UNIVERSITY OF WISCONSIN-MADISON
DEPARTMENT OF BIOMEDICAL ENGINEERING
BME 201 DESIGN

Temporomandibular Joint Disorder Device

Final Report

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Client: Jill Pongetti

Abstract

In the case of temporomandibular joint disorders, TMJ, there are often no easy solutions to the problem. Over the years there have been many attempts at finding a solution to the pain and discomfort that comes with the disorder, but as of yet there is no device on the market that is capable of doing this effectively. A device is desired that will relieve our client, Jill Pongetti of the UW Department of Surgery, of her pain and discomfort. After evaluating our designs in a design matrix and talking to Dr. John Doyle, Director of the Temporomandibular Joint Disorder Clinic, we decided on the massaging sling design. Future work involves further work on device components and testing on our client.

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Problem Statement

Our client would like a device that will effectively alleviate her pain that is associated with temporomandibular joint disorder. The client has been suffering from TMJ for the past 5 years and has been unable to find a solution to her problem. Heating/cooling components may be incorporated into the device if practical.

Background and Motivation

TMJ is a highly complicated disorder that can vary greatly in its severity and origin. There is no solid science as to what causes TMJ in certain individuals or how it can most effectively be cured. TMJ is both a physical and mental ailment [1]. Stress and other factors can cause an individual to grind their teeth and clench their jaw muscles, causing severe pain and discomfort. For some patients the TM joint pops out of the socket while in others the muscles strain and tighten Devices on the market for TMJ today are highly varied in their design and functionality [2]. To date our client has tried NTI devices (Figure 1) and full bite plates (Figure 2) but neither has supplied the level of comfort desired. These devices simply stop teeth grinding to protect the teeth and prevent further damage from occurring but do nothing to stop the clenching or allowing the jaw muscles to relax [3]. A design that addresses both the clenching and the grinding is desirable. Since

Figure 1. NTI Device.

Figure 2. TMJ bite plate, often referred to as a splint.

there is currently no such device on the market this gives our project the potential to be unique.

Design Constraints

Due to the nature of the project there are few constraints on the design. The patient stated that she would be willing to use any device that gives her relief from her pain and discomfort. However, there are still some restrictions on the design. The budget for the project including materials, fabrication and testing is $100. The device must provide relaxing massaging that will relax the patient's muscles while still being quiet and gentle enough so as not to annoy the client or keep her awake. The design must be easy to put on and take off with an easily adjustable strap to allow for specific placement of the vibrating sources.

Design Alternatives

There were three main designs we had brainstormed for this project. However, as the two devices that were not chosen are no longer relevant to our final design they have been omitted.

Massaging Device

Our third design alternative was a massaging device. This device will facilitate the patient's jaw relaxation. This design is completely different from our previous designs as it is placed entirely outside the patient's head and nothing goes inside the mouth. A strap wraps around the client's head and holds everything in place. It is made out of nylon with a soft interior surface on the patient's head. This allows for the strap to be strong and also

comfortable. The actual massaging components of the device are shiatsu massagers that would be attached to a supporting strap that allows them to be moved up and down to wherever the patient desires more massaging or heat at the time (Figure 5). The support strap has a belt buckle on the external side of the device that makes this possible. (Figure 6)

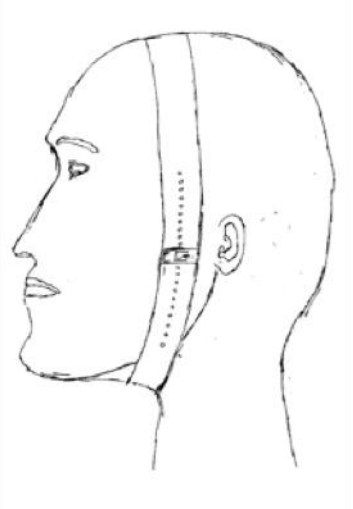


Figure 3. Side view of the massaging device, showcasing the adjustable belt strap.

The device would be powered by an Arduino microcontroller that would allow us to program the massager to turn on and off when the patient is clenching her teeth most regularly during the night. Research and testing would be necessary on the patient to see when exactly during the night she is experiencing the most excruciating pain [4]. Before this pain starts to occur we would be able to program the device so that it turns on automatically and massages the jaw muscles before they even begin to contract.

Since the device needs power to run the microcontroller and massagers this sill be supplied by an ac power adapter on the Arduino microcontroller. This approach eliminates worries about the Arduino or massagers drawing too much power from a battery source and shutting off in the middle of the night. However, the cord brings up the possibility of the client

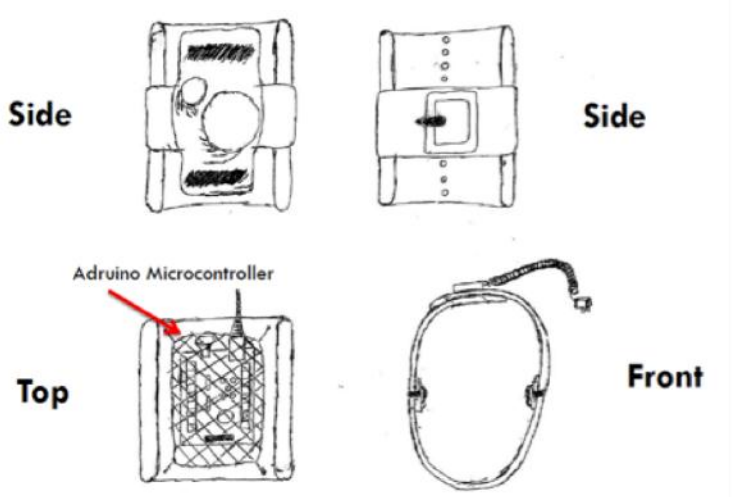


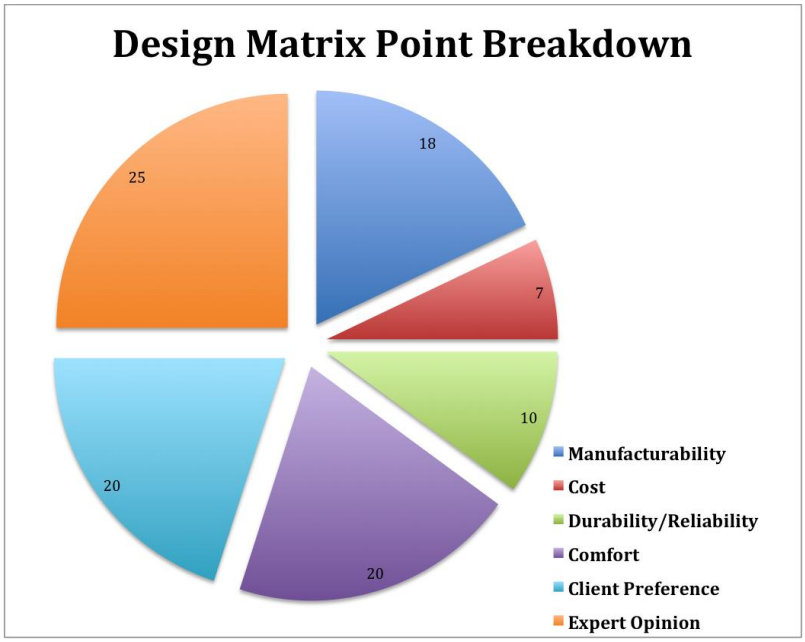
Figure 4. Massaging device

getting tangled in the wire. We solved this problem by using a curly cord that will contract as slack wire is produced. This will pull the excess wire towards the wall outlet and eliminate any worries about entanglement.

There is also the concern about the cost of the device. The massager device will be the most expensive design to implement for production but we decided that the benefits that come with the device far outweigh the extra cost that the device might incur. Used in conjunction with the bite plate that the client currently uses this device can potentially help to relieve most of the clients symptoms.

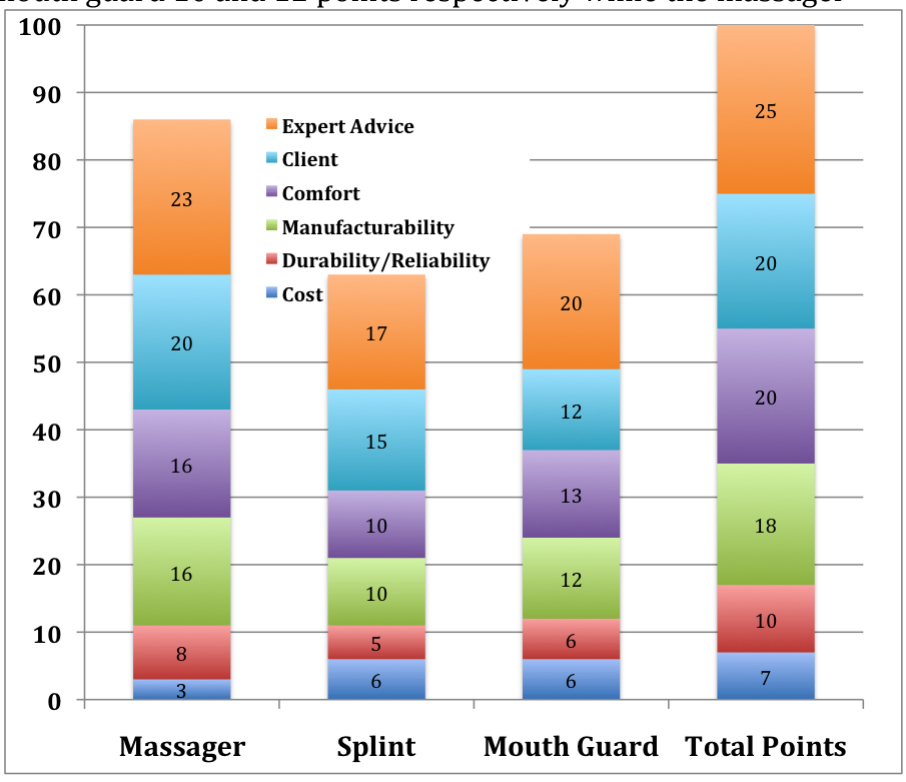
Design Matrix

The design matrix for the report was split into 6 different categories; manufacturability, cost, durability and reliability, comfort, client preference, and expert opinion. Figure ____ illustrates the point breakdown for each of the individual categories. The first category, manufacturability, received a total of 18% of the total points. Manufacturability is a necessary component of this design as the device must be custom fit to the client. Cost and durability were the next two categories and together they received 17% of the total points. The cost of the three devices was similar for each design



so this category was given limited weight. Durability was also given limited weight as the durability of the designs would be quite similar after production. Next comfort and client preference both received 20% of the total points each. Comfort is highly necessary as if the client is not compliant the device will not be used and hence will not do any good. This ties into client preference as if the client is not happy with the design she has at the end of the semester we have not done our job correctly. Lastly the expert opinion was given the most weight; while talking to Dr. John Doyle at the hospital he brought out interesting information that we had never heard before. Also he is the head of the TMJ department so any experience he has would greatly help our design.

For the manufacturability of the devices both the splint and mouth guard designs require molds be taken of the client's mouth to ensure proper fit of the device. This led us to assign the splint and mouth guard 10 and 12 points respectively while the massager received 16 points are since molds need to be taken for the massager. The cost of the splint and mouth guards would be similar and relatively inexpensive. The massager will be the most expensive design and therefore received only 3 out of the 7 points. For the durability and reliability of

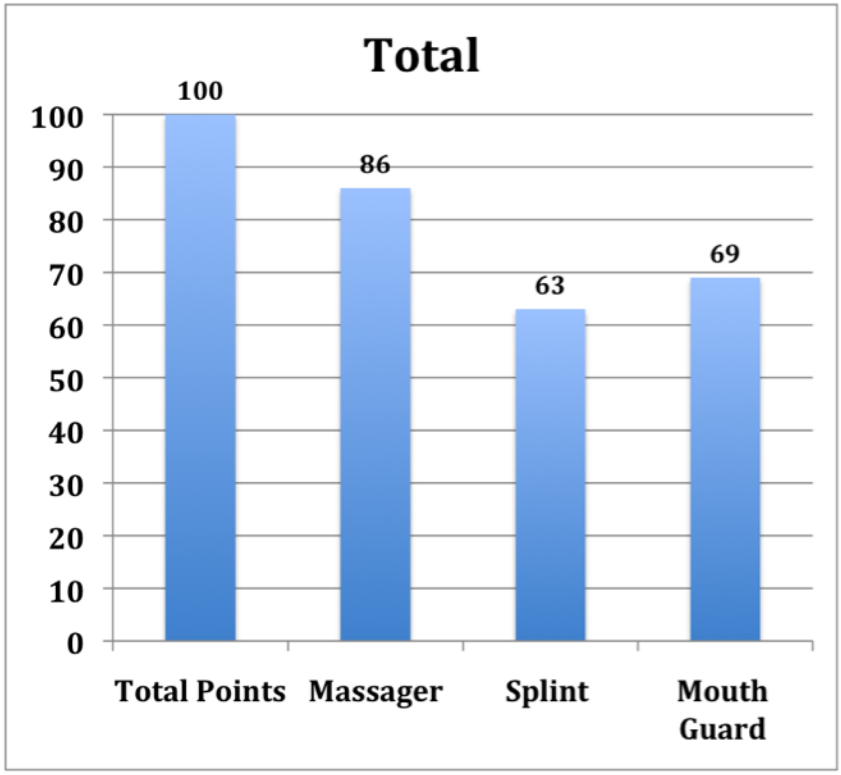


the design the splint and mouth guard both need to hold up to the pressure of the jaws clenching and strain. Since the massager is external and does not need to withstand these extreme pressures it received the highest marks in the reliability and durability area. Next the comfort of the device was considered. The splint and mouth guard both require a near perfect fit to be comfortable to the client. If even a small piece of the plastic mold is out of place it was be very irritating to the individual with the mold in their mouth. The mouth guard and splint are also relatively hard and unforgiving; if the patient desired to alter the device slightly it would be difficult to accomplish and new devices would become necessary if the client's teeth ever ended up moving slightly. However, the massager is highly adjustable and can be adjusted very quickly to the patient's preference. If they wanted to move the massager to a different spot on the side of their head all that would be necessary is the adjustment of the belt buckle strap holding the device in place. Also one side of the device could be removed if the client desired to sleep on her side instead of her back or if she wanted to temporarily take the massager and heat off of one side of her face. The next area we took into consideration was the client preference. The client already has a mouth guard that has been unsuccessful in supplying her with the level of comfort that she desires. The massaging device has the potential to improve her TMJ problem and she is very excited about implementing it and seeing if this is the solution she has been searching for all along. We therefore gave the massager 20 out of 20 points and ranked the other devices according to her perceived responses. Lastly we considered the expert opinion of Dr. John Doyle and gave it the most weight of 25 points. Dr. Doyle brought up considerations we had not thought of or even knew existed before such as the rupturing of certain teeth with the splint design [5]. We learned that uniform pressure was required

across the entire teeth line if a splint or mouth guard is to be used. Dr. Doyle seemed very interested in out massager design as there apparently is nothing like this out on the market today. He suggested we pursue this design and incorporate a warming or heat device into the design to help alleviate the client's pain as much as possible.

Final Design

After the design matrix was complete the totals for each design were accrued. The massager design emerged as a clear winner with a much higher percentage of the total possible points than the two other designs. These compelling results proved to us that the massaging device was clearly the best design option available. Although it may have been possible to design a splint or mouth guard that adequately addresses our client's problem there are already so many devices available on the market today the chances of coming up with an entirely unique and original design is minimal. The massager is therefore our chosen final design to pursue and is the one that we will be prototyping the second half of the semester.



The massager has the potential to greatly improve our client's TMJ problem when used in unison with the mouth guard she currently uses.

Fabrication

Headgear

The first thing we did when all our supplies came in was modifying the wrestling headgear. We drilled new slits in the earpieces for the head straps because the headgear was being used to fit the jaw and not the ears. We then drilled center holes in each of the earpieces for the receiving massager drive shafts. Since the jaw is further down the face, we had to add extensions to the Velcro straps so it could reach the jaw. We changed the position of the chinstrap, because after changing the head straps and the angle of the earpiece, the chinstrap was going across the mouth and not under the chin. The last thing we did was adding soft mesh material on the inside of the earpiece to have a non-irritating medium between the

Figure 5. Final prototype (Clockwise from top left): headgear with Dremel attachments; Dremel flexible shaft; device with Dreml shafts attached; motor and electrical controller

massager head and the patients skin.

Mechanical Massagers

The massagers were a little trickier to modify. First we deconstructed both the pillow and foot massager. We used parts from each one; the motor and electrical components from the pillow massager, and the massagers heads from the foot massager. The Dremel flexible shafts would transfer the torque from the motor to the massager heads inside the headgear. We had to modify each end of the Dremel shaft to connect it from motor to massager head. On the head of the Dremel (the part that connected to the massager heads), we welded the massager drive shaft to a Dremel tool tip that screwed into the head of the Dremel. On the tail end of the Dremel, we used a series of bolts and bolt heads to connect it to the motor drive shaft. We cut the head of a bolt off and drilled a hole through the center of it that had a circumference just a little bigger than the motor drive shaft. We then drilled a crosscut hole through the side of that bolt, which would connect to the motor drive shaft with codder pins. This modified bolt head was welded to the head of a 7mm bolt. This bolt was then screwed into the tail end of the Dremel shaft. We also added Velcro straps at the head of the Dremel shaft that could be connected to the headgear to give added support and/or alter the angle of the massager heads. To secure the motor and electrical components to the bedside tray, we used zip ties to strap it to the tray.

Budget

Description	Vendor	Cost
Foot Massager	Walmart	$40.00
Pillow Massager	Bed, Bath, and Beyond	$40.00
Miscellaneous Hardware	True Value	$30.53

Flexshafts	Ace Hardware	$74.63
Adruino Microcontroller	jameco.com	$35.14
GreatStuff Foam	Home Depot	$4.00
Box	Home Depot	$1.50
Bolts	True Value	$2.50
Headgear	matmonster.com	$28.00
Dremel tip, bolts, Velcro, and cotter pins	True Value	$25.00

When the team began buying some of the items and ran into complications, we realized that the client's initial proposed budget of $100 would not be enough to buy all of the necessary components of the massaging device. Therefore, we applied for a grant for rehabilitation since that was consistent with the purpose of the device. This grant should cover all of the expenses incurred from the construction of the device so staying within the $100 budget is no longer an issue.

Testing

Our client was given the opportunity to test the device for three days. After that time, our group met with her to hear her initial reactions and discuss what improvements she felt could be made to the device. Our client explained that she only used the massaging device on the left side of her jaw so she could determine whether or not the massager had any significant impact. She applied moist heat to her jaw muscles for five minutes using microwavable heating pads before using the massaging headgear. After using the device for fifteen minutes, our client said that she could tell a considerable difference between the left side of her face (the side to which the massager was applied) and the right side. In fact, she explained that the left side of her face felt more relaxed and she experienced less pain

and tension on that side of her face. Our client seemed very pleased with the device and was ecstatic to have a massaging device that she can use to help relieve the chronic pain and tension that results from TMJ. However, our client did have a few suggestions as to how the device could be improved to provide an even better massage to the temporomandibular joint. She felt using smaller rotating ball massagers would allow for a great surface area contact on the actually joint, allowing for a more thorough massage. Our client also suggested making the device fit more snugly on her face so that the massagers would come in closer contact with her jaw. We considered all of our client's feedback and suggestions when we made our final adjustments to the device.

Improvements

Client testing and team observations were used to determine what adjustments were necessary to improve the device's comfort and function. First, the smoothness of the rotating motion of the massager needed to be improved for when the client would be sitting in an upright position. To fix this, we added a Velcro strap to hold the Dremel shafts perpendicular to the head. This improved smoothness by ensuring that the Dremel shafts were in the proper position regardless of whether the client was lying down or sitting upright. Next, we secured the motor with zip ties to a holding tray that could clamp onto surfaces. This offered several different options of where to place the motor so that it remained stationed correctly in relation to the client using the device. Minor adjustments were made to the device to improve overall function. The cotter pins are responsible for holding the Dremel shafts to the gears and motor apparatus. We reinstalled the cotter pins so that they would neither bind nor bend as they rotated between the Dremel shafts and

motor apparatus. To increase the comfort and fit of the headgear, the chin strap position was adjusted. The chin strap was adjusted by adding additional holes to the earpiece of the headgear to improve the angle that the headgear fit on the head.

Future Work

There are several areas to be considered for future work should the project continue into future semesters of Biomedical Engineering design. Our client expressed interest in adding a heat component to the device that would help relax her jaw muscles while the massagers are turned on. Before using the massaging device, the client applied moist heat to her jaw muscles for five minutes using microwavable heating pads. She explained that the heat helps relax the muscles, making the massage both more comfortable and effective. Thus, a heating component would be a valuable addition to the device. We would also like to incorporate an Arduino microcontroller into the device. We initially ordered an Arduino microcontroller earlier in the semester with the hope of being able to run the device through pressure sensors. Our preliminary idea was to add pressure sensors to our client's current bite plate and connect these pressure sensors to the Arduino microcontroller so that the device would turn on when our client applies a certain amount of pressure to the bite plate (i.e. when she is clenching and/or grinding her teeth while sleeping). The Arduino microcontroller would then allow the massagers to be in operation only when the client is clenching and/or grinding her teeth, which is mainly when the device is needed. We would also like to modify the device so that the massagers can be run at various speeds according to the client's preference. In addition to the Arduino microcontroller, we would like to look into finding more compact massaging components that could be used instead of

relying on the Dremel flexible shafts. The Dremel shafts make the device bulkier and decrease the ease of transport, so if we were able to find rotating ball massagers that don't need a motor and can be battery-operated, the overall device would become more functional and marketable.

Ethical Considerations

With the final design selected, it is important that the client's comfort and safety continues to be a primary concern. Since the massaging device will likely be used while the client is sleeping, it is absolutely pertinent that we design the device so that the client can wear it safely and comfortably while lying down. The electrical cord attached to the device should not be able to get tangled around the client. As well, the heating components of the device should not overheat but instead stay at a soothingly warm temperature that is pleasing to the client.

References

[1] Donlon, William C., ed. Oral and Maxillofacial Surgery Clinics of North America: Diagnosis and Management of Facial Pain. Vol. 12. Philadelphia: W.B. Saunders, 2000. Print.

[2] Staff, Mayo Clinic. "TMJ Disorders -MayoClinic.com." Mayo Clinic. Web. 28 Feb. 2011. <http://www.mayoclinic.com/health/tmj-disorders/DS00355>.

[3] "TMJ Disorders." NIDCR. National Institute of Dental and Craniofacial Research. Web. 28 Feb. 2011. <http://www.nidcr.nih.gov/OralHealth/Topics/TMJ/TMJDisorders.htm>.

[4] “Timer.” Arduino Playground. Arduino Forum. Wed. 28 Feb. 2011. http://www.arduino.cc/playground/Code/Timer1

[5] Doyle, John. (February 25th 2011) Personal Communication / Interview

Appendix

Product Design Specifications

Problem Statement: Temporomandibular joint disorder, or TMJ disorder, encompasses both acute and chronic inflammation of the temporomandibular joint, which connects the mandible to the skull. Currently, patients with chronic and severe TMJ disorder use bite guards or bite plates. These devices help relieve pain but mainly serve to protect the teeth. However, these devices have proven to be ineffective since patients with bruxism clench and/or grind their teeth on the bite guards, resulting in chronic pain and inflammation due to increasing pressure on the joint and strain on the jaw and neck muscles. The purpose of this project is to develop a better night and/or day-time device for TMJ patients that keeps the jaw more relaxed, particularly during long periods (i.e. during sleep).

Client requirements:

- Alleviate muscle soreness that results from TMJ
- Durable and easy to clean
- Stays in place for full night's sleep
- Turning on and off at time intervals that would be effective and still conducive to the client's sleep
- Provides a high degree of comfort

Design requirements:

1. Physical and Operational Characteristics

a. *Performance requirements*: The device should be able to be worn on a daily basis for 8-10 hour periods. It should be easy for the client to put on and remove easily and fit comfortably on the head without causing discomfort no matter what sleeping position the client uses.

b. *Safety*: The material used for the device should be safe for the client to have on her head for extended periods of time. The device should be built in a manner to minimize the risk of strangulation by the device and its attached power cord.

c. *Accuracy and Reliability*: A high level of accuracy is not too necessary, since the fit should be adjustable. However, the massaging device should be accurate enough to target the key muscles and jaw areas to be effective. The electrical components need to have a high level of accuracy to give the correct amount of power without breaking down or short-circuiting. Also, the device should only consume a reasonable amount of power since it will be used on a nightly basis. Since this product will be used every night, it needs to have a high level of reliability.

d. *Life in Service*: The device should be durable enough to withstand 8-10 hours of use daily for 10 years.

e. *Shelf Life*: This device is custom made so it will not have a shelf life. After it is created, the client will begin using the device immediately.

f. *Operating Environment*: The device should endure a storage temperature range of -20^{o}C to 45 ^{o}C, and operate in a temperature range of 0^{o}C to 35^{o}C. The outer fabric of the device should be machine-washable.
g. *Ergonomics*: Client should easily be able to put the device on her head and strap it by herself. Also, it should not impede the client's sleep during the night.
h. *Size*: The device should be adjustable, but the size of the device should be able to fit the client's head. The massagers and microcontroller should be no larger than 8 centimeters wide.
i. *Weight*: The device should not exceed 500 g.
j. *Materials*: The strap should be nylon, with the adjustable component being buckle-like. The device will also consist of an Adruino microcontroller and the massaging and heating components.
k. *Aesthetics*, *Appearance, and Finish*: The device should be soft enough to not irritate the client's skin. The Shiatsu massager shouldn't cause discomfort.

2. Production Characteristics

a. *Quantity*: One device per client.
b. *Target Product Cost*: There are no current devices, but the budget is about $100.

3. Miscellaneous

a. *Standards and Specifications*: FDA approval is not required by the client.
b. *Customer*: The client is willing to try any solution that will provide pain relief.
c. *Patient-related concerns*: The device should be easy to clean whenever necessary.
d. *Competition*: There are no devices on the market. However the client could see a masseuse to have the same task accomplished.