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A Technical Note

Development of a custom-fit mouthstick appliance

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Abstract—Quadriplegics rely on mouth-controlled devices to perform a variety of tasks and to establish some degree of self-sufficiency. The most functional mouthstick appliances have custom-fitted mouthpieces which are fabricated by dental professionals, and in some cases are cost-prohibitive. An inexpensive lightweight mouthstick which incorporates a new thermoplastic mouthpiece and can be custom-fitted by the user is described.

Key words: *custom-fitted mouthpiece, mouth-controlled device, mouthstick, quadriplegic, thermoplastic mouthpiece.*

INTRODUCTION

Advances in medical care have increased the probability of patient survival from traumatic injuries to the spinal cord, but in many cases the injuries result in varying degrees of paralysis. Paralysis resulting in the loss of motor control to all four extremities is defined as quadriplegia. Currently, over 200,000 quadriplegics live in the United States; between 3,000 and 5,000 new cases occur each year (5).

This article describes the development of an improved mouthpiece for a device used by quadriplegics and others with partial or complete arm and hand paralysis. The device, commonly referred to as a mouthstick, is a simple but essential tool that allows quadriplegics (and others without the use of their arms and hands) to perform a variety of routine functions, such as dialing a telephone, typing, or turning the pages of a book. A variety of mouthsticks are currently available; however, no single design has been universally accepted. Each device possesses inherent problems, ranging from the inadequacy of the materials selected for its fabrication, to the process used for its manufacture.

The mouthstick appliance described in this paper resulted from the collaborative efforts of the Departments of Orthopaedics and Restorative Dentistry at the University of Mississippi Medical Center, the Mississippi Paralysis Association, and the Biomaterials/Biomedical Engineering Division of the Institute for Technology Development. The final design of the appliance was achieved after a careful review of the existing literature (1-4,6-10) and obtaining input from the quadriplegic members of the Mississippi Paralysis Association. The following design criteria were used:

1. The mouthpiece should contact all fully-erupted teeth.
2. Biting forces should be distributed to all available teeth.

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3. The mouthpiece should have wide occlusal coverage to give lateral stability.

4. The materials used should be attractive, have an acceptable taste and texture, and should be able to be easily cleaned.

5. The mouthpiece should be inexpensive and custom-formable to the user's dentition with minimal assistance.

6. The mouthpiece should be unbreakable and stable in the oral environment.

7. Users should be able to breathe, wet their lips, and swallow normally with the mouthpiece in place.

8. The mouthpiece should be easily adaptable to accommodate various attachments.

9. The thickness of the mouthpiece after fit should be between 2 and 4 mm to prevent a gagging response.

10. The mouthpiece should be easily adaptable to changes in the user's dentition.

MATERIALS AND METHODS

Using measurements of dental arches from stone casts, the dimensions for an average y-shaped mouthpiece were determined. These dimensions were used to construct an injection mold for production of the mouthpieces. The mouthpieces were injection-molded from Surlyn™ ionomer resin, using a Morgan Press vertical injection molding machine. Surlyn, which is manufactured by DuPont, is a copolymer of ethylene and methacrylic acid. It has been used for a variety of orthotic appliances for many years, including splints and braces, because of its excellent resistance to impact, cuts, and abrasion. It is also resistant to chemical attack and permeation by liquids. In addition, Surlyn contains no plasticizers, and therefore, its long-term performance prospects are excellent. The Surlyn product selected for molding of the mouthpiece is Surlyn 8940, which has a tensile strength of 33.1 MPa, a Shore D hardness of 65, and a melting temperature of 181 degrees F (83 degrees C). The cation for Surlyn 8940 is sodium.

Figure 1 illustrates the design of the mouthpiece. The mouthpiece possesses a hollow cylindrical orifice which will accept a solid or hollow rod (diameters between 6.3 mm and 7.4 mm). The wings of the mouthpiece are 12.7 mm wide and 6.4 mm thick. The mouthpiece was designed to be compatible with commercial mouthstick kits, such as those offered by Fred Sammons, Inc., Brookfield, IL, or Abbey Medical Distributors, Bernyn, IL.

To evaluate the mouthpiece design and materials, a simple mouthstick (shown in **Figure 2**) was fabricated. A graphite-epoxy composite shaft, 40.6 cm long and 7.4 mm in diameter (obtained from Glassforms, Inc., San Jose, CA), was inserted into the mouthpiece. The shaft was secured in place

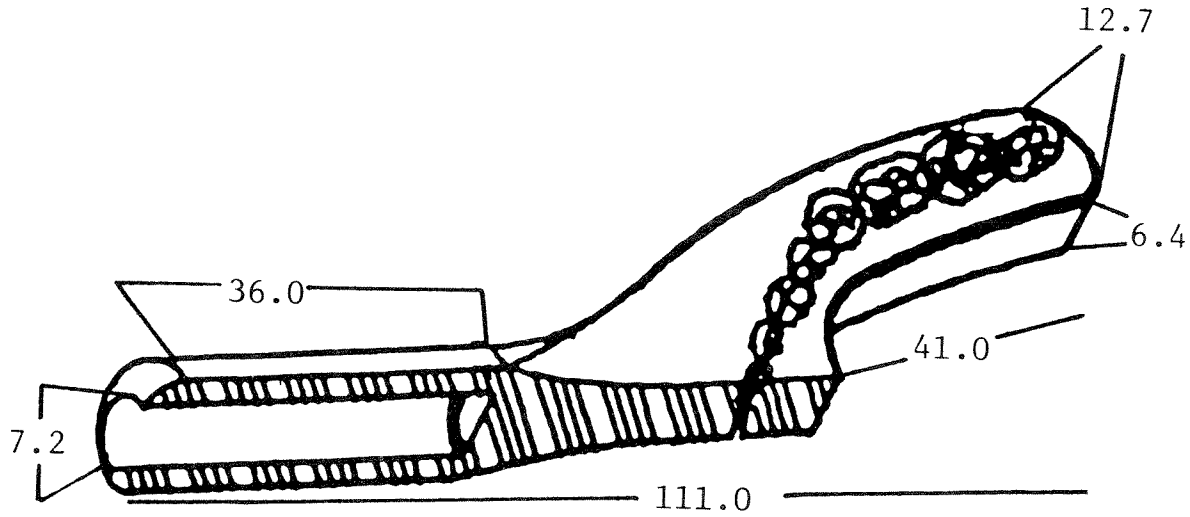

Figure 1.
Drawing showing a cross-section of the mouthpiece. All dimensions are in millimeters.

using a 76.2 mm length of heat-shrinkable tubing (ICO-Rally, Dallas, TX). A natural rubber pipet bulb (Fisher Scientific, Baton Rouge, LA) was used to cover the end of the shaft and to provide a high-friction surface for tasks such as turning pages, dialing a telephone, etc.

PATIENT FITTING

One of the major advantages of the mouthpiece is that it allows a mouthstick to be custom-fitted to the user at home in a matter of minutes. The first step is to heat the mouthpiece blank in boiling water for approximately 3 minutes, or until it softens and becomes moldable under moderate pressure. Following heating, a brief immersion (3 to 5 seconds) in cold tap water is used to cool the surface sufficiently to prevent tissue injury. The mouthpiece is then placed in the patient's mouth so that it covers all of the teeth. The patient bites down with sufficient force to impress the shape of the individual teeth into the cooling (but still soft) plastic material, as shown in **Figure 3**. The impression left by the teeth may range from 0.5 to 5 mm in depth. A fitted mouthpiece is shown in **Figure 4**. The mouthpiece is removed and allowed to cool further until it becomes rigid. The cooling process can be accelerated by placing the mouthpiece under running tap water. Since the mouthpiece material is a thermoplastic, the process can be repeated until a satisfactory fit is obtained. In addition, the angle of the stick can be adjusted to provide the optimum position for use by the patient.

EVALUATION

Five quadriplegic members of the Mississippi Paralysis Association were asked to evaluate the mouthsticks for a 6-month period. All participants had used another type of mouthstick before the evaluation period. The average time of use was four hours per day. The mouthsticks were used to

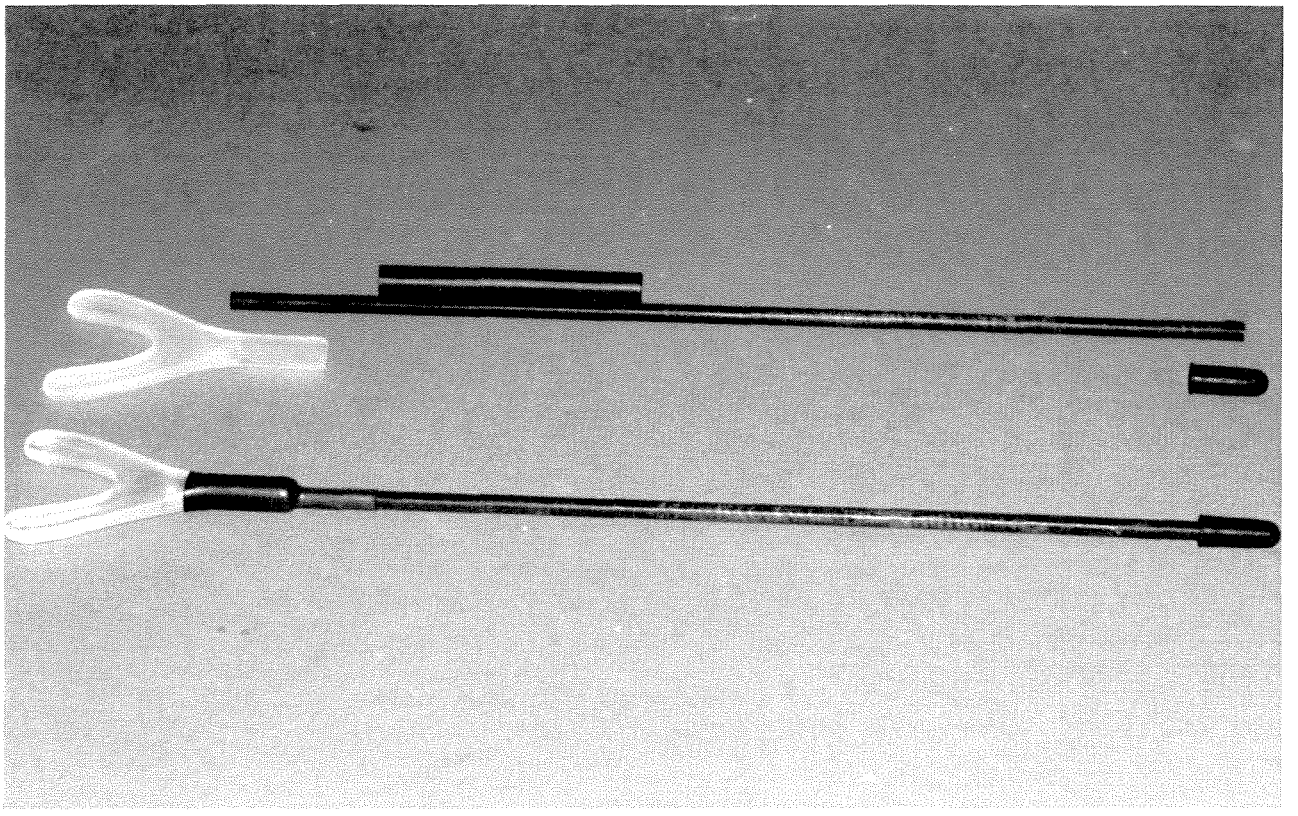

Figure 2.
The components and a fully-assembled mouthstick used for evaluation purposes.

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Figure 3.
An evaluator is shown making the initial bite impression into the mouthpiece. (Permission granted.)

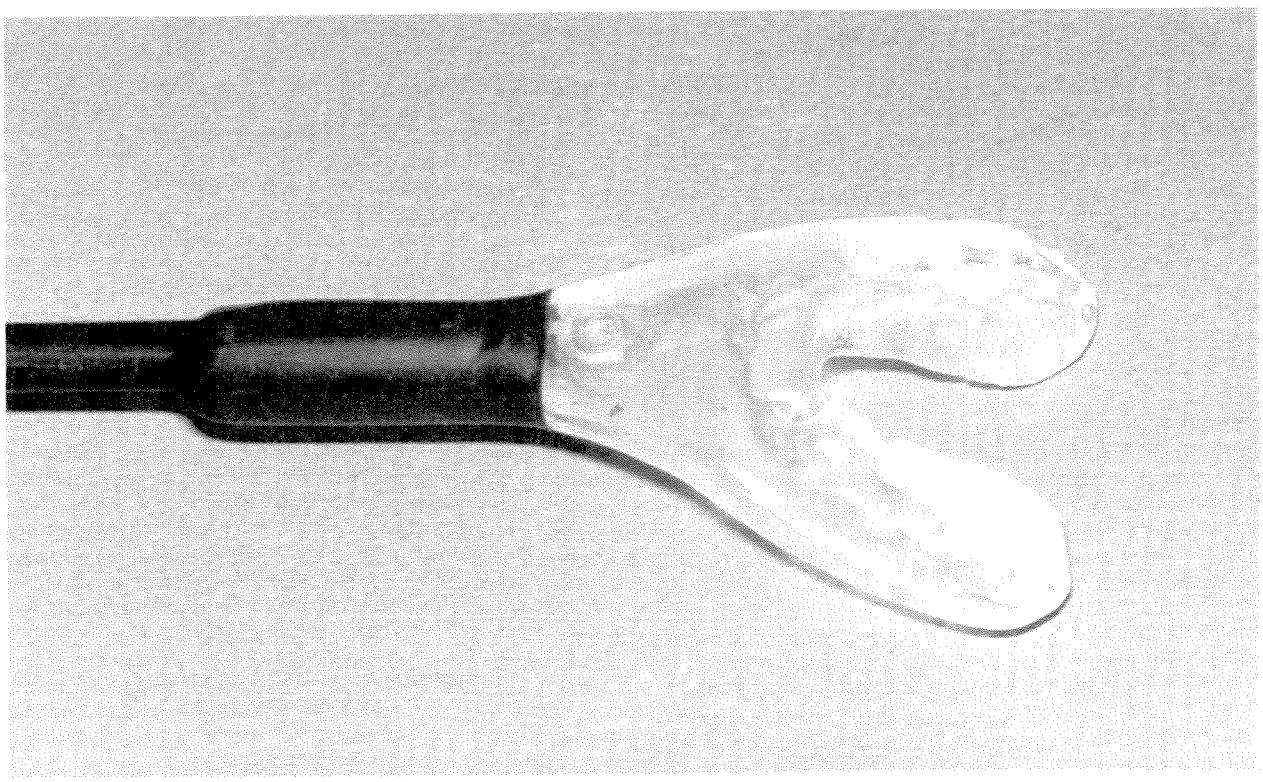

Figure 4.
The mouthpiece after an initial impression, showing the patient's bite morphology.

accomplish such common tasks as turning pages, or operating a telephone or computer terminal. An evaluator is shown turning the pages of a phone book in **Figure 5**.

Overall, the mouthpiece was well-received. A comfortable fit was obtained by all the participants and no problems with taste were encountered. One participant did report a slight irritation to the inside of the cheek; however, the irritation was attributed to a small amount of mold flash left on the mouthpiece and not to the composition of the thermoplastic material.

The ease of fitting and modifying the mouthpiece to the specific needs of the user were its two strongest points, according to the evaluators. Another particular advantage noted was the durability of the mouthpiece; in one instance, a mouthstick was run over by a van without damage. This incident would have been catastrophic for a mouthstick possessing an acrylic mouthpiece. At the present time, 50 mouthpieces have been in use for over a year with no failures reported.

Figure 5.
An evaluator is shown using the mouthstick appliance to page through a telephone directory. (Permission granted.)

CONCLUSION

A new and improved mouthpiece has been designed, fabricated, and tested. The mouthpiece is fabricated from a thermoplastic ionomer resin which can be custom-fitted to the user's dentition with minimal assistance. This mouthpiece eliminates many of the deficiencies encountered with current mouthpiece designs and materials.

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