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Development of a Clarinet Embouchure Assistive Device for People Suffering from Synkinesis

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Abstract: Bell's palsy is a disorder of the 7th facial nerve that has the potential to develop into a disease known as facial synkinesis if the nerve heals incorrectly. Patients suffering from synkinesis experience involuntary muscular movements accompanying voluntary movements. This creates undesired affects for those who play a musical instrument requiring a correct embouchure to maintain tone quality. The goal for this project was to design and develop an embouchure assistive device for a clarinetist suffering from facial synkinesis to improve her ability to maintain the proper embouchure around the clarinet piece and increase her playing time to at least 30 min. Two different devices were created and tested with the clarinetist with the results showing definite improvement in the quality of play.

Introduction

Synkinesis is the result of misdirected nerves after trauma which may result in the degeneration of neurons. When these neurons regenerate, there is no telling which motor endplates they would regenerate against, as shown in figure 1. Patients experience abnormal muscle movements during normal movements, such as involuntary squinting while smiling [1].

There are several treatments available for synkinesis: surgery, facial retraining, biofeedback, mime therapy, and Botox. Surgical procedures are very rarely used due to the temporary effectiveness and post-operational complications. Patients usually receive facial retraining treatment coupled with one of the other three methods [3]. The clarinetist worked with in this project has been receiving Botox treatment while attending facial retraining sessions.

To achieve a good tone, the proper embouchure, which is the shaping of the lips around the clarinet mouthpiece, is required. A clarinet embouchure requires a tight seal around the mouthpiece and/or reed while withstanding the high intraocular pressure that builds up inside the mouth during play. The main muscles used in forming the proper embouchure are the buccinators, zygomaticus, and orbicularis oris pictured in figure 2. There are other facial muscles that play a role in embouchure formation, but are not as essential as the three listed. The buccinators are the muscles that counteract the high intraocular pressure in the mouth by compressing the cheeks inward against the teeth, preventing the cheeks from puffing out. The buccinators also pull the lips against the teeth. To control the vibration of the reed and maintain that tight seal around the mouthpiece, the orbicularis oris draws the lips inward and compresses them around the mouthpiece. The zygomaticus is the muscle that pulls the corner of the lips slightly upwards, often being compared to a smiling formation of the mouth.

Synkinesis prevents the engagement of these correct facial muscles while playing the clarinet, resulting in accelerated fatigue and discomfort in the muscles. Another muscle, the platysma, which is not a normal muscle activated while playing clarinet, also begins to pull the mouth downwards at the corners. This makes it difficult to hold the tight seal around the mouthpiece as the mouth is being pulled away. The embouchure, and thus the tone, is forfeited. A constant air leakage at the corner of the mouth on the effected side of the face is also present. Currently there are no devices on the market that would benefit a clarinetist or any other wind instrument player for that matter suffering from synkinesis. Therefore, to compensate for the negative effects of the disease, a functional embouchure assistive device is needed to help maintain a correct embouchure and tight seal on the clarinet mouthpiece, as well as to reduce the air leakage in order to improve the clarinetist's current embouchure and to delay the onset of muscle fatigue.

Method

The function and operation of the embouchure assistive device surrounds a therapy exercise used by the clarinetist in this project. An example of this technique is shown in figure 3. The exercise involved the therapist pushing inward and forward on the left cheek with three fingers towards the mouth while the clarinetist played. As the therapist held that force, the tone greatly improved and air leakage decreased. It was also declared by the subject that it became much easier to play and it reduced stress placed on the opposite cheek's muscles. Both embouchure devices developed would simulate this exercise in the form of a headgear design.

There were several requirements needing to be addressed before design and fabrication of the devices. The embouchure assistive device was expected to extend the subject's practice time from approximately 10 min to at least 30 min, preferably longer. During the extended time of play, air leakage should have been minimal, and the tone should have remained uncompromised. To this end, the embouchure device should have been able to apply a constant, firm force for an extended period of time. The forces it was anticipated to apply are shown in figure 4. Both the forward component of force, tangent to the cheek, and the inward force, normal to the cheek, were approximated to be 16 N each for a net total force of 22.2 N on the left cheek. The device should not have encumbered the subject's playing for extended periods of time, and thus should have been lightweight and comfortable to wear. The device should have been easy to use, easy to clean, and should have required no training. Additionally, the device and its components were projected to cost less than $200.

After the two alternative embouchure devices were constructed, the both devices had to have quantitative force measurement testing done as well as user testing to determine whether the headgear design and force application was the appropriate approach to overcoming synkinesis to play clarinet. The force measurements were done using a compressive spring strain gauge which could measure up to 178 N of force. A comparison between the devices' results along with the response from the subject was considered in determining which design is more effective in improving the overall quality of play.

Detailed Description of the Constructed Devices

Ring Headgear Device

The ring headgear design shown in figure 5 is a ring component that rests over the ear on the effected side of the face. For the ring, it was rapid prototyped out of ABS plastic, which was strong enough for the device's function. Padding was added to the bottom of the ring for added comfort when it's worn over the ear. The ring was painted with a metallic finish to improve its appearance. The ring is secured to the head with an elastic strap that comes across the forehead and goes around the lower portion of the back of the head. The length of the elastic strap can be adjusted depending on the subject's preference. Built into the ring is a track that crosses through the middle of the ring. It is level with the top of the ring and is as thin as possible to reduce contact between the track and the ear. A sliding component was designed to slide within the track rather than the outside to also eliminate uncomfortable contact with the ear. The force arm extending from the sliding piece was meant to work like a preset cantilever beam to apply the appropriate inward force to the cheek. The force arm was permanently bent inwards towards the cheek to a point where the end of the force arm would pass the position of the cheek. As the force arm is pulled back away from the cheek when the ring is being placed on the head, it would return back to its original position once the ring was secured; this would lead to the force arm pushing into the cheek. The force arm was made out of two layers of 1095 spring steel. The 1095 spring steel was chosen because of its high strength and elastic properties. By layering the force arm, it would increase its strength and would be able to apply more force to the subject's face. The force arm was permanently attached to the sliding piece at one end with two small screws. Also connected to the top of the sliding piece was a handle that would make the moving of the sliding piece and, hence the force arm, easier. Padding was added to the end of the force arm to make it more comfortable when the force was applied and to increase the contact area of the cheek to make the force more uniform and efficient.

To use the ring headgear device, the ring is placed over the ear and the straps are situated over the head to hold the ring in place. The force arm is already pushing on the cheek, so all that is needed to be done by the user is pushing the sliding piece forward. This causes the end of the force arm with the padding to push the cheek forward. The user can stop pushing the sliding piece once the overall force is applied to the appropriate position.

Advantages to the ring device are that it is easy to use, it can be easily adjusted with one hand, and it is lightweight. When the head moves, the force arm should continue applying force due to the preset cantilever beam. This makes the ring headgear device very dynamic. Disadvantages to the ring device are that the force is not easily relieved if the subject wants to take it off between songs and the sliding piece does not slide as easily as expected back and forth. Reason for this is because when the force arm is applying force to the cheek, it is also causing the sliding piece to pull up within the track. This causes the sliding piece to push more on the track and increase the tension, making it difficult to move.

Coil Headgear Device

The coil headgear device shown in figure 6 is a very simplistic alternative to the ring headgear device. The coil device is made of two layers of 1095 spring steel that circles around the head and continues into a force arm that ends on the cheek. The spring steel is bent and coiled tighter than the circumference of the subject’s head so that when placed on the head, it will wrap nicely around the subject’s head as it recoils back inward. This recoil also helps push the force arm into the cheek. To increase the force applied by the force arm and to aid in directing the force correctly, a reinforcement bar of 0.0048 m iron bar stock was attached to the backside of the coil where it extends over the force arm. The reinforcement bar, shown in figure 7, helps the coil maintain its shape and it pushes in on the force arm. For added comfort, the inside of the coil is padded. To enhance the stability of the coil device on the head, the entire length of coil was wrapped with black grip tape which creates a friction interface between the subject’s head and the coil. The black tape also adds to the aesthetics of the device. In addition to the grip tape improving the coil device’s overall appearance, covers were created to go over the coil. This provides more options for the appearance of the device and one can choose the type of cover from day to day. The covers are also washable, which will help keep the device sanitary.

Using the device is very simple. The coil is stretched out and placed on the head, adjusting it to the appropriate position on the head so that the correct force is being applied to the cheek. The coil would remain in its fixed position once released.

Advantages to using this device are that it is easy to use, has a sleek design, provides an appropriate force, is comfortable, has a professional appearance, and it is easy to disengage the force between songs. Disadvantages to using this device are that the force cannot be adjusted; it is one magnitude of force as long as the coil stays tight on the head.

Testing

Force Testing

Force testing was done using a mechanical spring-loaded compressive strain gauge that measured 1 N to 175 N. The testing setup can be seen in figure 8. Briefly, the strain gauge was clamped vertically, so that it could not move. Each design was then pressed on the table, using a support to make it flush with the top of the strain gauge. The force arm of each design contacted the top of the strain gauge, in order to mimic the force being applied when the device would actually be worn. This was done three times for both the ring and coil designs, respectively. The results of this testing can be seen in table 1.

In this manner, it was determined that the ring design applied a greater force of 9.24 N compared to the coil design's 5.87 N. The goal this semester was to design devices that were able to apply approximately 22 N of force, however, and thus these designs fell short of the proposed design goals.

User Testing

In addition to the more quantitative force testing, user testing was also done with the subject, who can be seen wearing each design in figure 9. Each design was evaluated with regards to comfort, ease of use, function, and aesthetics.

The ring design was tried first, since it excelled in the force testing. The ring over the ear, elastic straps, and force applicator pad were comfortable and easy to use, although it provided insufficient force and was aesthetically unappealing. Although the ring design is smaller and has an inner track, the contact with the subject's ear was still deemed unsuitable. Additionally, it is possible that by positioning this prototype over the ear, there may be some attenuation of the sound the subject hears while playing in a rehearsal or performance setting. It was also found that the elastic straps, while effective in the previous design, were unable to counteract the force applied by the cantilever on the subject's cheek. This reduced the amount of force the ring design was able to apply. While the force was still noticeable, it was found to be unsuitable for prolonged practice sessions. Finally, the sliding track mechanism was also found to be difficult to adjust using only one hand, due to frictional forces supplied from the connected cantilever.

The coil design was also tested and was found to be less comfortable, but had preferable aesthetics, supplied greater force, and was easier to use than the ring design. While the force supplied from the coil design was found to be greater than that of the ring design in user testing, the force supplied was still insufficient for playing times greater than approximately 10 min. Additionally, the lack of a force applicator pad made the contact of the force arm with the face less comfortable than the ring design. During user testing it was also noted that there are unwanted torsional effects while wearing the coil that make it less comfortable and less efficient at force application. However, the design was much more aesthetically pleasing, maintained its position well, and, importantly, did not seem obstruct the subject's hearing or uncomfortably contact either ear.

Future Development

Improvements will need to be made to each prototype, assuming the subject wishes to pursue each design. For longevity, the ring design would be made out of aluminum, although the force arm would still be 1095 blue spring steel. The elastic straps would be replaced with tougher, inelastic straps to counteract the force from the cantilever. These straps would also be padded for comfort and, if necessary, also have some adhesive properties to maintain the headpiece's position on the head. The sliding piece on the inner track would need to be smoothed to reduce friction, making it easier to move with one hand. Additionally, a greater depth of the ring may be preferable so that the track does not contact the ear. To apply more force, another sheet of 1095 spring steel may need to be incorporated into the cantilever. Alternatively, the cantilever could be preset in towards the face further, thereby applying more force. Finally, an engage/disengage mechanism would need to be designed so that the subject could remove the force being applied in-between pieces of music.

The coil design also requires some design improvements before regular use. The efficacy of the coil design is largely dependent on the supporting iron bar. This bar could be extended along the force arm, which would effectively shorten it and allow it to apply a greater force on the cheek. A mechanism could be designed to make this elongation adjustable for varying amounts of force. This same mechanism could also fulfill the requirement of an engage/disengage function. Addition of a force applicator pad to the cantilever is also desirable to make the device more comfortable and to mimic the more natural feel of three fingers applying pressure to the cheek. Additional padding along the inner surface of the coil could also make the design more comfortable to wear for extended periods. Since the coil design is heavier than the ring design, the supporting iron bar could be replaced with a similarly rigid, but lightweight alternative, such as aluminum or titanium. It is also possible that a hollow rod of any of these materials may be able to confer a similar structural stability to the solid bar while making the device lighter overall. Finally, removable coverings for the coil design with improved aesthetics could be designed to better match subject preference.

References

[1] Synkinesis. http://en.wikipedia.org/wiki/Synkinesis

[2] Nakamura, K., Toda, N., Sakamaki, K., Kashima, K., & Takeda, N. (2003). Biofeedback Rehabilitation for Prevention of Synkinesis after Facial Palsy. *Otolaryngology -- Head and Neck Surgery*, *128(4)*: 539 - 543

[3] Botulinum Toxin. http://en.wikipedia.org/wiki/Botulinum_toxin

Figures

Figure 1. Misdirection of neurons to wrong motor endplate [2].

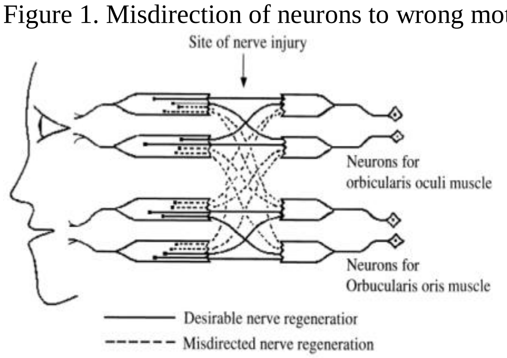

Figure 2. Muscles stimulated while forming the clarinet embouchure. The platysma is activated as well for a patient with facial synkinesis.

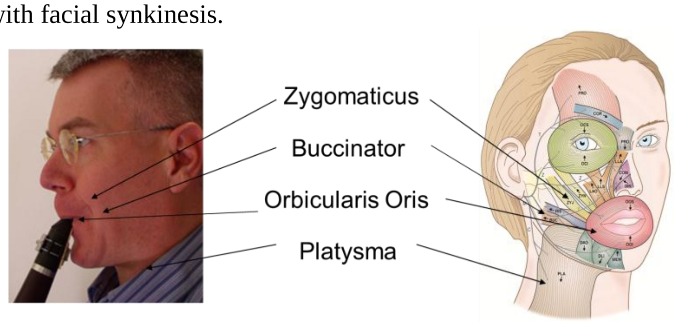

Figure 3. Therapy technique used with subject while playing clarinet. Force is applied inward and forward on effected side of face by the therapist.

Figure 4. Free body diagram of forces on synkinesis-effected cheek supplied by the device. The black arrow is the net force to be applied to the cheek. The green arrow is the required forward force (tangent to the cheek) and the red arrow is the required inward force (normal to the cheek).

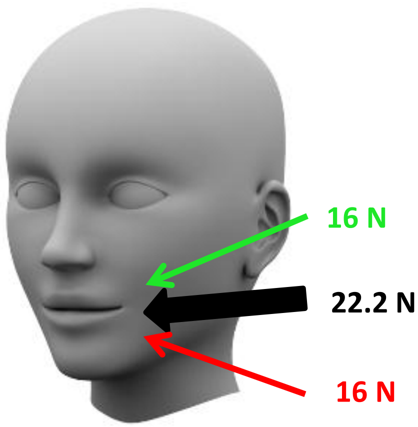

Figure 5. Ring headgear embouchure device developed for clarinetist.

Figure 6. Coil headgear embouchure device developed for clarinetist.

Figure 7. Reinforcement bar placed on the backside of the coil design.

Figure 8. Setup used for testing the applied force of each design.

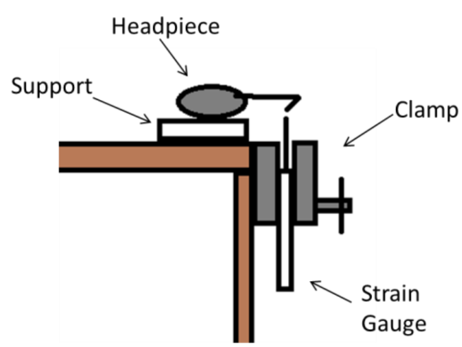

Table 1. Data from force testing.

Trial	1	2	3	Avg.
Ring	8.8 N	10.12 N	8.8 N	9.24 ± 0.62 N
Coil	4.4 N	6.6 N	6.6 N	5.87 ± 1.04 N

Figure 9. Subject wearing each design: ring (left) and coil (right).