Mouth Guard to Prevent Bruxism With Electrostimulation

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Abstract

The goal of this project is to design a mouth guard capable of applying electrical stimulus to a patient each time he clenches or grinds his teeth. Important requirements kept in mind during designing stages include patient comfort, cost, and product life. Three possible solutions are focused on. These included variation mainly of the sensor; other components were varied with each solution to best fit the design. The three main sensors being considered are piezoelectric, binary spring, and fluid-filled tube. We choose the design including a binary spring. Future work on the project includes finding a miniature reliable battery, adjusting the range of electrical shock, and fine-tuning the spring.

Design Problem:

The project is to design a night mouth guard capable of sensing pressure from grinding and clenching of the teeth. In response to pressure, this device will provide a tingling sensation (small electrical shock) to the patient. The sensation will cause the patient to stop grinding or clenching. Patent 5,490,520 Dental Appliance for Treating Bruxism is a basic starting block for the design of the product.

Background Information:

Bruxism is defined as grinding and clenching of the teeth. Grinding is the back and forth movement of the mandible and maxilla, lower and upper jaw respectively. Clenching is the application of a static normal force onto the teeth. The main muscles involved in clenching are the massater and the temporal muscles. Only five to twenty percent of the population is aware of having bruxism, but a far higher percent of the population could actually suffer from this disorder (Attamasio, 1991). Physical and emotional stresses are common causes of clenching and grinding. Alcohol, medication, and sleep disorders have also been linked to bruxism (Attamasio, 1997).

Problems resulting from bruxism are headaches, muscle strain, jaw pain, tooth sensitivity, minor wearing of the tooth surface, oral infection and excessive tooth mobility. In severe cases the teeth's surface will wear down, and the structure of the face will change.

Currently, there is no permanent cure for bruxism, but many treatments relieve the symptoms of bruxism. Physical therapy is used to strengthen the jaw muscles, increase jaw mobility, and decrease swelling and pain in the jaw. Splints (mouth guards) will reduce the wear and tear on the teeth's surface. Psychological therapies aim to reduce stress, which in turn reduce clenching and grinding. In severe cases surgical procedures are used to adjust the bite or biting surface.

A variety of tactile sensors such as piezoelectric, binary, and a fluid-filled tube sensors can be used to detect pressure. A piezoelectric sensor creates a voltage when change in pressure is applied. The piezoelectric sheet is either a crystal or ceramic material surrounded by two conducting plates. When the material is deformed a charge is distributed to the plates and thus a voltage is created. A binary pressure sensor, in response to certain pressure, either switches on or off. These sensors can be made from springs, where the spring constant determines the pressure at which the switch opens or closes. A fluid-filled tube with a remotely located sensor can also be used to detect pressure changes (Webster, 1988).

Our client has chosen electrical stimulation as a potential treatment for the reduction of clenching and grinding. Electrical stimulation will not cause a muscle to relax, but rather to contract. Methods such as Transcutaneous Electrical Nerve Stimulation (TENS) provide relaxation by fatiguing the targeted muscle (J. G. Webster, personal communication). Electrical stimulation could also be used as a behavioral therapy by signaling the body with a negative message when an undesired action is performed, which in this case is bruxism.

Most of the design constraints are to maintain patient comfort. If the mouth guard is uncomfortable to the patient, it is less likely the patient will consistently wear the product, resulting in an ineffective treatment. To start the retainer must be thin and be in correct proportion to the mouth. Next, large components are to be avoided to maintain the natural position of the mouth while wearing the mouth guard. Also the mouth guard should also be cost effective in order to be marketable to the patient. The voltage should be in a range that will not cause the patient to wake during sleep (See Appendix 2 for complete Product Design Specifications).

Design Ideas:

Each of the following design ideas contains a hard acrylic mouth guard, which currently is used by bruxism patients. Therefore, the same mouth guard is present in each design but with differing pressure sensing and shock delivering systems. Another constant part of the design is the positioning and material of the electrodes. Electrodes consisting of carbon rubber, a simple conductive material, will conduct a shock to the inner cheek. The positioning of the electrodes follows specifications of Patent 5,490,520.

Design # 1: Piezoelectric System

A change in pressure will create a charge in the piezoelectric material, which will cause a voltage between the two aluminum plates. No external power source will be needed. A voltage splitting resistor setup will control the magnitude of the voltage. The voltage will be delivered to the electrode via a tiny wire fitted through a drilled hole in the side of the retainer. The electrical components of the piezoelectric generator will be coated with an insulator to prevent a short circuit.

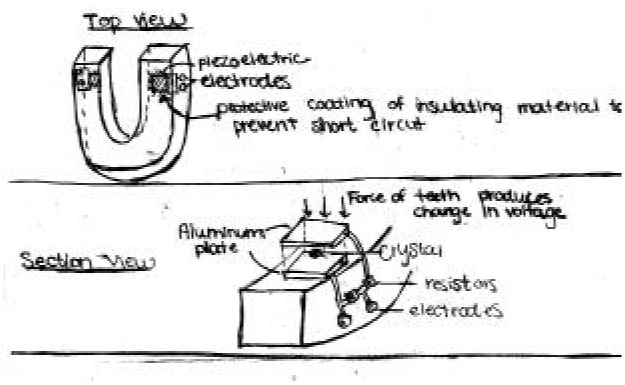

Figure 1. Design 1 uses a piezoelectric sensor to create the voltage and sense the clenching.

Design # 2: Fluid-Filled Tube to Complete Circuit

An overall change in pressure is detected through a fluid-filled tube. An external sensor will detect a stretching in the elastic material. This sensor will activate a switch to complete the circuit and deliver a shock to the patient. The wires of the circuit will be placed between the mouth guard and the fluid-filled tube. The battery will be encased in plastic with electrodes mounted on this case. A small rounded case will be included on both sides for the patient to feel symmetry in his mouth.

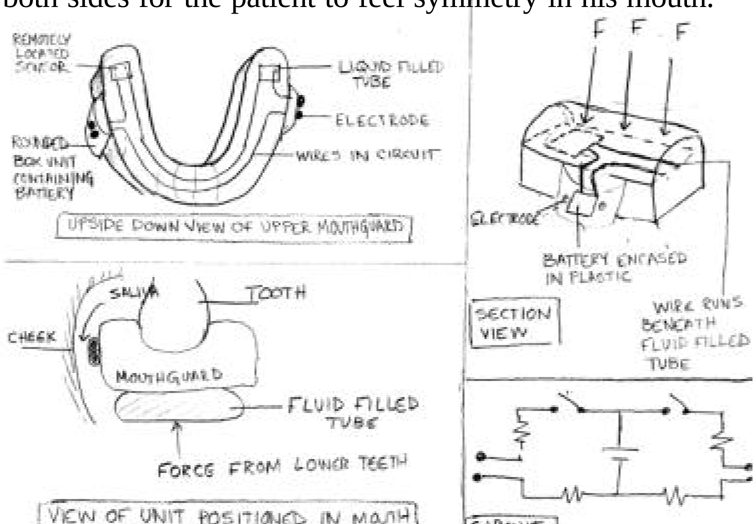

Figure 2. Design 1 uses a fluid filled tube to detect pressure changes over the entire surface of the mouthguard.

Design # 3: Simple Binary Switch to Complete Circuit

A binary pressure sensor will detect the pressure caused by the bruxating patient. When the patient bites down, a spring will be compressed, which will trigger a binary switch to close. When the switch is closed, the circuit will be completed sending a voltage to the patient. This circuit is composed of a battery, a capacitor to control the voltage applied to the patient, and electrodes for the output signal. The 2 springs will be located externally to the retainer, connected to the inferior surface of the retainer and superior to the surface of the lower molars. Cold-cure acrylic will be used to position the sensor in a shallow hollowed out area of the hard-acrylic mouthguard.

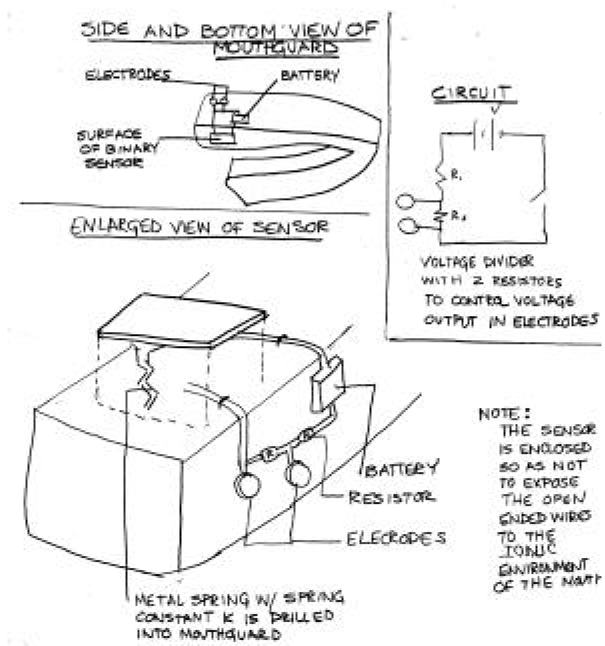

Figure 3. Mouth guard with a spring sensor and battery for each side of the mouth.

Other ideas briefly considered include an external system to sense muscle contraction and deliver a shock and the current existing patent where one portion of the circuit is completed with saliva.

Proposed Solution:

We eliminated design one based on drawbacks to the design. Piezoelectric sensors are unable to detect static pressure. This means that when a clenching patient bites down, they would receive only one short electrical shock upon initial contact. If the patient continued clenching at the same pressure, no further stimulation would result from the design. When the patient releases the clamping pressure, the sensor would once again be triggered by the change in pressure, and another shock would be delivered. In this situation the shock would not always be a result of the unwanted behavior.

Design two also has difficulties when implementing the design. Hard-acrylic mouth guards are able to withstand grinding more so than the soft-acrylic. We specifically chose a hard-acrylic because of the longer life-span of the product. A flexible fluid-filled tube would offset the choice of hard-acrylic since the flexible tube, like soft-acrylic would have a shorter life-span. Another complication to the fluid-filled tube is that it will add to the thickness of the retainer, decreasing patient comfort. Finally, the process for creating a fluid-filled tube around the hard-acrylic retainer may be a complicated process.

Design three also has potential problems with the design. First, the life of the battery may be shorter than the patient's need for the product, making replacements of either the entire product or battery necessary. Also, different patients bite down at different pressures. Springs that will sense different pressure ranges may be needed for desired results in all patients. Another drawback is that placing the sensor in the hard acrylic retainer may weaken the structure of the retainer. Finally, complications may occur in designing a circuit to deliver a correct amount of voltage to the patient's cheek.

We choose design three because binary sensors can be made extremely small. The sensor has a simple durable design that is low in cost. Unlike the other two designs, the difficulties are not specific to this design, but rather would exist in a variety of different designs. Resolving the problem of different pressures in different patients may simply involve using the lowest spring constant that will detect pressure just larger than normal teeth contact. Experimentation into drilling without weakening the structure will require care and practice. Possibly with practice on scrap pieces of hard-acrylic we can experiment without weakening structure. In order to deliver the right amount of voltage to the patient, we will need to use Kirchoff's Laws to calculate the voltage. Voltage can also be determined with a voltmeter.

Appendix 1: References

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Resources

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Appendix 2: (PDS)

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Preliminary Design Specifications

Title: Mouth Guard for Prevention of Bruxism

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Function: Our project is to design a nighttime mouthguard capable of sensing the pressure of grinding of clenching of teeth. In response to the pressure, this device will provide a tingling sensation (small electrical shock) to the patient. Ideally this sensation will cause the patient to stop grinding or clenching.

Client requirements:

- Must not wake patient up at night
- Cost effective
- Mouth guard must be able to firmly stay in position overnight

<u>Design requirements</u>

1. Physical and Operational Characteristics: The device is worn while sleeping each night. The device must be able to withstand the pressures of a clenching/grinding patient [insert pressures here]. The device must be durable to withstand daily cleaning.
2. Safety: The small shock must not harm the patient. Any components in contact with tissue such as cheeks, tongue, or gums must not have sharp or pointy edges.
3. Accuracy and reliablilty: The voltage should be adjustable within a yet to be determined range. Each time the patient clenches or grinds, the appropriate voltage will be applied.
4. Life in Service: At minimum the device must last 3 – 4 years. Because the bruxism is a lifelong problem, the longer we can make the device last, the lower the cost to patients in the long-run.
5. Shelf Life: A case should be designed in order to safely store the device during daytime hours. The unit **may** need to be charged during storage.
6. Operating Environment: Electronic parts must still function within the environment of the mouth. The device will experience temperature around normal human body temperature, 37 degrees Celsius. The largest likely range

would be between 42.6 and 31.4 degrees Celsius. Pressure range [insert]. The device will be in an aqueous environment. (find description of mouth environment)

7. Ergonomics: The device cannot interfere with the normal placement of the bite.
8. Size: The mouth guard must remain 2 - 3 mm thin. The battery must fit either in the lower mouth or in the inner cheek area. The electrode should be smaller than 1 cm.
9. Weight: The weight must be unnoticeable by the patient. Insert weight.
10. Materials: Hard acrylic should be used in the mouth guard so the patient does not chew through the device. All electronic components must be water-proof. No un-sealed harmful or toxic materials may be used in the mouth.
11. Aesthetics, Appearance, Finish: The shape must be fitted to the mouth from impressions made of the teeth. The retainer should be U-shaped following the line of the teeth. The chewing surface needs to be smooth.

Product Characteristics

1. Quantity: 1 prototype, in the future one mouthguard per patient.
2. Target Product Cost: $400 - $800

Miscellaneous

1. No FDA approval. No standards none of currently.
2. Customer: likes-inexpensive, effective, comfortable, short production time
3. Patient related concerns: The device must be able to be cleaned. The patient must not be woken-up by the shock.
4. Competition: The plain mouth guard, physical therapy
   A patent already exists on our product.