REVIEW

Prosthodontic Rehabilitation for Quadriplegic Patients

Isha Rastogi, Jitendra Jethwani

ABSTRACT

"I can do all things through Christ who strengthens me.

Nothing is impossible for it says i-m possible. We should thank Almighty for He has given us 2 hands and 2 legs such that we are able to live a normal life. Let's take an insight into the life of a quadriplegic- which cannot use all his four limbs. Perhaps dentistry and Prosthodontics has progressed and we can easily help such patients with a mouthstick appliance. They can be fabricated easily, be inserted into the mouth, and work mechanically. E.g. reading, writing, or turning pages of a book. Advancement in technology has seen the evolution of a simple mouthstick to a fully integrated wireless inductive tongue computer interface for this disabled people. It helps handicapped patients to improve their mental outlook.

Keywords: Rehabilitation; Quadriplegic; orthosis

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Introduction

Let us start our day by giving thanks to God. He gives us courage such that we are able to perform impossible tasks too. He has given us 4 limbs that we can use and perform our daily life activities easily. But unfortunately it is not same for quadriplegics- who have lost motor control of all four limbs by paralysis.(1)They are sheer objects of sympathy and need a support/attender always.

Most of us have heard of Christopher Reeves, perhaps best known for his role as Superman. In 1995 he had a terrible horseback riding accident that left him paralyzed from the neck down. Christopher Reeves, now a movie director, wrote his autobiography "Still Me," in 1998. He presses on to live life to the fullest and overcomes nearly insurmountable tasks with his "abilities" every day of his life.

Another famous person who is paralyzed from the neck down is Joni Eareckson Tada. She suffered nearly complete paralysis in a diving accident. This famous artist and author celebrated twenty years of ministry to the disabled this November, 1999.

Physical barriers, financial limitations, poor motivation, and lack of qualified care providers are some of the difficulties that must be overcome.(19)

It is estimated that one out of two persons with a significant disability cannot find a professional resource to provide appropriate and necessary dental care. Lack of access to dental services for this growing segment of our
population is reaching critical levels and is a national dilemma.\(^{(21)}\)

Since our hands are the tools with which we sustain life, a major goal of rehabilitation must be to restore the ability to independently carry out common activities of daily living such as feeding, grooming, and manipulation of devices which may allow resumption of educational and vocational goals. As health care professionals in the rehabilitation field, we must be aware of advances in technique and equipment which can enhance the ever-increasing life span of this young population whose educational, economic, and social progress has been so severely curtailed. The role of the orthotist and occupational therapist as members of the rehabilitation team is to address this very underemphasized problem of upper limb management.\(^{(17)}\)

Any intervention that improves independent function of a person with quadriplegia enough to reduce this need for attendant care should be investigated. Furthermore, if a device can allow a quadriplegic person to be gainfully employed, the cost to the individual and to society would be further reduced and the person with quadriplegia could be much more self-reliant.\(^{(12)}\)

Rehabilitative medicine and occupational therapy have long been involved in efforts to rehabilitate patients who have little or no functional use of their upper extremities.\(^{(16)}\)

In rehabilitation, patients are helped to use their remaining strengths to compensate for or adapt to losses resulting from various physical dysfunctions. Persons with severe upper extremity limitations often retain mouth, jaw, and neck control. They can be taught to use these parts of their body to operate devices and thereby improve their functional skills. Devices controlled in this manner are referred to as *orthosis, mouth sticks, bite sticks, or mouth-operated devices*. Each device includes an extra oral portion, which consists of a shaft, a tip, and a holder, and an intraoral (mouthpiece) portion, which may vary widely in design and complexity, but which is intended to hold the device in the patient’s mouth.\(^{(8)}\)

More and more handicapped individuals may be seeking dental treatment. Treatment may include construction of special devices to help these patients lead more productive and fulfilling lives.\(^{(3)}\)

A quadriplegic requires an aiding device therefore such patients are much relevant to our field. This device enables invalid persons to perform simple, everyday actions.\(^{(6)}\)

For individuals with upper extremity dysfunction, the use of an oral orthosis can be helpful in allowing the patient to communicate in written form, operate tape recorders and computers, telephones and other activities. A variety of devices are available on the commercial market and through local hospital rehabilitation medicine departments or physical and occupational therapists. A relatively simple orthosis can be constructed by the dentist after determining the patient’s particular needs.\(^{(4)}\)

Mouthsticks enable an extensive variety of low-force manipulative functions within a limited distance of the operator’s head. Quadriplegics rely on mouthstick appliances to perform a variety of tasks to establish more self-sufficiency. Techniques to fabricate a quality mouthstick appliance requires professional expertise, time, and laboratory expense.\(^{(5)}\)
Rehabilitation of quadriplegic patients is a significant challenge to health care resources and many of these patients need to use mouthstick appliances to control their environments. (2)

Quadriplegic patients rely on mouth-controlled devices to perform a variety of tasks and enhance their intellectual well-being. The mouthpiece or mouthstick allows these patients to express their artistic abilities, communicate with written words, utilize a computer keyboard, and perform functions which would otherwise seem impossible. A variety of mouthstick designs are available; however, no single design can be used for every function. (7)

1. REVIEW

Historically, dentists were reluctant to treat the medically compromised because of the patients' fragile physical conditions and the dentists' lack of training in this area. Today, dentists receive education in the management of the medically compromised and routine dental treatment of these patients has become commonplace. (18)

The use of these devices was first widely reported in the 1950s, when mouth sticks were used extensively with clients who had poliomyelitis (Bastable, 1956; Buckley, 1957; Evans & Cooley, 1956; Georgia Warm Springs Foundation, 1957; Moore, 1956; Sniderman & Hollis, 1954). Currently, persons with spinal cord injuries constitute the major population using mouth sticks.

Dental, occupational therapy, and rehabilitation medicine literature contain no follow-up studies on the long-term effects of mouth-stick use. Dental literature reflects general agreement on design standards for the intraoral components of mouth sticks and orthodontic devices and on the commensurate risks associated with mouthpieces that fail to meet those standards. Occupational therapists, who are responsible for recommending individual mouth sticks and for training clients in their use, make key clinical decisions based on knowledge that emphasizes client function rather than oral safety.

Three widely used textbooks on occupational therapy for physical dysfunction introduce mouthstick use but do not discuss design or precautions, factors that must be considered in occupational therapy treatment (Pedretti, 1985; Spencer, 1983; Trombly, 1983) Wilson, McKenzie, Barber, and Watson (1984) offered information on mouth-stick components and mouth-stick use and stated that a mouthpiece based on a dental impression could "further distribute pressure over the molars". However, they did not describe what circumstances would lead the therapist to use a dental impression in the mouthpiece design Nawoczenski, Rinehart, Duncanson, and Brown (1987) stated that the mouthpiece should be made by a dentist, but they did not provide the rationale, design, and treatment precautions necessary for the therapist to make well-founded decisions regarding treatment. (8)

The use of mouthstick activities with the CJ to C4 quadriplegic patient is a major component of an occupational therapy program. Skills in these activities allow patients to perform otherwise impossible tasks. According to Jay, people with these levels of spinal cord injuries are not commonly seen in rehabilitation centers because of either an early death or too severe of a traumatic injury. Two major textbooks used in occupational therapy schools do not address C1 to C3 quadriplegic persons, but these
books state briefly that mouthstick activities may be performed by C4 quadriplegic persons. The mouthstick activities mentioned are typing, page turning, and writing. Additional activities (e.g., painting and playing cards, checkers, and chess) are explained and illustrated. Functional aids references describe the use of mouthsticks and construction guidelines for them. Although the literature is replete with information that describes types of mouthsticks and their uses, there appears to be no information describing a structured program of mouthstick training or other aspects of occupational therapy treatment for the C1 to C4 quadriplegic patient.

Most mouthstick prostheses previously described in the literature have severely limited application or availability. They are either highly specific and sophisticated and difficult to fabricate or very crude and uni-functional. Most do not conform to basic functional and physiologic criteria as outlined, nor are they sufficiently flexible to meet the various needs and physical capabilities of a wide spectrum of patients. But it is different now.

The possibility of periodontal disease, chipping of various teeth, or extrusion from use of a mouthstick is minimized with a mouthpiece that covers the complete dentition. Even the simplest of these devices permits increased function for the quadriplegic patient.

Dental Theories
Dental principles of mouthpiece design are based on three orthodontic theories (Hemley, 1938):
1. Functional pressure on teeth stimulates bone development.
2. Excessive pressure retards bone development.
3. Bone grows along the path of least resistance.

Hemley supported the application of these principles to the design of bite plates.

Potential Problems
Improperly fitting mouth sticks, such as a round dowel or an anterior bite stick that contacts only the anterior teeth, can cause several oral problems (Buckley, 1959). Damage to the anterior teeth can result from degenerative and necrotic changes in the supporting periodontal tissue, stretching of the periodontal ligament, and re-absorption of the angular bone. This damage becomes evident when the teeth move, wear unevenly, and abrade (Buckley, 1959; Materson & Lotz, 1975).

A second problem that can result from improperly fitting mouth sticks is "eruption [movement in the direction of no pressure] of the posterior teeth and eventually whole mouth distortion" (Buckley & Slominski, 1958, p. 24). This problem is often identified by the dentist before the mouth stick user becomes aware of it. A third potential problem relates to the vertical dimension of the mouthpiece. The use of any oral device can cause temporomandibular joint dysfunction if the required mouth opening is greater than that in the physiological resting position (2-mm to 3-mm vertical opening) for extended periods of time (Materson & Lotz, 1975). This disorder generally begins with temporary muscle pain, proceeds to chronic pain, and then makes it difficult for the user to open his or her mouth. In addition to these oral problems, Buckley (1957) cited the following functional problems that can result from improperly fitting mouth sticks: (a) inability to insert and remove the mouth stick independently, (b) poor retention of the mouth stick, (c) poor lateral stability, (d) unpleasant taste, (e) gagging, and (f) fatigue.
Dental Standards for Mouthpiece Design (8)

To address these problems, Blaine and Nelson (1973) established the following standards for mouthpiece design. A mouthpiece should:
1. Not exert pressure on erupting teeth but should fully contact all completely erupted teeth to prevent supraversion and to distribute the biting force
2. Be stabilized on opposing teeth with the jaw in or closed from the physiological resting position
3. Provide wide occlusal coverage for lateral stability
4. Allow for retention without pressure when in use
5. Permit independent insertion and removal
6. Be (a) comfortable, (b) sturdy enough for a variety of functions, and (c) out of the client’s line of vision
7. Allow the necessary tongue movement for talking, swallowing, and wetting the lips while in place
8. Not act as an orthodontic device (i.e., function to correct dental irregularities)

Fabrication of a Mouth Stick (8)

Dental literature indicates wide support for these standards and offers detailed descriptions of designs and fabrications for mouthpieces that meet the standards by fully covering all teeth. Some of these mouthpieces cover the palate and some do not. The fabrication of a mouthpiece that provides this coverage and fit requires that maxillary, mandibular, and interocclusal impressions be made: and positioned on an articulator to establish the correct interocclusal relationship. Wax onlays are then made on the casts over a metal frame designed to interface with the extraoral portion of the mouth stick. Finally, these onlays are processed in a dental laboratory to remove the wax and produce an acrylic mouthpiece. Blaine and Nelson (1973); Frankel, Hawkesford, and Simonson (1975); Lutwak (1979); Materson and Lotz (1975); Mulligan (1983); O’Donnel, Yen, and Robinson (1985); Olsen, Prentke, and Olsen (1986); and Smokier and Rappaport (1979) presented detailed procedures for the fabrication of a mouth stick and also demonstrated the ability to achieve both safety and function.

A variation reported by Kozole, Gordon, and Hurst (1985) follows the same preparatory steps but creates a metal bite fork that is contoured to the dental arch. This bite fork is coated with a resilient ethyl vinyl acetate thermoplastic shield (mouth guard material), and a heat gun is used to mold the material to the casts to create a mouthpiece that has improved durability and fit.

A mouth stick’s extraoral components can provide telescoping action or prehensile function (see Table 1) (Cloran, 1974; Garcia & Greenfield, 1981; Kozole et al., 1985; Lutwak, 1979; O’Donnel et al., 1985; Olsen et al., 1986; Stow, 1966) These components have resulted in a variety of commercially available products.

### Table 1 Extraoral Component for Mouth Stick

<table>
<thead>
<tr>
<th>Function</th>
<th>Mechanism</th>
<th>Method of Activation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telescopic action</td>
<td>Extending wand</td>
<td>Tongue activates external battery power to extend shaft</td>
</tr>
<tr>
<td>Telescopic action</td>
<td>Interlocking(docking) action</td>
<td>Pressure exerted through the mouthpiece and shaft with a friction grip snap locks shaft to tip portion</td>
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<tr>
<td>Telescoping action</td>
<td>Ball and socket action</td>
<td>Protrusive-retrusive (anterior-posterior) jaw motion activates ball and socket which extends shaft portion</td>
</tr>
<tr>
<td>Prehensile function</td>
<td>Pincer</td>
<td>Bite closes pincer arms. Tongue protrusion closes pincer arms. Protrusive-retrusive jaw motion activates ball and socket.</td>
</tr>
<tr>
<td>Prehensile function</td>
<td>Suction</td>
<td>Slipping action creates vacuum to hold light weight objects</td>
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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 has been described by Puckett et al(1).

They combined department of Orthopedics, Restorative dentistry and Biomaterials for this, criteria used was:

1. The mouthpiece should contact all fully erupted teeth and biting forces should be distributed to all available teeth. The mouthpiece should have wide occlusal coverage to give lateral stability. The materials used should be attractive, have an acceptable taste and texture, and should be able to be easily cleaned. The mouthpiece should be inexpensive and custom-formable to the user's dentition with minimal assistance. The mouthpiece should be unbreakable and stable in the oral environment. Users should be able to breathe, wet their lips, and swallow normally with the mouthpiece in place. The mouthpiece should be easily adaptable to accommodate various attachments. The thickness of the mouthpiece after fit should be between 2 and 4 mm to prevent a gagging response. The mouthpiece should be easily adaptable to changes in the user’s dentition.

2. 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 hardness of 65, and a melting temperature of 181 degrees F (83 degrees C). The cation for Surlyn 8940 is sodium.
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 fabricated. A graphite-epoxy composite shaft, 40.6cm long and 7.4 mm in diameters (obtained from Glassforms, Inc., San Jose, CA), was inserted into the mouthpiece. The shaft was secured in place 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.

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. The impression left by the teeth may range from 0.5 to 5 mm in depth. 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.

The ease of fitting and modifying the mouthpiece to the specific needs of the user were its strongest points. 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.

This 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.

G Schmeisser et al in 1979 wrote about a motorized mouthstick holder that moved the mouthstick within easy reach of the user, allowing full access to the keyboard. (11)

D L Goldstein in 1992 wrote about the mouthstick appliance for a 7-year-old quadriplegic male with paralytic scoliosis, including weakness of the right neck and facial muscles. The appliance was constructed in coordination with the child's occupational therapist, who was dissatisfied with those presently available. This appliance has enhanced the child's ability to communicate, learn, and better enjoy the pleasures of childhood.

Following initial oral examination, alginate impressions and an occlusal wax record were obtained and the models mounted in centric relation on an articulator.
The screw portion of a stainless steel bicycle spoke (Wheel smith Fabrications, Inc., Menlow Park, CA) was placed on the cast perpendicular to and directly behind the maxillary central incisors. Next, a maxillary biteplate with a uniform thickness of approximately 2 mm was fabricated in occlusion with the mandibular model using orthodontic cold cure acrylic. The spoke screw was embedded in the resin with the screw entry hole left exposed to allow attachment of the spoke. The acrylic covered the occlusal surfaces of the teeth, and the palate, and ended at the junction of the hard and soft palate. To enable additional retention, the acrylic engaged the buccal height of contour of the teeth. The appliance was equilibrated and then polished. A Klick pencil holder (Fred Sammons, Inc., Brookfield, IL) was soldered to the bicycle spoke end. A pencil, brush, stylus or any other desired device now could be secured firmly in the holder's spring-loaded rollers.

J E. Viljoen has written bout different bitesticks.  

1. Tooth–borne oral device: This is a tooth-borne device with a mechanical rod fixed to a mouthguard, exiting the mouth in order to operate a keyboard. Advantages of this device include: No biting forces are required for this device, inexpensive to fabricate, simple to use, occlusal forces are equally distributed throughout the device. Disadvantages of this device include: the length of the device can't be altered by the user.

Telescopic oral device: This is a telescopic mouth instrument, which is held in position between the teeth, which gives a large working range from the mouth. The telescopic instrument is completely self-contained with toggle and push-button switches, or sub miniature micro switches. Advantages of this device include: the length of the extending mechanical rod can be altered, no biting forces are required in order to retain the device, the patient is self-supporting when using the device. Disadvantages of this device include: heavy in mass, difficult to fabricate and use, expensive to fabricate, require maintenance.

Extra oral chin cap: This is a chin cap, which is secured with straps around the head. A rod extends from the chin cap operating the keyboard. Advantages of this device include: easy for the patient to communicate with this device, easy to keep this device clean. Disadvantages of this device include: uncomfortable for the patient to wear, user has no independence when making use of this device, and therefore, another person has to put the device on and remove it after use.

Most suitable and chosen treatment option: The mouthstick device

Reasons: inexpensive to fabricate this device, simple for the patient to use, device is easy to fabricate, not necessary for the patient to extend or retract the device.

Laboratory procedures: Impressions were taken from the special trays, which were fabricated, and models were then cast. Plans were then drawn up for the special mechanical parts and these plans were then taken to Omnipless engineering company where the parts were manufactured. These parts were all made from anodized aluminium, due to the fact that the metal is light in weight, and corrosion resistant. The fabricated parts consist of an extra-oral mechanical rod, which is approximately 30 cm in length, with a 130° anterior bend 10cm posterior to the anterior tip. A magnetic tip was incorporated in the tip of the rod for the various tips to snap into position. A special U-bar was fabricated which screws into the posterior side of the rod,
which in turn attaches to the gum-guard. Various tips were then also fabricated for the patient in order to accommodate her in various tasks such as typing, drawing, and painting.

Custom made aluminium tips made to facilitate patient in various tasks such as typing, painting and drawing. These tips are also made from aluminium, but has a miniature stainless steel disc incorporated within the tip in order for the tip(s) to snap into position when making contact with the anterior, magnetic, part of the mechanical rod. Two-ply gum-guard material is then applied to the maxillary model, by the use of anerko press thermo-vacuum machine.

This gum-guard material is a thermoplastic material, which means that is softens upon heating, and hardens upon cooling. The gum-guard material is then trimmed to the deepest part of the sulcus as indicated with red in the photo below. Four holes are then carefully drilled into the U-bar, and special Dentaurum screw sleeves are placed. The U-bar is then further secured to the gum-guard material by the use of orthodontic acrylic, which is applied into the inter proximal surface found between the gum-guard and the surface of the U-bar. It is then finished by pumicing and polishing the device in a conventional manner.

The construction of a tooth-borne oral device with a magnetic anterior tip to facilitate a quadriplegic in the use of a keyboard has been described. Taking part in tasks involving more than just the application of existing knowledge could contribute to the help of other people with disadvantages, capable of being reduced or eliminated by such participating individuals (13).

Discussion

This appliance was simple to construct, economical, adaptable, and readily acceptable to a quadriplegic patient. The mouthpiece is lightweight, durable, stable in the oral environment, and easily and quickly inserted with minimal modification. It proved to be comfortable for the patient and has required very little training.

Initially, the patient was only able to tolerate the appliance for several minutes before tiring; now he uses it for hours at a time. In only two weeks, he was able to begin using watercolors with a brush, punch a computer keyboard, and dial a telephone. A special drawing table has been constructed for this patient; it can be moved up and down with his mouthpiece. This appliance has provided him with a more positive attitude, boosted his morale, and increased his motivation by opening a whole new world of activities. An individual may not accept the appliance, so it is advisable to construct a trial mouthpiece. To test this patient's tolerance, a vacuum-formed soft mouthguard initially was fabricated. According to Hemley, the deposition of vertical alveolar bone may be disrupted by abnormal pressures when permanent teeth erupt. If a patient has a mixed dentition, the appliance design should allow for this normal bone development. In this mouthpiece, anterior teeth were left uncovered, and the area immediately above the occlusal surfaces of the six-year molars was relieved to allow for their continued eruption and normal bone growth. The mouthpiece would function best with the anterior and posterior teeth fully covered, incorporating the buccal surfaces, but in this case the anterior teeth were not included, and the appliance proved stable.
These modifications should enhance the fit of the appliance and decrease the need for future adjustments and fabrications. Following complete eruption of the anterior teeth, a new appliance including coverage of these teeth should be constructed to prevent their over eruption.

One also must anticipate remaking the appliance between ages 10 and 12 to accommodate the remaining permanent teeth. Continued use of this appliance is needed to decide if these modifications are justified, and to determine the effects on occlusion.

The incorporation of a bicycle spoke makes this appliance unique. Individual spokes are easily inserted into and removed from the embedded screw and can be modified through shortening or bending to the desired length and angle. The attached holder further enhances the appliance’s versatility. This patient continually expresses excitement about and appreciation for the availability of his new appliance. Using this special mouthpiece, the patient has every chance to better develop and enhance his own cognitive skills, resulting in a more productive and fulfilling life.

RECENT

In relation to computer interfaces for disabled people, aesthetics have a high priority, and discreet interfaces are therefore desirable. One way of implementing a discreet interface is to hide the major part of the interface inside the mouth. Different interfacing methods have previously been attempted, such as electrical contacts, hall elements, and pressure sensors. The later being the most successful method, resulting in a commercial product. Still, having 9 sensors, this commercial system is far from utilizing the high selectivity of the tongue, this can easily pick out each of our 32 teeth. Further, talking and drinking alone is capable of generating tongue-palatal forces of up to 20-60% of the maximal obtainable force. This motivates more research within other sensor technologies than those based on pressure. Recently, an inductive tongue computer interface was suggested and shortly after, a tongue interface based on magnetic sensors was presented. Nevertheless, none of these systems provide more sensors/commands than the commercial system from New Abilities, and none of the systems were fully integrated into the mouth. Therefore, this study presents a fully integrated wireless inductive tongue computer interface, incorporating 18 separate inductive sensors, distributed on a key area and a mouse-pad area. (15)

The interface fits into the mouth and can be activated using a small activation unit on the tongue. The system presents a novel design incorporating both a key area and a mouse area. Further, having 18 separate sensors, the system incorporates more sensors/commands than previously reported implemented for tongue control systems, and thereby allows for many different user commands. The preliminary results shown in this study indicates, that despite having 10 typing keys, and 8 keys for a mouse area, the system can produce a similar response time: 1.2 sec. with 84% correct characters as a system with only 6 command possibilities, resulting in a response time of 0.8 sec. with 87% correct characters. Still, practicing is necessary in order to obtain a consistent high typing rate, since there was great variability on the number of correctly typed characters in this preliminary study. We believe that the results encourages for further studies with disabled individuals.
CONCLUSION

1. Collaboration among dentists, occupational therapists, orthotists, and rehabilitation engineers exists in some treatment settings, as is seen in the literature (Buckley & Slominski, 1958; Frankel et al., 1975; Kozole et al., 1985; Sniderman & Hollis, 1954). Collaboration between dentists and therapists is especially important in mouth-stick provision and training. (8)

2. The primary purpose of the occupational therapy program is the development of skills that maximize independence for C1 to C4 quadriplegic persons. Despite severe physical disability and often decreased respiratory function, these individuals often achieve a level of function and control that was impossible in the previous decades. Occupational therapy, in combination with medical and engineering technology, has had a major impact on the rehabilitation of these patients. (14)

3. Health care providers need to embrace a multi-disciplinary approach to quality to meet the needs of persons with disabilities. Funders and purchasers need to provide flexibility in funding to enable a comprehensive primary care approach, while health service researchers need to adopt a broad view of quality to capture issues of importance for persons with disabilities. (20)

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