Original article

Model Fabrication for Practicing Manual Reduction of Temporomandibular Joint Dislocation

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Abstract

Temporomandibular (TMJ) dislocation occurs when the mandibular condyle has displaced completely out of glenoid fossa and anterosuperiorly to the articular eminence. This condition is considered an urgency since it causes physical pain and mental trauma which is needed to be handled straight away. TMJ reduction, a technique in which the dislocated jaw is pushed downward and backward into its normal position, is the standard treatment for both acute and chronic TMJ dislocations. Accurate placement of the operator's hand position and force direction make the reduction more effective. The aims of the study were to fabricate the three-dimension (3D) model for practicing accurate manual reduction of acute anterior TMJ dislocation and to assess the satisfaction of the model simulation from unexperienced dental students. The 3D-TMJ dislocation model was fabricated, and redesigned based on the usability principle by Oral and Maxillofacial surgeons until the final design was achieved. The satisfaction, ease of use, proper posture, convenience to hold the jaw, and demonstration of the direction for jaw relocation were assessed using the final prototype in unexperienced dental students. The results indicated that the overall satisfactory level for the final prototype was moderate to high in the formative phase and the overall satisfactory level was high in the summative phase. The 3D-TMJ dislocation model enabled the students to understand how to properly adjust patient position, hand placement, and force direction. The 3D-TMJ dislocation model simulation offers the opportunity for the students to practice their skills and to allow detailed feedback and assessment of their performance.

Keywords : Instructional media, Manual reduction, Three-dimensional solid model, TMJ dislocation, Usability principles

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Introduction

Temporomandibular joint (TMJ) is a ginglymo-arthrodial joint. To understand TMJ function, consideration of the relationship of glenoid fossa-articular eminence, articular disc-disc ligaments, condyle, synovial membrane, capsule, accessory ligament, and muscles of mastication is required.[1,2] The primary muscles of mastication are important muscles that play a role in the mandibular movement. The function of masseter and temporalis muscles is to elevate the mandible causing the mouth closed. The function of medial pterygoid muscle is to elevate and

protrude the mandible. Bilateral contraction of the lateral pterygoids act to protrude the jaw. Lateral pterygoid muscle with assistance of gravity and the digastric muscle also open the jaw.[3] Anterior mandibular condylar dislocation occurs when the mandibular condyle has displaced completely out of glenoid fossa and anterosuperiorly to the articular eminence.[4] TMJ dislocation incidence has been reported to be between 3-7 % in the general population[5] and has had an incidence about 3% of all dislocations throughout the body.[6]

TMJ dislocation has been classified into 3 groups depending on how long and the frequency it has occurred: acute dislocation (most common), habitual or chronic recurrent dislocation and long-standing or chronic persistent dislocation.[7,8]

Acute dislocation can be managed with a manual reduction, such as the Hippocratic, the wrist pivot[9], combined ipsilateral staggering[10] and the extraoral methods.[11] However, Hippocratic method is the most common technique which has the highest success rate.[12,13] The operator should stand in front of the patient and place their thumbs on the posterior lower molars bilaterally, while other fingers wrap laterally around the mandible. The operator subsequently forces downward pressure on the lower molar region, which direct the mandible downward and backward. The other fingers pull upward on the mentum of the mandible. This levering force will tend to rotate the mandible, providing additional inferior and posterior movement of the condyles. Once this occurs, the mandible will be reduced as the condyle translates back into the glenoid fossa.[1]

Treatment of TMJ dislocation should be initiated as soon as possible. Once dislocation has occurred, spasms of the masseter and pterygoid muscles may be worsen over time. The first reduction is the most effective. Multiple attempts make subsequent reductions more difficult because the patient will have more pain and muscular spasm.[4] Quite often, the ineffective treatment may be attributable to the limited experience of the surgeons.

To make effective treatment, dental students are required to develop their practical skills. Teaching using media is one of the most important components in the teaching and learning processes.[14] The advantages of using a 3D solid model are to allow the learners to examine a model which may not be easy in the real object or patients, and to handle and permit close-up practicing in a safe and controlled environment. Moreover, instructional media promotes critical thinking skills and connect theory to practice.[15]

Consequently, the opportunity to perform the first reduction of TMJ dislocation can prepare dental students and help them feel confident as well as improve the development of practical skills. Therefore, practicing the reduction of TMJ dislocation by using the 3D solid model may improve the skill and confidence of dental students. Thus, in this present study, the three-dimension (3D) model for practicing accurate manual reduction of acute anterior TMJ dislocation was fabricated and then the satisfaction of the model simulation from unexperienced dental students was assessed.

Materials and Methods

Design and setting

This study consisted of 3 parts. The first part was the design and construction of the prototype. Then, the formative usability test was performed in the second part to improve the design of the prototype. The formative evaluation was conducted with the intention of improving the design, and the results were used for the redesign. This step was repeated until the final prototype was achieved. Lastly, the third part, the final prototype was used for the summative usability test to confirm the effectiveness in a larger number of participants.

Participants

The population of formative usability test consisted of Oral and Maxillofacial surgeons who had experience in the reduction of TMJ dislocation at least 3 times per year (n=5). The population of summative usability test consisted of the 4th year dental students of Prince of Songkla University, who had never performed a manual reduction of TMJ dislocation (n=20).

The project was approved by the Human Research Ethics Community, Faculty of Dentistry, Prince of Songkla

University. Each participant gave written informed consent prior to the model testing.

Data collection

Outcome

The questionnaire regarding the use of this fabricated model gave a satisfactory outcome. The formative usability test questionnaires were given to experienced Oral and Maxillofacial surgeons. This part was composed of general information, experience of treating TMJ dislocation, and satisfaction of using this fabricated model. The summative evaluation questionnaires were given to dental students. This part was composed of general information and satisfaction of using the final prototype model.

Each item of the questionnaire was determined to be low, moderate and high.

1) The model was easy to use: low meaning unstable holding platform and difficult to prepare anterior dislocation of TMJ, moderate meaning unstable holding platform or difficult to prepare anterior dislocation of TMJ, and high meaning stable holding platform and easy to prepare anterior dislocation of TMJ.

2) The model allowed for proper posture: low meaning the standing posture is not very comfortable such as stoop down, moderate meaning the standing posture is moderately comfortable, and high meaning the standing posture of operation is very comfortable.

3) The model was convenient to hold the jaws for reduction: low meaning the model was less comfortable to hold, moderate meaning the model was moderately comfortable to hold, and high meaning the model was very comfortable to hold.

4) The model was able to demonstrate the direction used for jaw relocation: low meaning the model was not able to demonstrate the direction used for jaw relocation, moderate meaning the model can show some direction in which the jaw moves, and high meaning the model was able to demonstrate the direction used for jaw relocation.

5) The model shows a realistic simulation for jaw dislocation as in actual patients: low meaning the model cannot represent the real patient in the practice, moderate meaning the model resembles a real patient, but cannot represent the actual patient in the practice, and high meaning the model resembles a real patient and can represent real patients in the practice.

Data collection procedure

The participants were invited to attend the three-dimensional solid model testing. Each participant performed a reduction of TMJ dislocation with model under the supervision of one professor. The professor provided additional information when necessary or if requested by participants. After completion of the model testing, all participants were asked to complete a questionnaire.

Prototype fabrication, formative and summative assessments

Three prototypes were designed and constructed by replica cast of the skull by making a polyester resin cast from a silicone rubber mold of the skull from the usability concepts.

Prototype 1

The first prototype was fabricated by using a plastic container that fitted the original skull model and leaved a space of at least 1 cm between the container wall and the skull. RTV-2 silicone was the material used for rubber mold mixture in a ratio of 100:2. The silicone mixture was then gently poured from the top of the container to avoid air bubbles and left to set for 24 hours. When the silicone mold was firm and fully set, the container was then removed using bur cutting and the skull model was removed using blade cutting. The silicone mold was then put back into the container to be casted using polyester resin mixture in the 100:1 ratio for 1 minute. The polyester resin mixture was gently pouring from the top of the container to avoid air bubbles and left to set and harden for 24 hours before removal from the silicone mold. Coil springs size 7x51 mm representing the masseter and temporalies muscles and coil springs size 7x38 mm representing the medial pterygoid muscle were fixed to the resin skull in the positions of masticatory muscle attachments.

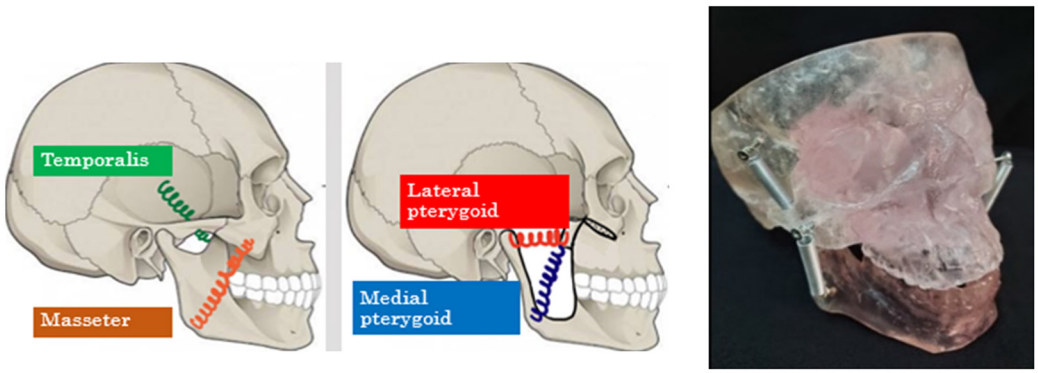

Figure 1 *Prototype 1 was fabricated by polyester resin and coil spring without handle platform*

The formative usability test was performed by experienced Oral and Maxillofacial surgeons to improve design of the prototype. Participants criticized the difficulty of use because the model needed to be held by another person during usage causing difficulty in force assertion and low stability. Moreover, they mentioned that the resistance was too low so it was too easy to relocate the jaw in the model. Some of the participants suggested that it might be better if the model could have more stable handle and a stiffer spring to create more resistance against jaw reduction as in the real patients.

Prototype 2

From the 1st formative comments, the second prototype was redesigned to be a solid block without an internal space, Additional micro-balloons were added for strength enhancement. The screws were fixed in positions of muscle attachments, consisting of the masseter, temporalis, and lateral pterygoid muscles. Rubber bands were used instead of coil springs and holding platform was designed to be stabilized with table.

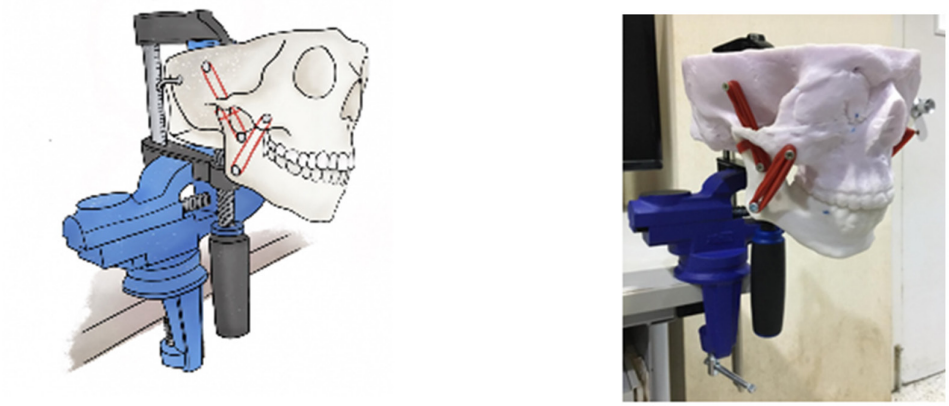

Figure 2 The second prototype with a non-adjustable platform handle

Then, the formative usability test was performed by experienced Oral and Maxillofacial surgeons to improve design of the prototype. Participants were satisfied with the handle making the model more stable. The hand positions used on the model were similar to those in real patients, helping dentists understand the hand positions in jaw reduction. All participants were highly satisfied with simulation of force direction used for jaw reduction shown by the model because the anatomy could be seen very clearly and could help them direct a proper force direction. The easy handling benefited the participants to feel the mandibular movement. However, they criticized that

mandible in the model could be touched and moved directly unlike in real patients in which mandible is covered by layers of soft tissues. As a consequence, jaw reduction in the model was too easy.

Some surgeons suggested that it might be better if the model could have a more realistic skin coverage because the exact anatomy is not obvious in real patients and the operator should not see condyles as clearly as in the model.

Prototype 3

From the 2nd formative comments, the third, final prototype was re-designed. It was fabricated by polyester resin and rubber band with an improved handle neck that locks tighter to the model and was adjustable in both horizontal and vertical directions. The mask was designed to simulate the facial skin and was removable at will.

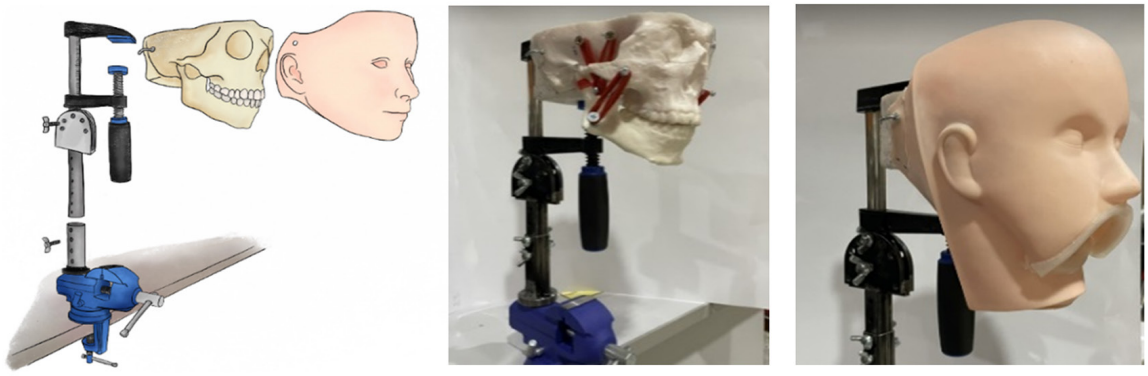

Figure 3 *Final prototype with adjustable platform handle in both horizontal and vertical directions. The mask is designed to simulate the facial skin and is removable at will*

The formative usability test was performed by experienced Oral and Maxillofacial surgeons to evaluate design of the prototype. Participants commented about the stability and location of the dislocation. The displaced condyle usually came too anteriorly which caused the coronoid process to end up anteriorly to the zygomatic arch and the range of vertical adjustment was insufficient. Tall operators had to stoop down to use the model. In term of hand position shown on the model, they stated that the posterior interocclusal space was too narrow for proper finger placement on the occlusal surface of the posterior teeth and the operator had to place their fingers more anteriorly which is not the best position for force application in jaw reduction. In term of simulation of force direction used for jaw reduction shown by the model, they detailed about the rubber mask being too thick and stiff and was less likely to move along with the mandible, making it more difficult to reduce the mandible into place. All users affirmed that having a removable mask was a good idea because it was much easier to see the force direction of jaw reduction when the mask was not on.

Some surgeons suggested that it might be better if the mask was thinner and softer for a better adaptation and unison to the mandible, so the operators could better feel the mandibular movement.

Results

Five experienced Oral and Maxillofacial surgeons participated in the formative usability evaluation. The demographic data of the experienced participants were shown in Table 1. The satisfactory scores of the 3 prototypes from experienced Oral and Maxillofacial surgeons were shown in Fig. 4.

Table 1 *Demographic characteristics of experienced Oral and Maxillofacial surgeons*

Total participants, n		**5**	
Sex, n			
Female		2	
Male		3	
Age, years			
Mean	(Minimum, Maximum)	33.2	(29, 37)
Year of experience, years			
Mean	(Minimum, Maximum)	8.4	(5, 11)
Cases of TMJ dislocation per year, case			
Mean	(Minimum, Maximum)	3.4	(3, 4)
Success rate, percentage			
Mean	(Minimum, Maximum)	93	(80, 100)
Overall dislocated duration, percent			
sudden case		20	
referral case (<24 hours)		80	
Percentage of surgeon based on number of attempts, percent			
1		40	
2		40	
3		20	
Number of surgeons based on position of operator, n			
Anterior		4	
Posterior		1	

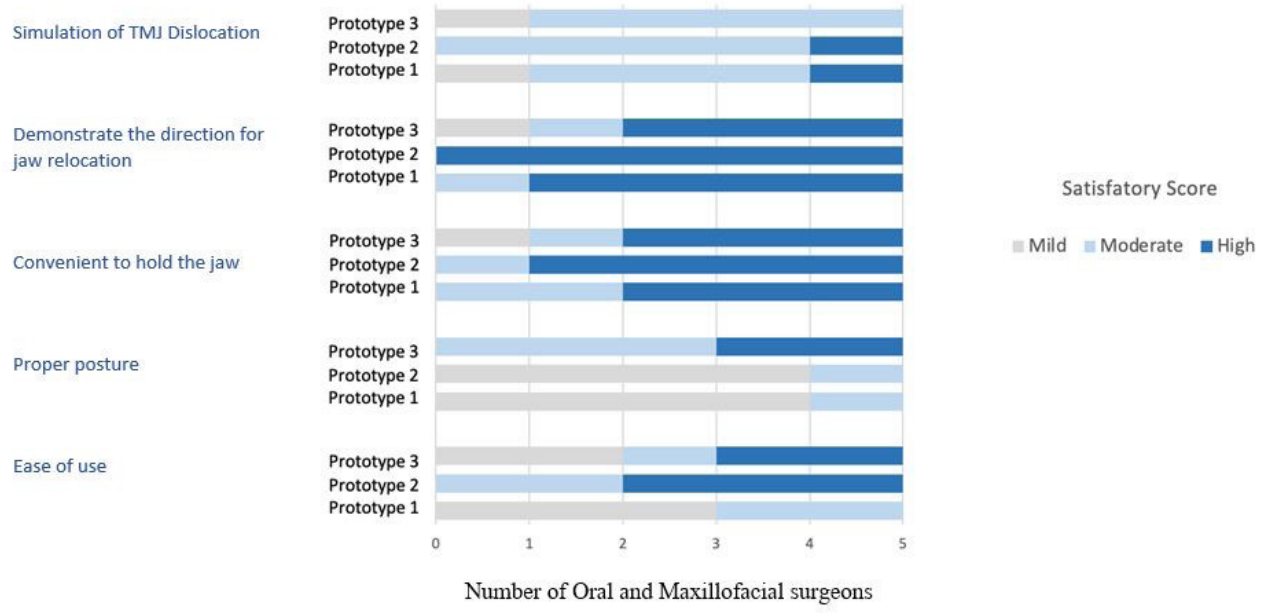

Figure 4 *The satisfaction of Oral and Maxillofacial surgeons on 3D-TMJ dislocation model*

Summative usability test

The final prototype was used for the summative usability test to confirm the effectiveness in unexperienced students (Fig. 5). Most of them were highly satisfied with the simulation of TMJ dislocation. The reason was that the

model was able to demonstrate force direction used for jaw relocation more clearly than just lectures and they were satisfied with the hand position shown on the model which was similar to that in real patients. This helped dentists understand the hand position in jaw relocation. Eleven out of 20 users complained that the rubber mask was too thick and difficult to carry and therefore caused difficulty in sensing the mandible. Four out of 20 people complained about the stability and location of the dislocation because the displaced condyle usually came too anteriorly.

Some of the students suggested that it might be better if the dislocation could have a precise and repeatable location, while the mask could be thinner and softer for easier handling.

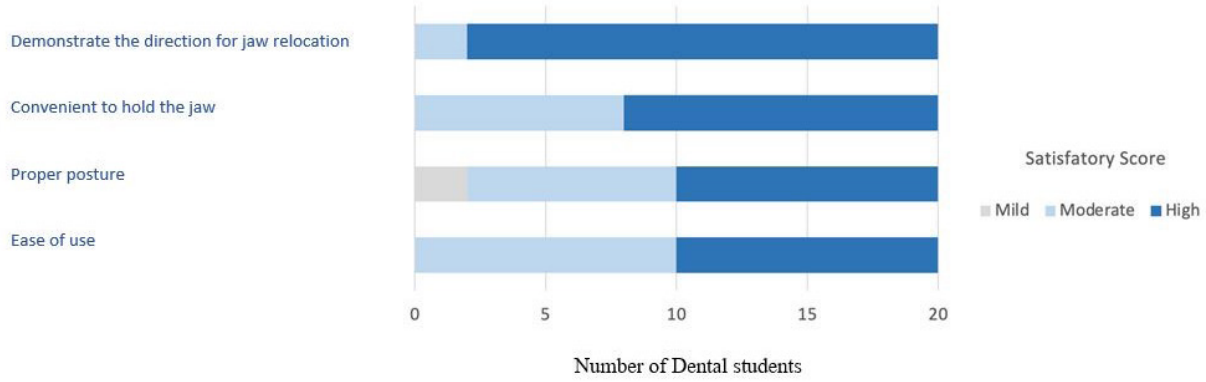

Figure 5 *The satisfaction of unexperienced dental students on 3D-TMJ dislocation model*

Discussion

TMJ dislocation is considered an urgency which is needed to be handled straight away. However, TMJ dislocation is not a common event. Most dentists are not familiar with the proper treatment and often fail to perform jaw reduction correctly which might unintentionally cause the condition to go worse, and therefore require a more complex treatment.

This model was created to help dental students understand better about TMJ anatomy and muscle force directions in jaw reduction and condyle relocation. Student should have the opportunity to practice with the model before the real performance in real patients. The model helps students understand how to properly adjust patient position, hand placement, and force direction. The model does not just improve clinical skill, but also help decrease the number of procedural errors in the clinical setting.

In jaw reduction, force direction is more important than force quantity because the difficulty of reduction is different in each patient, making it impossible to determine the exact quantity of force required for jaw reduction. Therefore, this model was designed to focus more on the understanding of force direction used in jaw reduction rather than force quantity.

The results showed that the second prototype was highly satisfied by the users in the simulation of force direction and hand positions for jaw reduction which is similar to circumstances in real patients because the anatomy could be seen very clearly. This helps the students understand better. However, users suggested that it might be better if the model could have a more realistic facial skin cover because the exact anatomy, including condyles, would not be such obvious in real patients. Therefore, the third prototype was designed with a removable skin cover for the users to be able to try to reduce the naked mandible and see the condylar movements, anatomical relationships, occlusion, and force direction clearly. Then the users can

put the skin mask back on before reducing the mandible again with skin coverage to simulate the proper action in real patients where the clear anatomical relationship is not seen. However, the skin cover is made by a thick stiff rubber, making it more difficult to reduce the mandible into place and results in less satisfaction in force direction and hand positions. This still needs to be improved further to make the mask thinner and softer in order to adapt to the mandible and move along as one unit.

A limitation to this model was that it was unable to simulate the articular disc and ligament, which are key anatomies of TMJ movement. As a result, users need to be cautious about trauma to ligaments which may poses the risk of disc displacement. However, the main purpose of this model is for training of jaw reduction which is suitable for acute anterior TMJ dislocation where the articular disc is less important. Unlike cases of chronic dislocation where the disc may be deformed and interferes with jaw relocation. The manipulation in the model may not be the same as in the actual patient due to neuromuscular involvement. Pain or fear makes the patient more tensed. Moreover, the model only simulates anterior bilateral TMJ dislocation.

A further study might be necessary in order to investigate the effectiveness of the model on skill improvement of manual jaw reduction of TMJ dislocation.

Conclusion

The 3D-TMJ dislocation model offers the students to understand how to properly adjust patient position, hand placement, and force direction. The 3D-TMJ dislocation model simulation offers the opportunity for the students to practice their skills and allowing detailed feedback and assessment of their performance.

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