve, and a pulse of 150 will operate the valve for a quarter of a second.

4. ASSEMBLY
Assembly included fitting, adjustment, and part selection. Assembling the parts respectively and then fix the screws at the joints with appropriate screw thread lock is important in this stage. Spare parts before the pneumatically operated machine assembled is as shown below.

5. WORKING METHODS
After design and assembling the apparatus, it is mounted onto the hand-piece using clips and paste exit and entry tubes are connected to the outlet lid of substances. It is then moved on the hand-piece to make its other end to meet the setting. The cylinder is subsequently fixed on the hand-piece using clip (part number 5) as it is shown in figure 8. At this stage, compressed air entry hose with a pressure of two atmospheres is connected to rear of the cylinder; the compressed air is supplied with compressor in dentistry unit. In the following figure, finely designed test bench layout is shown.
In general scope, this apparatus has been designed for distributing similar substances in a safe and hygienic manner and contains a removable cover mounted on the hand-piece body. The respective cover has a passing canal in the middle. One end of this canal is connected to the paste inside the paste container and the other terminal is positioned in the place where the substance is to be distributed. In the final design, an efficient dentistry hand-piece is achieved with improved hygienic conditions. A noteworthy technical point is the ability to control the volume of existing substances from hand-piece by adjusting the pressure exerted on the pedal. These substances are charged into the apparatus head after exiting and rubbed onto and polish the surface of teeth. For proposed polishing system 1 gram of prophylaxis paste diluted with five 5cc water is sucked into the cylinder by putting the end of charger tube in the vessel containing the substance and pulling back the piston handle (this process is similar to filling the injection syringe). The cylinder is now dilled with prophylaxis paste and the piston has moved to the rear of the cylinder and the apparatus is ready for injection.

The pneumatic force of compressor in dentistry unit can be utilized for injecting the paste into the instrument head. For this purpose, the pressure inside compressor air is connected to the rear of the cylinder after passing through the relief valve (for regulating the needed pressure), pedal (for connection and disconnection of compressed air) and full-control valve (for controlling air flow rate to adjust the piston movement speed) as it is shown in figure9. In this technique, the dentist orders the piston to move back and forth by pressing the connection and disconnection pedal of compressed air. As a result of this movement, the substances inside the container are recharged into the instrument head through the cylinder. Predefined value of prophylaxis paste stored in a container is used in the mechanism. There is a piston moving longitudinally in the hand-piece, which has pulsed and pressure control. The paste is injected simultaneously with rotation of the hand-piece head and proportional to the pressure exerted by the dentist’s foot on the pedal. Dental substances are directly charged into the container and applied in the system. Figure 8 illustrates the designed mechanism and application case in the current research. Dental hand-piece coupled with this system turns into an appropriate way to distribute a controlled amount of paste over the patients’ teeth, and, there is no strict need to provide highly sterile environment though the apparatus features the possibility of being sterilized. The total volume of container for storing the prophylaxis paste was measured to be 6 cc. Duration of head substitution and insertion of paste is lengthy in the available systems on the market. The proposed apparatus mitigates the problems with the connectable design for a dental hand-piece which can be easily cleaned and sterilized.

6. CONCLUSION

The use of novel system for polishing presented in this study is very flexible in data experimental intervals. Consequently, there is need for presence of paste supply and charging mechanism on the apparatus because these accessories increase weight of device, and leads to early fatigue of dentist’s hand in tasks other than polishing operation. As a result, quality and quantity of proposed system decline. In the present study, the novel system for polishing was successfully used to control prophylaxis paste instruments for achieving the maximum output of tool based on the teeth conditions. The new system developed in this project is capable of simulating human experience, intelligence, and reasoning while polishing preparation processes. On the other hand, this study does have some limitations due to control of pneumatic injection system. Ergonomic mechanical design, pulse and pressure control of system and the automation that implement in polishing is advantage of this system. Another advantage of the novel system is the fact that it will help periodontics reduce the cost of wasted prophylaxis paste by adjusting the device precisely as applied in ordinary system. Further studies are necessary to explore the application of other control systems such as artificial intelligent controllers in this process. Further research is needed to elucidate the insight on the effect of this particular polishing system before adopting any effective control strategy.
REFERENCES


