Development of Tooth Retainer by 3D Printer

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Abstract

Additive manufacturing (AM) has been created 20 years ago. This kind of technology can manufacture parts without using tools, such as such as mold, die and lathe tools. It' s been improving its standards day by day. Came up with many advancements. The basic principle of AM technic is to build parts layer by layer. 3D printing is one technology of AM technic. It is the most common AM technic people can see in the daily life. This kind of direct metrical fabrication technology has been used in many aspects, such as aerospace, automotive, customer products, and medical applications. The purpose of this paper is to design a modal with required dimensions of tooth retainer and build it in the 3D printer and applying biocompatibility tests to compare the results. In recent years, orthodontic treatment becomes more and more popular. However, the normal orthodontic treatment is extremely expensive; and the process is complicated. 3D printing is a simple way to manufacture a tool of orthodontic treatment which can simplified the process of orthodontic treatment. This tool, named tooth retainer, also can reduce the cost of the treatment. The method that we used is to build up a model using NX 10 and then manufacture the model through the 3D printer, Objet30. The first step is to build up a model using NX10 and transfer it to STL file. The next step is to upload this STL file to Objet30's software and print it directly. After printing it out, the Objet30 machine should be clean. The last step is to remove the support material from the tooth retainer and clear it.

Major issues I find is when 3D printer prints this tooth retainer.

(i) it needs a lot of support material.
(ii) The shape of the tooth retainer should be modified because it is not an ergonomic tool.
(iii) 3D printing can reduce a lot of time in producing tooth retainer.
(iv) Material is not the suitable material for tooth retainers.

Key words:

tooth retainers, aligners, 3D printer, maker bolt, tooth problems, medical applications, object30, additive manufacturing, and analysis.

1. Introduction

The goal of retention is to achieve occlusal stability for aesthetics, and function following which the corrected tooth is kept stable by retention appliances. Orthodontic treatment alters the contacts of the tooth during the early stages of treatment, but after completion, the number of contacts increases with settling of the occlusion (Pravin deva prasad, 2013). The importance of the treatment to get good contact of tooth and aligned properly. Tooth positioners are well-known orthodontic appliances formed as an arch-shaped or parabolic body. Which are keep within a patient's mouth between the upper and lower arches. Adjustments are made to fit patient's teeth position surface. Will try to obtain the shape of the tooth retainer and manufacture it in 3D printer.

3-D printer is an additive process based on inkjet printing principles using a digital file to produce almost any shape via additive process that lays down the material into a successive layer of the materials. There are about 30 different types of 3D printing processes, which use and depending varying printer technologies, speeds, and resolutions, and hundreds of materials in a software computer-aided design (CAD) file that why they use it in medical applications. Where complex shapes can be created. 3D objects can be produced in 3D printers based on CT or MRI volumetric medical images. To manufacture tooth retainer in 3D printer first of all we need to know about basic 3D printer information.

1.1 Additive Manufacturing and 3D printing background

AM technic has been used in manufacturing for almost 20 years that can manufacture near-net shape components directly. It builds components through 3D model data. AM technic can reduce the time, cost, material, and energy (Herderick, 2011). In recent years, it becomes to enter the mainstream increasingly (Basic medical education (B. M. E.) 2015). AM build components by adding materials layer by layer based on a 3D solid model (Huang, 2012). According to Huang and his teammates, AM technic has some advantages. The first one is "customized healthcare products to improve population health and quality of life"; the second one is "reduced environmental impact for manufacturing sustainability"; the last one is "simplified supply chain to increase efficiency and responsiveness in demand. According to Piazza and Alexander, AM also has a lot of challenges. The first one is materials, the second one is systems, the third one is software, the fourth one is design and the last one is production.

However, this kind of technic is not mature and available in many different labs. Now a days Scientists, medical doctors, students and professors, market researches, and artists like to use it (Wong, 2012). It is hard to find it in manufactories. However, this situation has been changing very fast. Also, used for Biotechnology and Chemical Sciences for its improvements (Bethany C. Gross, 2014)

Some people begin to form a team and building their own 3D printer company. According to Wohler's Report 2010, the growth rate for 3D printing in 2010 was 24.1% (Wohlers, 2010). The below Figure 1 shows the growth of rapid prototyping according to author. Nowadays, this technic can be associated to computer-aided design (CAD), computer-aided manufacturing (CAM), and computer numerical control (CNC). CAD, CAM, and CNC technic can let 3D printer create three-dimensional objects directly. However, limited materials are the most important problem in 3D printing. In some situation, CNC machining is much better than 3D printing. Therefore, 3D printing still has long way to go.

2. Overview of study

2.1 Purpose of the study:

Where in this course am looking forward to designing a tooth retainer in designing software and make that modal in 3D printer equipment with accelerating the details in order to solve the problem in different aspects. 3D printers are used very highly in dental applications to solve many problems. By using 3D printers like maker bolt looking forward to obtaining the exact shape of the product. And going to apply biocompatibility tests on it where respected results gives furthermore details of the product.

2.2 Statement of Problem and its significance:

Tooth retainers are generally used to protect the teeth from the damages caused after the dental braces are removed. The correction of teeth may change once the braces are removed so in order to prevent this. Tooth aligners or retainers are used. Where every person has different alignment of teeth and different kinds of oral problems it differs from person to person. Same kind of tooth aligner can't be used by every person. It needs to be designed based on his oral structure. So, in order to make different kinds of tooth aligners based in sizes it takes very long time and it needs very high cost.

It is evident that 3D printers is the one of the best ways that anyone make their own design of tooth aligners. Economically costs very less. Takes very less time to make complex structured part. And no need to worry if the aligner is lost or broken it can easily make other. More and more people now a days want to do orthodontic treatment. More aesthetic and less visible orthodontic appliances are what they demand. According to Tarraf, 2013, orthodontic patients increase 23% comparing to 10% in 15 years ago (2015). Frongia and Castroflorio also mention that the number of adult patients has been increased in recent years. People have "a desire for aesthetic alternatives to conventional fixed appliances" (Frongia, 2012). When doing adult orthodontic treatment, several factors should be taken into consideration. The first one is there is no or little growth when doing orthodontic treatment. The second one is adults may have extensive medical and dental history. Therefore, it makes orthodontic treatment more difficult. In recent years, some new technologies can be used in orthodontic treatment, such as digital three-dimensional treatment-planning tools, aligner treatments, and lingual orthodontics (Tarraf, 2015).

3. Literature Review

In this literature (carl.T Drake, 2012), it consists of case reports, editorials and articles with biases. Clinical trials of the aligner have examined the entire course of treatment. There are two types of materials hard and soft. Different test was conducted as controlled clinical trial was performed at university of Florida in 2005 evaluating the safety, tolerability, and efficacy of recombinant human relax in during OTM using clear aligners. Designed a tooth aligner that instructed to were full time. They are allowed to remove while eating, drinking and brushing. Some scanning's are required to suggest the aligners they are (i) PVS impressions; (ii) Intraoral and extra oral and (iii) CBCT imaging

Injuries may occur in any kind of sports it might be organized competitive sports as well as unorganized recreational activities. Orofacial injuries may be caused for different causes. When the injury hits the mouth, it causes more impact in his/her personal life oral has soft organs like lips, gums, cheeks etc. If a person loses his teeth in any injury it might take some years to get back or else, he may lack it permanently. So, precautions should be taken to prevent this type of problems. So, after researching researchers found a way to fix this problem. They invented mouth guard in 1892 was made by Woolf Krause. Where it helped many sport persons. There are three categories of athletic mouth guards including the stock, mouth formed, and custom made. These three different types of mouth guards score differently on each of the following mouth guard qualities (Association, 2005). The most commonly used mouth guard mouth-formed mouth guards which are designed in such a way that it fits the teeth and covers it completely and decrease the air flow. There are different types and shapes of mouth guards well positioned to help prevent injuries

In this paper author address about how patients benefit from providing orthodontic solutions to orthodontic problems (Renato Pagani, 2016). Aligner therapy is very useful for many patents and it's been very successful in treating the oral problems. In this paper, they provided many live examples how they treated patents by clear aligner therapy. There are four types of tooth aligners he provided: (i) U-shaped; (ii) V-shaped; (iii) Square & (iv) Omega. U and v shaped aligners are used for small changes on tooth. Square is for bit complex. Omega are used for extreme shaped teeth and takes very long-time process.

This paper tells about the invisalign system treatment in orthodontic. The aim of the present report was to illustrate the management of a malocclusion by means of Invisalign system associated with the traditional surgical technique (Renato Pagani, 2016). Conducts tests the results shows how this system helped in solve oral problems. They presented a case to study deep into the subject. Diagnosed a 23-male patient presenting a Class III malocclusion with a lateral deviation of the mandible to the left side associated with a cross-bite of teeth 2.2, 2.3, and 2.4 measurements they noticed teeth position is not in right direction. Started putting the clear aligner and treatment carried for few weeks they noticed the changes of teeth by aligner. The teeth being getting to the right direction. They differentiated the changes before the aligner and after the aligner.

In this paper author address about the importance of mouth guards and how they are used. The author itself is a doctor and has an experience of 20 years he aims to research scientifically deep into the dental problems. He focused on why dental problems are formed and started to research on it. It is founded as damage is inversely proportional to area over which force is applied. Appling small amount of force can make huge change. So, he used same technology which can create a force by mouth guard by this moved teeth can be straighten easily. Mouth guard can be made of flexible material when it is compressed of enlarged it can easily come to its original position. Mouth guards are made in such a way that it fits correctly and adjust the tooth. The extra thickness of the Custom Mouth guard means that it can be compressed far further than a boil-and-bite mouth guard before springing back. Greater Elasticity = Less Energy (BDS) It protects the tooth from varies forces and when it is in impact it does not allow the force to the brain. Which protects the inner parts safely.

4. Methodology

Many people are using orthodontic braces very regularly to straighten their teeth. There are two types of orthodontic braces, one is orthodontic aligner braces and orthodontic retainer braces. Generally, braces are used to teeth with fixtures and clippers where it connects each tooth to one other through wire, so that it can straighten the teeth and make teeth to reposition to its original position but the usage is very difficult it has some disadvantages that is. It is very uncomfortable for the beginners and it leads to be painful. The most important problem is food traps in between the wires and clips it's very hard to clean it where it takes very long time to clean it.

Due to this type of drawbacks, tooth retainer become more and more popular now a day, especially invisible tooth retainer it can reduce these problems a lot. Usually they are used after the braces are removed these retainers are used for one or two hours a day which keeps the teeth in its position, to make an invisible tooth retainer has several steps. First is making a polymer impression of the teeth. Then create a 3D model to help doctor to develop a treatment plan. The last step is to produce the retainer. It's usually use stereolithography to produce the retainer. Using thermoforming processes for the thermoplastic sheet is also a very effective method. But today we focus on how to use additive manufacturing (3D printing) to produce the tooth retainer.

In this project, we design and use 3D printing machine to manufacture the tooth retainer. Basically, to use the 3D printing machine, we need use some software like three-dimensional CAD or NX to build a 3D model first. Below figure shoes the tooth retainer image.

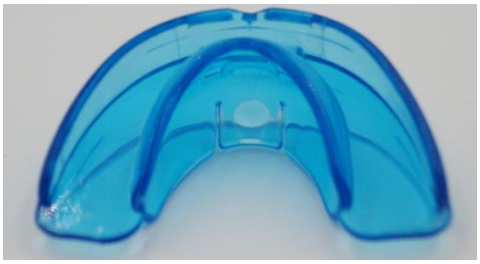

Figure 1: tooth retainer by silicone material.

We can also scan the modal and get the design modal by 3D scanner. We tested by scanning the modal but due to the small size and details of the tooth retainer, 3D scanner is very hard to scan out every small dimensions and details clearly. So, we tried to design the modal in NX 10 designing software which is available in our Marshall University.

4.1 Designing the modal

Teeth as one of the most important parts of our body, it should be protected carefully. However, almost of us cannot have perfect alignment of teeth. The technology of orthodontic aligners is out of date, and teeth retainer is the new technology in recent years. In order to product the retainer, the first step is to build a mode of it. 3D scanner is the first method which is used because there are many details on the teeth retainer. 3D scanner is one kind of laser scanner, so that here are many limitation of the scanner, for example, the transparent retainer cannot be used in this case, many targets are needed before scanning, the scanner handle must be hold for long time to get as much details as it can, and special software is also needed to edit the graft. Which takes lot of time and need to be done so many trails. So, scanning many times we found that it is still difficult to get the accurate shape due to the retainer has so many curve surfaces, holes and grooves. Using three-dimensional software (NX 10.0), we build our own model in following way.

4.2 Designing procedure

There are so many steps involved in the designing procedure. Where it took around 1-2 months to design the shape of tooth retainer. With the required dimensions. Data id collected based on silicone tooth retainer as shown below. Below figure shows the dimensions.

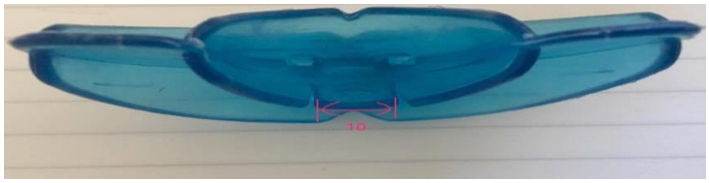

Figure 2 (4.1): dimensions. Back view of retainer

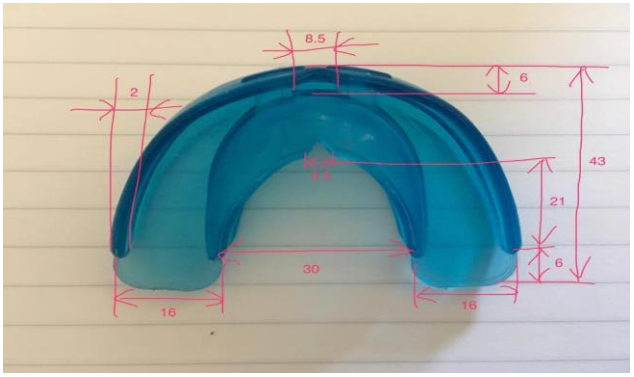

Figure 3: dimensions; Top view of the retainer

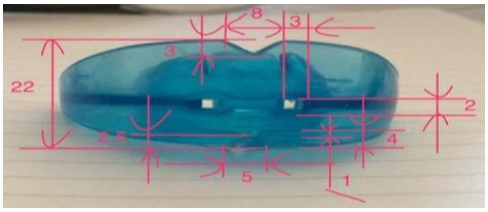

Figure 4: dimensions; Front view of the retainer

By applying several steps as shown in the above figure we obtained the tooth retainer modal.

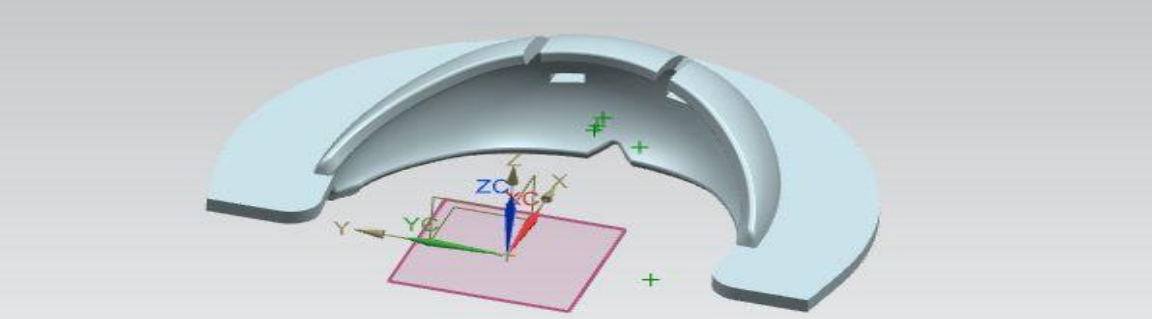

Figure 5: basic modal

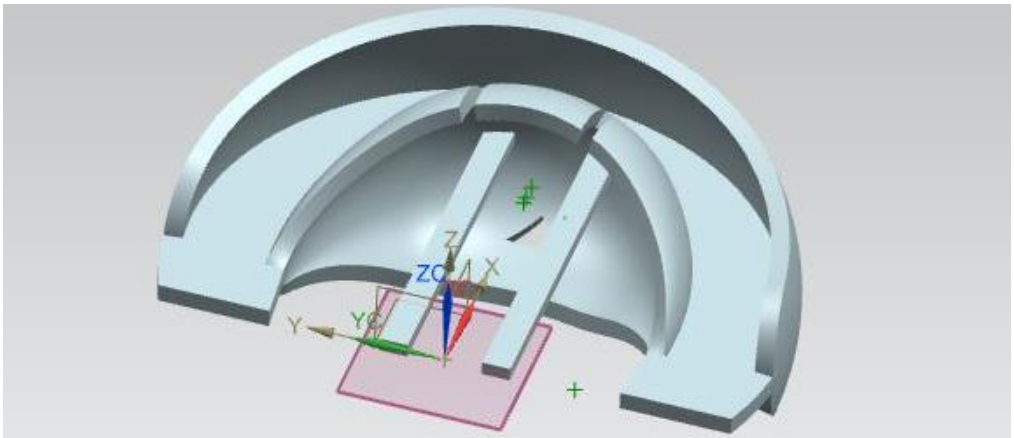

Figure 6: basic shape

After editing the modal more into the retainer shape we finally got the shape

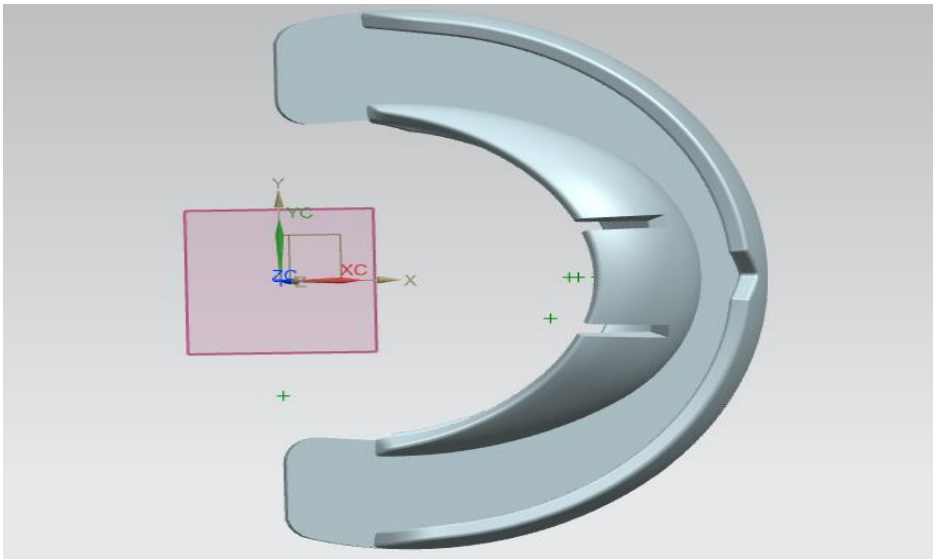

Figure 7: design of teeth retainer

It is can be seen clearly that the outline of this teeth retainer looks like a semi cycle, unfortunately, this design could let patient feel uncomfortable because the shape of human teeth is more likely a parabola, like the inside line shows.

4.3 Modelling

So, we thought there should be done some development in order to match the exact shape. we focused more into the design. As we found the first design model for tooth retainer has many blemishes, we want to revise it. Following is the pictures of new design model for tooth retainer.

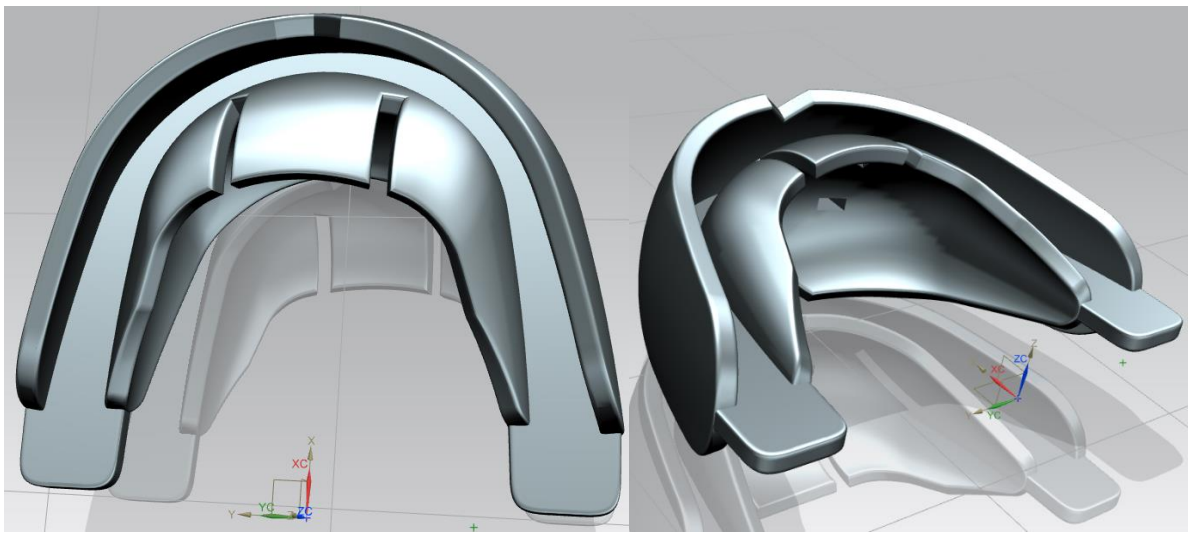

Figure 8: modeled design.

4.4 Characteristics of modal

This model has following characteristics

- Out contour has been modified to a parabolic shape.
- The dimension of the model has been corrected.
- The radian of insider contour has been revised.

Study of Results

We finally got the design now it's time for printing the design in 3D printer. Now the fine is converted to STL file and design is uploaded to the 3D printer (Oject30).

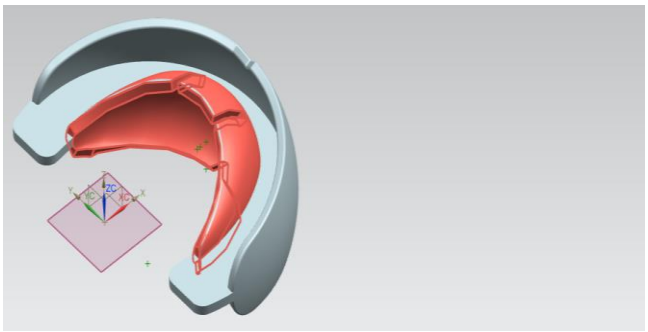

Figure 9: final modal of design.

After getting the 3D model use NX 10.0, we use 3D printer to print the tooth retainer.

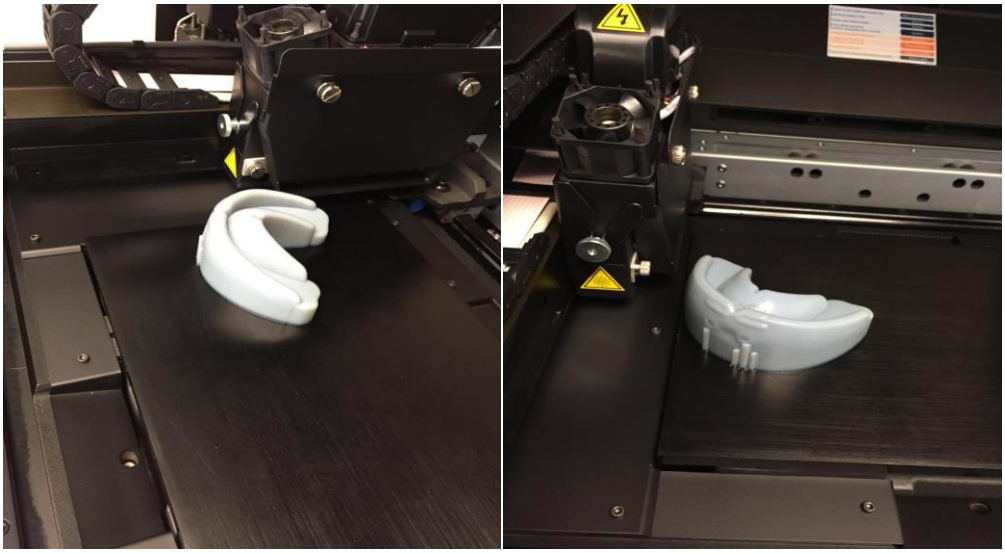

Figure 10: printed Modal.

Obtained the modal. Carefully removed the modal and cleaned the supported material which makes the modal complete. This modal took around 8 hours to complete. By using three-dimensional software (NX 10.0) to build 3D model then produce it use 3D printer, we find some parameters:

(i) The environmental condition will not affect the research. Because to build 3D model just need know the tooth retainer' dimension and know how to use the software, then you can do it.

(ii) It's easy to develop the tooth retainer when design the angulation and inclination. Because the jaw's shape is not the semi-circle, it's like a parabola. At first, we build the model with a semi-circle curve. But we find the jaw's shape is like a parabola, then we change the model use NX 10.0. Using three-dimensional software is very easy to develop the tooth retainer.

(iii) This research interests can replace conventional/traditional existing theory/model of tooth retainer in some way. Because it's cheap and easy to develop. It also has a problem is speed. If only produce one tooth retainer every time, it need over 8 hours. But use 3D printing is also an innovative and effective way to produce tooth retainer.

(iv) Because not every material can be used as the raw materials of 3D printing, so the characteristics/parameters/properties of the raw materials always affect the performance. Tooth retainer has two functions: protect and straighten the teeth. If the raw material is too soft, it doesn't have force to straighten the teeth. If the raw material is too tough, it will not have the protect function.

5 Testing analysis

In order to know where more stress is impacting on the design, tested in FEMAP software and obtained some results This experiment shows how the software works and views stress in clearly.

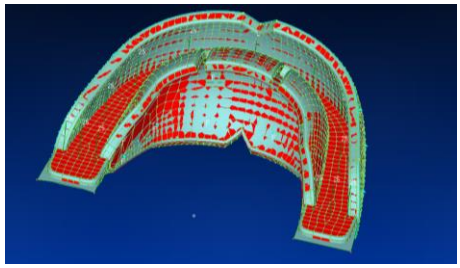

Figure 11: Loaded Modal

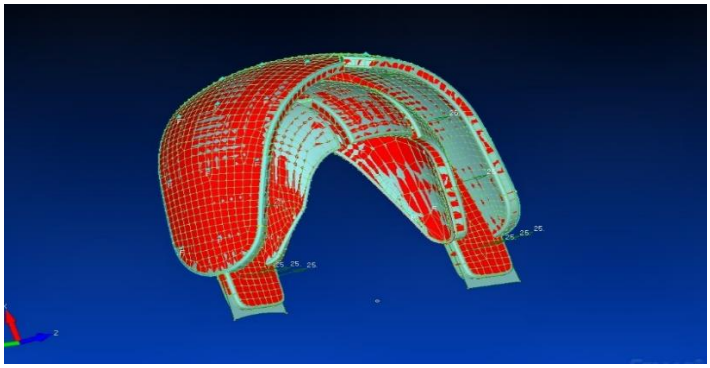

Figure 12: FEMAP modal

The above figure shows the design modal in FEMAP software. Where I applied some stress on it. The red portion shows the stress impact areas

Benefits of approaching this approach to this design is:

- Accurate results are obtained.
- Data from this can be used in different modeling or designing software's.
- Same properties can be applied for different structures.
- Time taken to calculate is very less.

5.1 Testing on another 3D printer

We also tested by printing the modal on makerbot 3D printer which is available in our Marshall University. This printer is used for printing small products. Advantage of maker bolt is it takes very less time to print the product and support material which is used is very less (Berman, 2012).

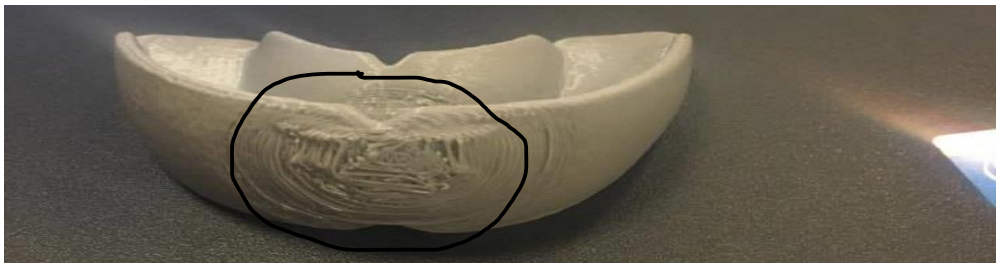

Figure 13: MakerBot Modal

The above image shown is the modal we obtained from the makerbot printer. The circled portion explains the errors we obtained from this printer. We tried to print several times with different orientation, but the same error is noticed and I found that complex shaped parts are difficult to print in this printer without errors. Object30 printer gives the better modal results than makerbot.

6. Conclusion

After studying and reviewing about some different technologies of orthodontic aligners and retainer technologies, and researching the characteristics and usages of the orthodontic aligners and retainer, the conclusion is orthodontic aligners technology is out of date due to the disadvantages painful, hard to clean, time consuming. Therefore, teeth retainer is the new technology which is applied in recently using 3D scanning, 3D printing or combine with 3D technology and thermoforming technology to produce the retainer beautiful and easy to use for patients is becoming popular in recent years. There are many 3D printing technics which can be used to produce tooth retainer such as BJ, FDM, SLA, LOM, SLA. Among

them my opinion is, the FDM method is the most suitable technic to product tooth retainer. As new technology, are still growing in some areas for invisalign teeth retainer to explore in the future, such as, to find better materials, after all 3D printing technology cannot be used for all material, the retainer must not harmful for human teeth and health, and how to keep the retainer off when eating food. Furthermore, this kind of retainer has low flexibility only one retainer can be printed out once, every time to print where several support materials are needed. Future more study is needed to know more about the printing technology so that it uses less support material and done in less time.

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Biography / Biographies

Sarder Sadique, Lecturer, California Polytechnic State University, 1 Grand Avenue, San Luis Obispo, CA 93407, USA. He has a Bachelor degree in Materials Engineering from the Bangladesh University of Engineering and Technology, and a Masters leading to Ph.D. in Mechanical Engineering from the National University of Singapore (NUS 2013 ranking: 24th in the world). He has been a faculty member and Department Head at the Curtin University of Technology, Malaysia; faculty member and researcher at Centennial College, Toronto, Ontario, Canada; member at Sheridan College, Toronto, Ontario, Canada faculty member at University of Texas at El Paso and University of Southern Mississippi; and most recently a faculty member at Central Michigan University. He has published journal and conference papers. Dr. Sadique has a broad-based research interests such as Advanced Manufacturing Processes, Hybrid Renewable Energy (solar and wind), Biosensors and Biorobotics, Nanobioengineering, Nanobiomechanics, Elastohydrodynamic Lubrication, Nano-tribology and Fuel Cells. He is affiliated with IEOM, PEO, OSPE, STLE, EA, IEB etc.