Mouthstick to Facilitate Quadriplegics' Use of Computer Keyboard

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Abstract:

Mouthsticks are used by quadriplegics to communicate in their daily lives. One important aspect of this communication is using a computer. In order to depress keys on a computer keyboard quadriplegics use a mouthstick. (See Figure 1) A mouthstick is a simple device composed of a thin, plastic, V-shaped mouthpiece attached to an aluminum rod. The user grips the mouthpiece with the teeth. The stick is moved forward and backward by extending and retracting the lower jaw. This jaw movement causes the mouthpiece to slide across the teeth. Hence, the user suffers wear and chipping of the teeth from repeated grinding of mouthpiece against the teeth. The purpose of our design is to solve this problem of the current mouthstick. The current mouthsticks cause wear and chipping of the teeth. Our design project proposes three alternative design solutions: spring mechanism, fluid design, and sliding mechanism. These designs are evaluated using a design matrix. A final design solution, a slide mechanism, is proposed along with future development suggestions for the project.

Figure 1: Typical Use of Mouthstick (mouthstk.net, 2002)

Problem Statement:

To design a device that will allow quadriplegics to more easily depress keys on a computer keyboard without causing the wearing or chipping of the teeth caused by the current mouthstick design.

Introduction:

According to National Spinal Cord Injury Association (2002), there are approximately 450,000 people (82% men, 18% women) with Spinal Cord Injury (SCI) or Spinal Dysfunction in the US. The highest rate of injury is between the ages of 16-30. The causes of spinal cord injury are motor vehicle accidents (44%), acts of violence (24%), falls (22%), sports (8%) and other (2%). The spinal cord is the major bundle of nerves that transmits nerve impulses to and from the brain to the rest of the body. The general functions are controlling mobility and feeling. Once the spinal cord is damaged, the person is unable to move or feel part of his/her body depending on the level of spinal cord injury.

There are eight cervical vertebrae (C1-C8) present in the neck, where the C1 vertebra is closest to the base of the head. Generally, C1-C3 damage causes the most serious injury, which includes loss of function in arms and legs. Many of these patients also need a ventilator to aid in breathing and are physically dependent on others. A C3-C4 patient may shrug shoulders and can control their head and neck. C5 patients can bend their elbows, turn their palms face up and control their head, neck and shoulders. Our client, Mr. Steve Christensen is a C4-C5 quadriplegic.

In our background research, we found that there are high-tech devices, such as eye tracking and headgear with laser. These devices are expensive and not commonly used. The mouthstick is commonly used by quadriplegics because of its affordable price.

There are still some problems with the current mouthstick design. Since our client has used the mouthstick to depress keys on a computer keyboard for years, his teeth have sustained significant damage. This includes chipping of his front teeth, exposure of nerves, and cracking of molars. Mr. Christensen would like us to improve upon the current design of the mouthstick. Both the mechanism for extending the mouthpiece and the materials used are key components in our improved design.

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Client Requirements

In addition to preventing grinding against the teeth, the new design must have an adjustable angle between the plane of the mouthpiece and the mouthstick (see figure 2) to accommodate different keyboard setups and varying heights of patients. Our client specifies an angle of 18° from the horizontal.

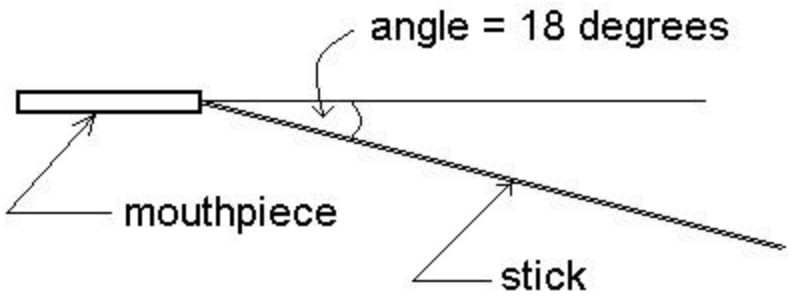

Figure 2: Mouthstick Angle

A material that is comfortable to the patient as well as conducive to an oral environment must be used into order to ensure complete ergonomic use. The materials that are being considered are thermal plastic, Ethylene Vinyl Acetate (EVA), Hard-Soft acrylic material, or acrylic tubing. For the stick portion, where the material must be as lightweight as possible, a T-6 aluminum alloy will be used.

A minimal exertion to extend the stick is necessary to eliminate the grinding and not cause other problems such as pain in the facial muscles or jaw. This is a very important consideration in order to ensure comfortable usage. The cost is important because the mouthstick needs to reach a variety of individuals at different economic levels. A cost below $60 would be affordable for the average person, taking into consideration that the mouthstick would last a minimum of 5 years.

Safety

The mouthpiece must be a non-toxic material conducive to an oral environment of 95°F and 100% humidity. It must withstand a biting force of 150-250 N (BME 200, 2001) without wearing. In addition, it cannot present a choking hazard. Therefore, the mouthpiece must not wear or chip off in the mouth and all pieces must be larger than 1 cm in diameter. The mouthpiece should also be manufactured so no pieces will potentially fall off in the mouth. The material of the mouthpiece must be able to be sterilized to prevent a possible build-up of bacteria.

Characteristics

The mouthpiece must ideally weigh 6 oz. This will be light enough so there is no strain on the facial muscles while in use. Dimensions are to be 5 x 4 x .5cm (see figure 3).

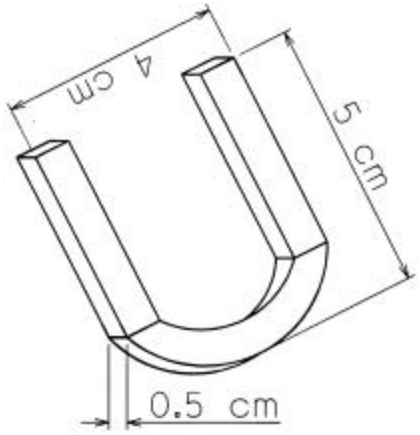

Figure 3: Dimensions of Mouthpiece

This mimics the mouthpiece of the current design which is the preferred size for our client. A thin mouthpiece is especially important so a normal position of the mouth can be maintained, and it does not feel bulky when in use.

Design Alternatives

- **Spring Mechanism**

The first proposed solution utilizes a spring to solve the problem of mouthstick movement. It allows the tongue to push the stick out. The mouthpiece fits similarly to an athletic mouth guard. This allows the mouthpiece to remain stationary while force is exerted outward. A chamber runs out the front of the mouthpiece that contains a spring (See Figure 4 below). A button extends back from the spring while the mouth stick extends forward, around the chamber. When force is exerted on the button from the tongue, the spring is compressed, and the stick is forced out. The stick only extends a maximum of one centimeter. This is ideal for a few reasons. First, when the stick is in the resting position, the button cannot extend too far back into the mouth. This would be

uncomfortable for the user. Second, the stick only has to move about one centimeter because its function is to depress keys on a computer keyboard. Once the stick is extended, the pressure applied by the tongue can be removed causing the stick to return to the normal, resting position. It is important for the spring to be easily compressed because minimal exertion is preferred.

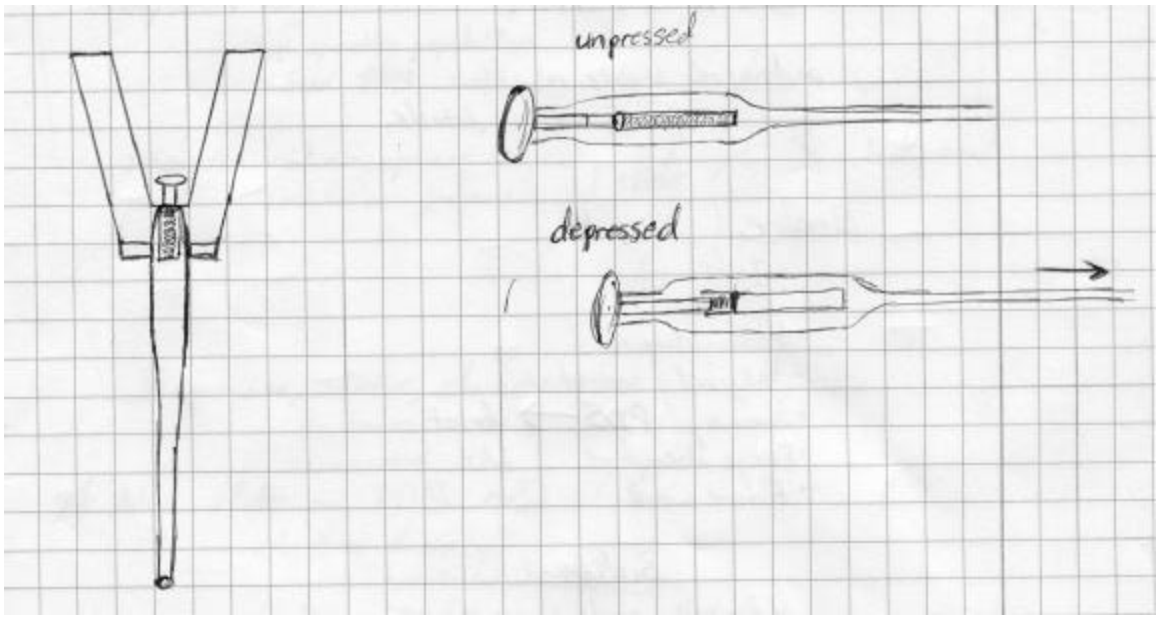

Figure 4: Spring Mechanism

- **Fluid Device**

The second proposed solution is based on fluid mechanics. Overall, it lets the jaw do the work by utilizing biting force. The material of the mouthpiece must be firm and slightly compressive. Fluid chambers run inside and out the front of the mouthpiece (See Figure 5 below). The stick is positioned inside the front chamber. When a biting force is applied, the fluid compresses and moves outward. However, since there is no place for the fluid to go, it naturally thrusts the stick forward. The stick is guided out through a cone and is stopped when the end of the stick reaches the base of the cone. It is stopped

by a hole which otherwise acts as a guide and a stopper on the distal end of the stick. An extended chamber is needed to assure accuracy of pointing. When pressure is relieved, the stick will return to its normal position.

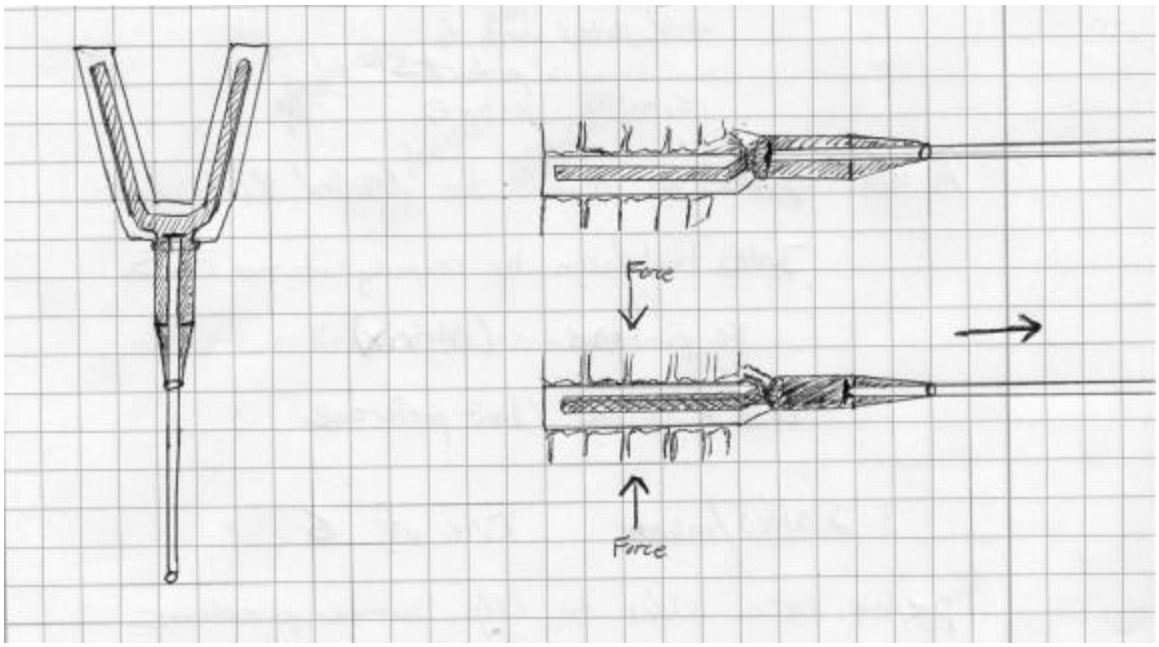

Figure 5: Fluid Design

- **Sliding Mechanism**

The third proposed solution utilizes a sliding mechanism. The device is composed of a stationary plate and sliding plate. The lower jaw is used to extend and retract the sliding plate which is attached to the stick (See Figure 6 below). To make the plate easier to grip for the bottom teeth, a groove is placed on the underside of the sliding plate. This allows the teeth to fit in and manipulate movement easily. When the bottom teeth push the plate forward, the stick extends. A second measure is taken by creating ridges on the top of the stationary plate in order to provide a support for upper teeth. When a force is applied outward, the mouthpiece stays in place because of these features.

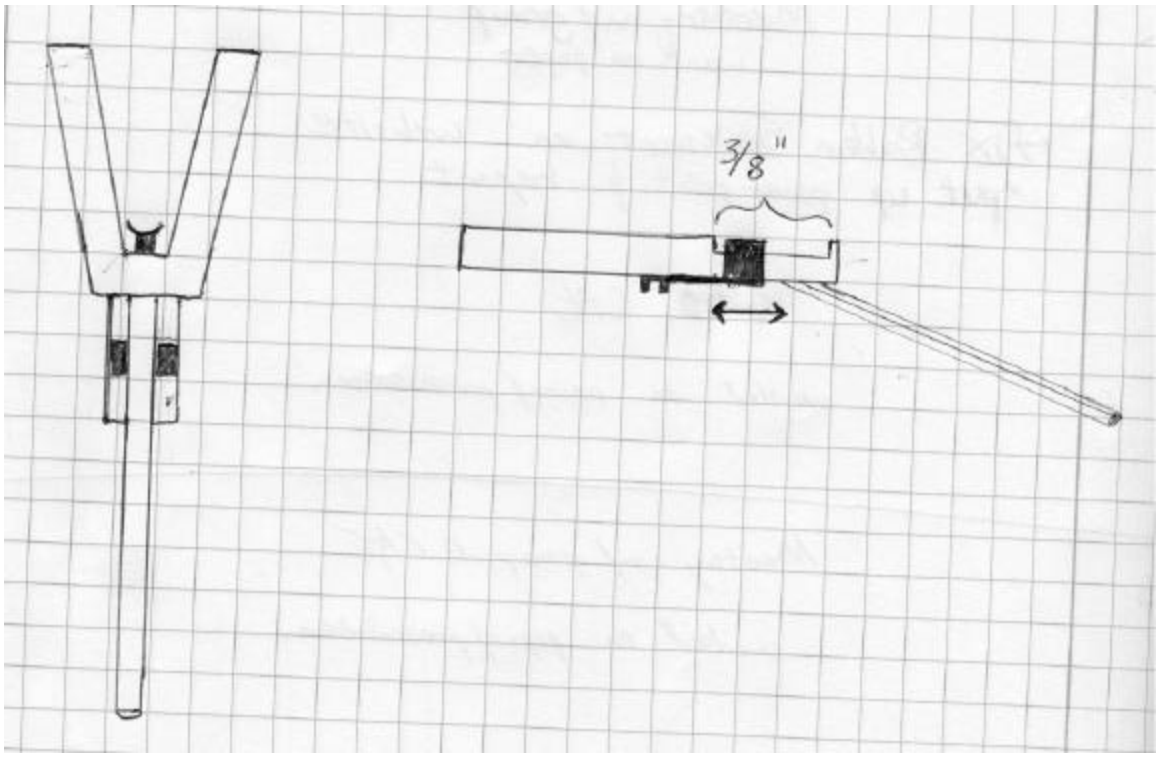

Figure 6: Sliding Mechanism

Evaluation:

Table 1: Decision Matrix

	Spring	Fluid	Sliding
Safety	+	-	+
Cost	+	-	+
Weight	+	-	+
Size	+	+	+
Exertion	-	+	+
Client Preference	-	+/-	+

Table 1 indicates how each design rates in various factors of the PDS. The spring design fits the requirements for safety, cost, weight and size in our PDS. However, the main reason the spring design would not be feasible is the large amount of exertion needed to extend the mouthstick. The design would lead to excess fatigue of the tongue

and would not be practical for use during extended periods of time. After surveying our client's preferences, we learned that this type of design was attempted but failed because of fatigue of the tongue after only a short time of use.

The fluid design requires the least amount of exertion needed to operate the device (extend the stick) of all the designs. The simple biting down action needed to extend the stick made it an appealing option to our client. However, he also felt that the complexity of the device would make it much less dependable than a simple sliding mechanism. The fluid design also did not fit several requirements of our PDS. It did not meet our safety requirements because of the risk involved with the mouthpiece possibly cracking and leaking fluid into the mouth. It would also cost considerably more to produce than the other designs (over the $40-60 range). Another downfall of the fluid design is its weight. The added weight from the fluid and the portion of the mouthpiece needed to store the fluid would put this design over the limit specified in our PDS.

The sliding device requires a moderate amount of exertion and utilizes a similar motion that the client uses to extend the current mouthstick. The simplicity of the design would keep production cost low (within the $40-60 range) and allow us for more freedom in choice of materials. This gives us the ability to choose from many materials that are known to be safe for use in an oral environment (e.g. plastics used in mouthguards). The design would also enable us to minimize the weight and thickness of the mouthpiece. This option was also considered to be the most practical approach by the client. For these reasons, we decided to choose the sliding mechanism as our final design.

Future Goals:

In order to keep our design within the limits of the PDS, the materials used for the design will be an important consideration. Cost and weight must be minimized while durability and comfort of the mouthpiece material must be maximized. Our research on materials thus far has given us some leads as to the types of plastics (for the mouthpiece) and metals (for the stick) that would be optimal for our design. In order to gain more information about these materials we plan on obtaining sample of materials to test and also seeking the opinion of a professor/researcher in the materials science department.

The design will also be refined, including more detailed sketches/perspectives and specific measurements for each section of the device.

References

"Extensions for Independence…the Mouthstick Connection" 2002. http://mouthstick.net/mouthstc/mbromain.htm. Website. (February 1, 02).

"Force Testing Information" 2001. BME 200. http://www.cae.wisc.edu/~bmedesgn/fall01/bruxism/ Website. (February 12, 02).

"SCI/D Information Databases" 2002. The National Spinal Cord Injury Association http://www.spinalcord.org. Website. (February 20, 02).

Appendix:

Product Design Specification **3/14/02**

Title: Mouthstick to facilitate a quadriplegic's use of a computer keyboard.

Function (a general statement of what the device is supposed to do): The function of the new design will allow for a quadriplegic patient to more easily use a computer keyboard without causing wearing or chipping of the teeth.

Client requirements (itemize what you have learned from the client about his / her needs):

Design requirements:

1. Physical and Operational Characteristics

a. *Performance requirements*:

- Used for 1-2 hours at a time
- Maneuver/hold the stick with only a small amount of pressure applied by the mouth
- Press the keys on the keyboard using only force from movement of jaw or tongue and not applied by neck.
- Stick should move in and out of the mouth with no grinding across teeth.

b. *Safety*:

- Made of non-toxic material (e.g. thermal plastic)
- Must not contain any type of coating that could peel/chip off in the mouth.
- Not present a choking hazard (i.e. any parts of mouthpiece that could possibly break off or become detached should not be smaller than 1 cm in diameter)
- Material that can be cleaned/sterilized and reused.

c. *Accuracy and Reliability*:

- Accuracy not applicable
- Not wear or degrade in shape from use in mouth

d. *Life in Service*: 5 years

e. *Shelf Life*: Product should have a ten year shelf life when stored at room temperature (18-26°C or 65-80°F) .

f. *Operating Environment*:

- Conducive to an oral environment. Temperature 95°F or 35°C. 100% salival humidity.
- Withstand forces from biting down ~150-250N (force values taken from experiments performed by Fall 2001 BME mouth guard for bruxism group) and force from falling.
- Should not shatter/crack if mouth stick is dropped from height of up to 2m.

g. *Ergonomics*:

- Held in the mouth when the mouth is relaxed.
- It must be lightweight
- Torque of mouthstick should not exceed 0.25 Nm.
- Angle between plane of mouth piece and stick should be 18° (angle needs to be adjusted for height of individual users)

h. *Size*:

- Mouthpiece: 5-6 cm X 4-5 cm and thin (0.25-0.5cm).
- Length of "stick": 56cm (stick used for laptop computer) and 63cm (stick used for desktop computer).
- Possibly make length of stick adjustable by 10cm.
- Stick diameter .5 cm.

i. *Weight*:
"Stick"
Optimum weight – 28g (1 ounce) +/- 2 oz

Mouthpiece
Optimum weight – 170g (6 oz) +/- 4 oz

j. *Materials*:

- Lightweight but durable materials
- T6 aluminum alloy for the stick
- Thermal plastic, EVA (ethylene vinyl acetate), or acrylic for the mouthpiece

k. *Aesthetics, Appearance, and Finish*:

- Neutrally colored mouthpiece
- Bright, metallic colored stick
- Mouthpiece Y-shaped and made of smooth materials.
- Non-threatening appearance.

2. Production Characteristics

a. *Quantity*: 1

b. *Target Product Cost*: $40-60 per mouthstick.

3. Miscellaneous

a. *Standards and Specifications*:
   - FDA approval

b. *Customer*:

   - Angle of stick relative to the mouthpiece is critical (angle needs to vary with height of person).
   - The thickness of the current mouthstick is desired.
   - Length of stick needs to vary for different tasks (i.e. using laptop computer vs. desktop).

c. *Patient-related concerns*:

   - Current material is too hard.
   - The way it is maneuvered in the mouth causes the mouthpiece to grind against the teeth causing wearing/chipping of the teeth and increased sensitivity in the teeth due to nerve exposure.

d. *Competition*: There are several other similar devices on the market.

   - Sammons Preston: Bendable Telescopic Mouth Stick
   - http://www.wisdomking.com/line255.html
   - http://www.abilityhub.com/mouse/joystick.htm