STUDY OF MOUTHGUARD DESIGN FOR ENDURANCE AND AIR-FLOW ENHANCEMENT

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ABSTRACT

Recently, mouthguard is one of the important device to the athletes during sports and exercise. Wearing a mouthguard is a must to prevent them from any orofacial injuries occurs during their sport activities. Therefore, to make sure it is safe and comfort, a study on the mouthguard design is carried out to investigate the performance of the mouthguards, in term of stress distribution and air flow path by improving the pressure difference between the ambient (outside) and the oral cavity pressure (inside). A preliminary design has been study to simulate its total deformation and stress, in terms of Von Mises Stress by using ANSYS 15.0 Workbench. From the results, the critical parts are identified on the preliminary design and later being used to improve the design to the new one. By increasing the thickness of the preliminary design, the total deformation has been decreased for about 0.2 mm to 0.16 mm for the exerted forces of 50 N to 500 N for external forces comes from outside, whereas, for internal forces from 100 N to 600 N has decreased about 0.24 mm to 1.44 mm. The simulation process is then followed by the air flow study in the oral cavity with the open mouth about 0.5 mm when the athlete is doing the exercise with 4.43 m/s speed of flowing air entering the mouth. The finding indicates that the modified mouthguard has large value of velocity streamline compared with the preliminary design because it is thicker than the first design. The difference pressure between both of the designs are, 140.09 Pa for the preliminary design and 401.86 Pa for the modified design. Velocity stream line also showed that higher speeds occur in the near mouth guards, that is, between the bottom surfaces of the mouthguard and the lower teeth. The results show that, the thicker the mouthguard design, the better it is for prevention but less in air flow distribution into the oral cavity.

ABSTRAK

Pada masa kini, pengawal mulut adalah alat yang penting kepada atlet dalam sukan dan senaman. Dengan memakai pengawal mulut dapat menghalang mereka daripada sebarang kecederaan oro-wajah semasa aktiviti sukan. Oleh itu, untuk memastikannya selamat dan selesa, kajian mengenai reka bentuk pengawal mulut telah dilakukan untuk mengkaji prestasi pelindung gigi, dari segi taburan tekanan dan menentukan tekanan aliran udara pada pelindung gigi untuk mendapatkan perbezaan tekanan antara ambien (di luar) dan tekanan rongga oral (di dalam). Reka bentuk awal telah dikaji untuk mensimulasikan jumlah perubahan bentuk, dan tekanan dari aspek Von Mises dengan menggunakan ANSYS 15.0. Daripada keputusan yang diperoleh, bahagian-bahagian kritikal telah dikenalpasti pada reka bentuk awal dan kemudian digunakan untuk menambah baik reka bentuk kepada yang baru. Dengan menambah ketebalan pada reka bentuk awal, jumlah perubahan bentuk telah menurun sebanyak 0.2 mm hingga 0.16 mm untuk daya yang bertindak sebanyak 50 N ke 500 N, untuk daya luaran yang bersentuh dari luar muka, manakala, bagi daya dalaman sebanyak 100 N hingga 600 N telah menunjukkan penurunan sebanyak 0.24 mm hingga 1.44 mm. Proses simulasi kemudian diikuti oleh kajian aliran udara dalam rongga mulut dengan mulut terbuka seluas 0.5 mm apabila atlet melakukan latihan dengan 4.43 m/s kelajuan aliran udara. Dapatan kajian menunjukkan bahawa pengawal mulut yang diubah suai mempunyai nilai yang besar bagi halaju arus berbanding dengan reka bentuk awal kerana ketebalan yang bertambah. Perbezaan tekanan antara kedua-dua reka bentuk adalah, 140.09 Pa bagi reka bentuk awal dan 401.86 Pa untuk reka bentuk yang diubah suai. Halaju garis arus juga menunjukkan kelajuan yang lebih tinggi berlaku berhampiran dengan pengawal mulut, iaitu, antara permukaan bawah pengawal mulut dan gigi. Keputusan menunjukkan bahawa, lebih tebal reka bentuk pengawal mulut, lebih baik untuk perlindungan, tetapi kurang dalam pengagihan aliran udara ke dalam rongga mulut.

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CHAPTER 1

INTRODUCTION

1.1 Background of study

Mouthguards are a device that made of a specialized rubber-like. It is typically used to fit over the upper teeth and help to prevent injury at the teeth, lips, cheeks and tongue. Mouthguards usually being used during sports by an athlete to prevent tooth loss and may reduce the risk and severity of jaw fractures and concussions because of the body contact while doing these sports activities.

The use of mouthguard had been started in a boxing sport back to about the turn of the 20th century. At that time, a primitive mouthguard or known as a mouth piece is use and made up by cotton, tape, sponge and even small pieces of wood (Keystoneind, 2013). The first mouthguard or 'gum shield' was developed by a dentist from London in 1890 to protect boxers from debilitating lip lacerations whereas, it is a common injuries in boxing competition during that time. It is made from gutta percha and was held in place by clenching the teeth. Starting in 1927, mouthguards become a common use during a boxing match.

In 1947, a dentist in Los Angeles, Rodney O. Lilyquist used transparent acrylic resin to make a mouthguard. It is moulded to fit over the upper and lower teeth and made for a much more unobtrusive object. Since then, many athletes who involved in basketball use to wear this type of mouthguard to prevent dental injuries. During 1950s, the research on mouthguard is increasing in American Dental Association (ADA) and they started to promote the benefits of mouthguard to the public. By 1960,

latex mouthguards are being recommended by ADA in all contact sports and all high school football players in the U.S. Since the promotion of mouthguards, the number of dental injuries had been decreased dramatically.

Presently, wearing mouthguards are required in many sports. There are 29 sports have being recommended by ADA to wearing mouthguards which are acrobatic, basketball, bicycling, boxing, equestrian, football, gymnastics, handball, ice hockey, inline skating, lacrosse, martial arts, racquetball, rugby, shot putting, skateboarding, skiing, skydiving, soccer, softball, squash, surfing, volleyball, water polo, weightlifting, and wrestling (JADA, 2004).

However, there are still increased in orofacial injuries even when the athletes are wearing the mouthguard. Therefore, many researches have been done to come out with the results of, which parts of mouthguard can protect the orofacial injuries. The researches have cover on mouthguard's materials, the designs, and the ability of mouthguard to protect athletes from orofacial injuries. Hence, this study is part of collaboration with National Sport Institute (ISN) to investigate the performance of two designs of mouthguard in order to find out which of those designs can prevent athletes especially junior athletes from orofacial injuries.

1.2 Problem statement

The tremendous popularity of organized youth sports and the high level of competitiveness have resulted in a significant number of dental and facial injuries.
Over the past decade, approximately 46 million youths in the United States were involved in some form of sports. In Malaysia, sports among youth have being started since in their primary school. It is compulsory to each student to play at least a sport to claim that they are active in the school.

However, all sporting activities have an associated risk of orofacial injuries due to falls, collisions, contact with hard surfaces, and contact from sports-related equipment. Sports accidents reportedly account for 10 to 39 percent of all dental injuries in children. The Lucille Packard Children's Hospital reports that more than 775,000 children aged 14 and under are treated in hospital emergency rooms (ER) each year, often from falls, collision, or overexertion during unorganized or informal sports

activities. Most organized sports injuries (62%) occur during practices, not games. According to Miller (2012), 25% to 30% of youth sports injuries occur in organized sports, and another 40% occur in unorganized sports.

Oral Health Division, Ministry of Health Malaysia, MOH (2011), has reported that, injuries to anterior teeth are on the rise in 12- and 16-year-old schoolchildren. This is related to increased participation in sports and recreational activities associated with active lifestyles and ignorance of or disregard for wearing injury-prevention devices.

Abdullah et al (2013) has claimed that, there are dental injuries while playing sports among athletes who were university students over 18 years and under 30 years of age. The injuries occurred more frequently in hockey (65.3%), basketball (60%) and soccer (45.2%). This occurs due to the lack of knowledge about using the mouthguards during sports activities.

Children are most susceptible to sports-related oral injury between the ages of seven and 11 years. The administrators of youth, high school, and college football, lacrosse, and ice hockey have demonstrated that dental and facial injuries can be reduced significantly by introducing mandatory protective equipment such as mouthguard. Therefore, it is important to design the proper mouthguard and to study its comfort when wearing among the junior athletes.

1.3 Objectives

The objectives of this study are as following:

i. To investigate the performance of the mouthguards, in term of stress distribution.
ii. To determine the air-flow pressure effects on the applied mouthguards for improving the pressure difference between the ambient (outside) and the oral cavity pressure (inside).

1.4 Scope of study

The scopes of this project are lists below:

i. Two designs are used for the comparison
ii. The Autodesk Inventor is used to design the mouthguard.
iii. The material used for the mouthguard is Ethylene Vinyl Acetate (EVA) with density of 930 Kg/m3, young's modulus, 1.379x107 Pa, poisson's ratio, 0.3, bulk modulus, 1.1491x107 Pa, shear modulus, 5.3037x106 Pa, and specific heat of 1400 J/kg.
iv. The stress that is determined is Von Mises stress.
v. Force exerted is from 50 N to 600 N.
vi. The mouth-guard designed for junior athletes
vii. Computational Fluid Dynamics (CFD) Software - ANSYS 15.0 is used to investigate the stress and fluid flow test.
viii. The study of airflow is conducted during the open mouth condition by 5 mm between the mouthguard and the lower teeth with air velocity 4.43 m/s.

1.5 Significant of study

An appropriate mouthguard design gives comfort to the wearer, especially among junior athletes to prevent facial and dental injuries. To produce a suitable design, studies need to be done into all important aspects of mouthguard to avoid unfitted design.

CHAPTER 2

LITERATURE REVIEW

2.1 Mouthguard

A mouthguard is a plastic shield and a flexible custom fitted device which held in the mouth by an athlete to protect their teeth and gums from damage because of their athletic and recreational activities. It is also known as a mouth protector because of its function. The mouthguard, also defined as a resilient device or appliance placed inside the mouth to reduce oral injuries, particularly to teeth and surrounding structures (Mantri, 2014). Generally, mouthguards will cover the upper teeth only. However, in some cases, where there are a user wear braces or another fixed dental appliance on their lower jaw, the dentist will make a mouthguard for the lower teeth as well. Figure 2.1 shown the picture of mouthguard that have being used by an athletes.

Figure 2.1: Mouthguard use by an athlete (JADA, 2004)

The use of mouthguard should help the user to buffer damage to the teeth, the brackets and any other fixed appliances from blows and physical contact during their activities. By wearing a mouthguard, the risk of soft tissue damage will be lessen because it can act as a barrier between teeth and the cheeks and also, between the lips and tongue. An effective mouthguard should provide a high degree of comfort, resist tears, be durable and easy to clean, odourless, tasteless, can stay firmly in place during action and should not restrict your breathing or speech. Figure 2.2 shown an illustration of a human orofacial side view with a mouthguard wearied at the upper teeth. The red point shows the parts where mouthguard could prevent from damage when one have being wearing the mouthguard.

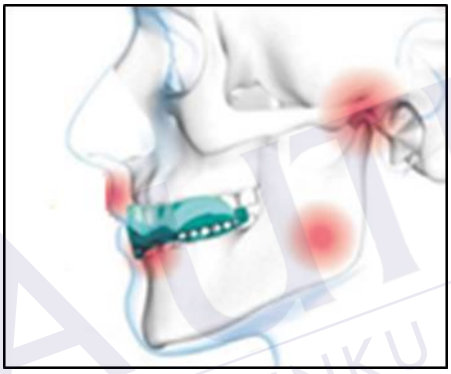

Figure 2.2: How a mouthguard should be wear (ADA, 2014)

There are three categories of mouthguard that use to protect the athletes' teeth according The American Society for Testing and Materials. Each categories of mouthguard are differences in their qualities such as their artificial ways, price, and the ability to protect the user's mouth or teeth.

2.1.1 Stock mouthguard

Stock Mouthguard (SM) is one of the cheapest mouthguards among the other two categories. Stock mouthguard can be found easily at any department stores or sporting goods stores. It comes pre-formed and ready to wear. However, most of the dentist

does not recommend stock mouthguard to be used because it the worst fitting, least comfortable and less protective mouthguard. It can be bulky to the users, increase the tendency to gag, and make the user hard to breath and talk because they required the jaw to be closed to hold the mouthguard in place. Usually, it is made of rubber or polyvinyl. Figure 2.3 shown the stock mouthguard that can be found in the department stores or sporting goods stores.

Figure 2.3: Stock mouthguard (ADA, 2014)

2.1.2 Boil-and-bite mouthguard

The second category of mouthguard is Mouth-formed mouthguard which also known as, Boil –and-Bite mouthguards (BBM). This category of mouthguard is including all the mouthguards that are formed directly in the mouth. User can bought it directly at sporting goods stores, inexpensive and may offer a better fit than stock mouthguard. There are two types of mouth-formed mouthguard which are; shell liner type and thermoplastic type.

The shell liner mouthguard usually consists of an outer polyvinyl chloride shell that is filled with a soft liner made from plasticized acrylic resin gel or silicone rubber. However, there are some disadvantages of this type which are decreased retention because of repeated biting into the soft lining material, hardening of the soft liner, increased occlusal vertical dimension, discomfort, and bulkiness. The thermoplastic mouthguard is made up by soften it in hot or boiling water and then, placed in user mouth and will be moulded to the contours of the teeth using the fingers, lips, tongue

and biting pressure. The mouthguard can be refitted if it is not properly made at the initial fitting. The example of boil-and-bite mouthguard has shown in Figure 2.4.

Figure 2.4: Boil-and-bite mouthguard (ADA, 2014)

2.1.3 Custom made mouthguard

The greatest fit, comfort and protection of mouthguard category are the Custom- made mouthguard (CMM). Because it is the better one, it becomes more expensive than other types of mouthguards. Custom-made mouthguard is made from a cast to precisely fit the user's teeth. The dentist will makes an impression of one individual's teeth and then, it is moulded over a model using special material. The mouthguard will be constructed under dentist's instruction at dental laboratory or in the dentist's office. Because of this, custom- made mouthguard will need some time to be done and wear by the user. There are two types of custom mouthguards which are the out dated Vacuum mouthguard and the modern Pressure Laminated mouthguard.

2.1.3.1 Vacuum-formed mouthguard

The vacuum-formed mouthguard is made up of single layer thermoplastic material that is adapted over the mould with a vacuum machine. The vacuum machine will form a mouthguard using a wet model. However, the wet model make it difficult to fit, so

there are some researchers recommend to use a dry model cast with its surface temperature is elevated. Therefore, a better fit mouthguard will be obtained. However, there are some defects with vacuum mouthguard which are, the incisal edges can become thin, and occlusal, labial and lingual aspects of the mouthguard can shrink. Figure 2.5 shown a vacuum-formed mouthguard that has been made by Australia Dental Association (ADA).

Figure 2.5: Vacuum-formed mouthguard (ADA, 2014)

2.1.3.2 Pressure laminated mouthguard

Compare with all types of mouthguard, the pressure-laminated mouthguard have a greater fit, comfort and protection, with little deformation when it is worn for a period of time. The process of pressure lamination has more advantages than the single layer vacuum-formed design. The material will be layered to a specific thickness to suit the specific sport and can provide more protection to certain exposed areas in the mouth as needed.

Both Australian Dental Association and The American Dental Association (ADA, 2014) had strongly recommended to wearing a custom-made mouthguard to ensure a very maximum protection. Because of the dental injuries can be very costly and it might be permanent for the rest of one live, so, it is worthwhile for investing in a custom-fitted mouthguard especially for the athletes who are the one who always facing the physical contact's activities. Example of pressure laminated mouthguard made by Australian Dental Association has shown in Figure 2.6.

Figure 2.6: Pressure laminated mouthguard (ADA, 2014)

Clemente et al. (2011) reported that, the custom-made mouthguard has the best characteristics in order to prevent orofacial trauma among the other types of mouthguard and it should be informed to all the athletes. The characteristics that the custom-made mouthguard has respect the quality criteria which are comfort, fit, retention, easy of speech, resistance to tearing, ease of breathing, as well as, good protection of the teeth, gingiva and lips, essential for successful prevention of orofacial and dental injuries.

Agron & Behlul (2013) has studied the functional efficiency of mouthguards in martial arts sports and has been conclude that, the custom-made PlaySafe maxillary and maxillary boil-and-bite mouthguards do not significantly reduce airflow dynamics of oral breathing when compared with the bi-maxillary boil-and-bite. However, these two types of mouthguards were found to positively affect aerobic capacity.

2.2 Mouthguard material

To form a good mouthguard for sports activities, mouthguard need to be made by using an appropriate material which it can be constructed and prevent any arofacial injuries to the athletes. Material used is one of the important things to take into account. Mouthguard materials should have an optimal consistency, energy absorption, and strength in order to cushion the traumatic impact.

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