

## **HARD OCCLUSAL SPLINTS MADE BY VACCUM MACHINE VERSUS 3D DIGITAL PRINTED SPLINTS IN TREATMENT OF MUSCLE PAIN (ELECTROMYOGRAM)**

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### ***ABSTRACT***

The use of hard occlusal splints (Michigan splint) may be a useful tool to promote reduction of muscular pain caused by bruxism, which is one of the parafunctional habits.

**Aim:** To assess the efficacy of hard occlusal splint made by vacuum machine or 3D digital printing with patients reporting muscular pain due to parafunction habit.

**Methods:** In group A Michigan splint was made by vacuum machine and in group B Michigan splint was made by 3D digital printing. An electromyographic (EMG) evaluation of the masseter and temporalis muscle was done before the treatment, then after 3 and 6 months after the initiation of the treatment.

**Results:** Comparison of the electrical activity at the times of measurement revealed a statistically significant difference in masseter and temporalis muscle after 3 and 6 months but revealed no statistical significant difference between different technique of construction.

**KEY WORDS:** Temporomandibular disorders, bruxism, Michigan splint, electromyography.

### **INTRODUCTION**

Temporomandibular disorders (TMD) is a collective term embracing a broad spectrum of clinical joint and muscle problems in the orofacial area, these disorders are characterized primarily by pain, joint sounds, and irregular or limited jaw function. It is multifactorial disorder due to trauma direct one or micro trauma as in parafunctional habits.<sup>(1,2)</sup>

Para functional disorders are known as any activity that is not considered functional activity as chewing, speaking, and swallowing. Para function habits are either diurnal habits occurring during day (e.g. clenching, grinding) or nocturnal habits that occur at night may be single episodes as clenching or rhythmic contraction as bruxism.<sup>(2)</sup>

Bruxism which is a sleep disorder that occurs during change from deeper to lighter sleep due to emotional condition and occlusal discrepancies,

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bruxism result in excessive tooth wear, muscular pain specially at morning, severe malocclusion, degenerative joint condition, T.M.J disk derangement, muscle hypertrophy and headache.<sup>(2)</sup>

Diagnosis of TMD includes the subjective symptoms as T.M.J sounds (click, pop sound, and crepitation), limited range of movement of mandible, tenderness in the jaw muscles, acute malocclusion, tender teeth, teeth wear, tinnitus and vertigo.<sup>(2,5,6)</sup>

The treatment OF TMD basically consists of occlusal correction, use of splints, physiotherapy, and psychological therapy.<sup>(7)</sup>

Many splints are used in the treatment of temporomandibular joint disorders. The two most common are the centric relation and the anterior repositioning splint. Others include the anterior bite plane, posterior bite plane, pivoting splint and soft or resilient splint.<sup>(8)</sup>

The characteristics of a successful splint should include. Stability, Balance in centric relation, Equal intensity stops on all teeth, Immediate posterior disocclusion, Smooth transitions in lateral, protrusive and extended lateral excursions (crossover), Comfort during wear, Reasonable esthetics and Patient compliance.<sup>(9)</sup>

Indications for Michigan splint are as follows: TMDs of arthrogenic and/or myogenic origin, management of nocturnal bruxism and uncontrolled parafunction during the day, maintaining of centric relations as a precondition to extensive prosthodontic restoration in patients with painful and stiff masticatory muscles or limited mandibular movements, and as a means of differential diagnostics of TMDs with respect to other ailments with similar symptoms (orofacial and craniocervical pain, tension headache, secondary tinnitus.)<sup>(10,11)</sup>

In Michigan splint, centric relation serves as a

therapeutic position which stabilizes the mandible in occlusal relations, wherein the habitual mandibular position is often identical to the centric position in the TMJ. Apart from excluding occlusal interferences, the relaxation of masticatory muscles is achieved by increasing the occlusal vertical dimension by the amount of thickness of the occlusal part of the splint. Michigan splint is most often indicated for the maxilla, but esthetic and phonetic reasons can also indicate its placement on the mandibular teeth.<sup>(11)</sup>

Conventional methods of splint manufacture are highly technique sensitive and often lead to poor splint fit, over contour, and hence poor patient compliance. They also require extensive chair-side time for adjustments to achieve passive fit and an appropriate occlusal scheme.<sup>(12)</sup> Moreover, these appliances are more prone to fracture and failure during use.<sup>(13)</sup>

With advent of the computer-aided design/computer-aided manufacturing (CAD/CAM) technologies, most of these problems resolved. The CAD/CAM splint eliminate of individual human errors inherent in technical processes, resulting in time savings and higher levels of predictability at both the technical and clinical level.<sup>(14)</sup>

## MATERIALS AND METHODS

Twenty dentulous patients were selected from the outpatient clinic of diagnosis department and prosthodontic department, Faculty of dentistry, Ain shams university.

Patients were selected with range of age from 18 to 60 y, no sex predilection, suffer from bruxism from 2 months up to 2 years.

### Inclusion criteria:

Based on the clinical examination , the patients

were suffering from some or all of the following signs and symptoms, and were considered to suffer from one of the parafunctional habits “Bruxism”

- 1- Pain in the temporomandibular joint region that might be worse in the morning or associated with eating.
- 2- Tenderness of temporomandibular joint with palpation at rest and/or at function.
- 3- Pain and/or tenderness of masseter and temporalis muscle.
- 4- Intra orally on examining the teeth for occlusion, mobility and any special finding for bruxism as wear of teeth presenting as multiple, smooth and shiny facets.
- 5- The patient should have trigger points.

**Exclusion criteria:**

- 1- Pregnancy or breast feeding.
- 2- Prior Botox treatment.
- 3- Trigeminal neuralgia.
- 4- Pain of dental origin
- 5- Muscle relaxant use.
- 6- Aminoglycoside use.
- 7- Rheumotoid arthritis.
- 8- Neuropathic pain.
- 9- Vulnerable groups (prisoners, mental disorders, patients not capable of decision making ).
- 10- Any local skin infections over the masseter or temporalis muscle.
- 11- Patients with low vertical dimension.
- 12- Patients having TMJ sounds.

**2- Diagnosis**

For proper diagnosis case history was taken, and clinical examination was performed.

**A-History:**

Case history of all patients was recorded including personal, dental, medical, and sleep history.

**Personal and dental history:**

Personal, and dental history were assessed using the following bruxism questionnaire:

Date _____			
1. Name _____			
Age _____			
Sex _____			
Occupation _____			
Address _____			
2. Which of the following do you have (circle all that apply)			
Headache	Neck pain	Jaw pain	Ear pain
Facial pain	Other _____		
3. Which side hurts (circle one)			
Right	Left	Both	
-How long have you had this pain?			
-Is the pain constant?			
-Is the pain (circle all that apply)			
Aching	Burning	Stabbing	Other
-Is the pain the worst in the (circle all that apply)			
Morning	Afternoon	Evening	Night
-What makes the pain better?			
- What makes the pain worse?			
-What medication(s) do you take or have you previously taken for your pain?			
Medications _____		Dose _____	
Frequency _____			
4. Does it hurt to chew?		Y	N
5. Does it hurt to open wide?		Y	N

6. Which side of your jaw makes a popping noise? R			L
-Which side of your jaw makes a clicking noise? R			L
7. Has your jaw ever locked?	Y		N
-When did this first happen?			
-When did this last happen?			
8. Has your jaw ever slipped out of place?	Y		N
- Which side?	R		L
9. Have you noticed a change in you bite?	Y		N
10. Are your teeth sore or sensitive?	Y		N
- Do you clench your teeth?	Y		N
-Do you do grind your teeth?	Y		N
-Do you do this during the day or night?	Day	Night	
-When did you start clenching or grinding?			
11..Do you have tongue indentations	Y		N
12. Do you have problems with your ears?	Y		N
-Dizziness?	Y		N
-Ringing?	Y		N
-Hearing?	Y		N
-Other?	Y		N
13. Is it difficult to swallow?	Y		N
-Is it painful to swallow?	Y		N
-Have you noticed lumps in your face?	Y		N
-Throat?	Y		N
-Neck?	Y		N
-Other?			
14. Have you had any prior treatment for Bruxism? Y			N
-Splint?	Y	N	When?
Did it help?	Y	N	
-Bite Adjustment ?	Y	N	When?
Did it help?	Y	N	
-Orthodontics?	Y	N	When?
Did it help?	Y	N	
-Other			

### Medical history includes:

Patient having any of the following should be excluded:

- 1- Any systemic disease affecting bone or muscle including rheumatoid arthritis .
- 2- Ear infection.
- 3- Periocular pain.
- 4- Any medications especially steroids, and muscle relaxant.

### Sleep history:

History of any sleep disorder and type of treatment the patient follows if present. Transient sleep interruptions should be taken in consideration.

### B-Clinical examination

Patients clinical examination was carried out including TMJ, muscles of mastication and intraoral examination.

### Temporomandibular joint (TMJ) examination:

- a) **Inspection:** Inspection of the skin covering the TMJ region for any swelling, exudates, bruises, skin infection, scar or any other abnormalities.
- b) **Tenderness:** Bilateral palpation of the condyles during both rest and function.
- c) **Joint sounds:** Joints sounds are assessed by palpation during opening and closing, thus patients with joint sounds were excluded from this study.

### Muscles of mastication examination:

#### a) Masseter muscle

The deep part of the masseter muscle was palpated extra orally just below the zygomatic arch and approximately 10mm in front of the condylar head, while the anterior part of the superficial muscle was palpated bidigitally from the origin in the zygomatic arch to the insertion at the angle of the mandible.

### b) *Temporalis muscle*

Temporalis muscle was palpated at its origin on the temporal fossa on the lateral surface of the skull and its insertion was palpated intra-orally at the retromolar fossa with the index.

#### **Intra oral examination**

Examination for malocclusion, attrition, mobility and any special findings for bruxism as wear of tooth presenting as multiple, smooth and shiny facets at cusp tip and incisal edges with brown discoloration of exposed dentin and / or broken filling or tooth.

#### **Electromyogram procedure**

Electromyogram equipment\* was used for the evaluation of muscle activity and to monitor the prognosis after different treatment modalities.

- The patient was seated upright in a relaxed position with head unsupported looking in a forward direction, and both masseter and temporalis were located.
- The patient was asked to perform maximum molar clenching in centric occlusion and the muscle under examination being palpated to

define the trigger points .A mark was drawn on the patient's face corresponding to the trigger points.

- After determining the points for the surface electrodes positioning, the marks was transferred on a face template made of celluloid paper in relation to canthus tragus line, which is a line drawn from the outer canthus of the eye and the middle portion of the tragus of the ear. The line was drawn on both sides of the template, and with the aid of a window cut at the ala of the nose, to help reposition the template each time during EMG measuring and also during treatment.
- The skin will be swapped with 70% alcohol, then a conductive electrode gel\*\* was applied on the electrodes surface, the active surface electrodes was applied to the trigger points 2-3mm away from each other, while the ground electrode placed on the forehead (fig 1).
- The patient was asked to chew on a cube of carrot 1 cm thickness on the side of the muscle being tested for 30 seconds, and this was repeated with each muscle.



Fig. (1): A: The ground electrode placed on the forehead, B: active and reference electrodes placed on temporalis muscle, C: active and reference electrodes placed on the masseter muscle.

\* Dantec "keypoint" trademark of Apline Biomed in U.S.A.

\*\* Ten 20 conductive gel, Waver and company, Clorado U.S.A.

### Grouping of the patients

The patients were randomly divided into 2 equal groups, ten patients in each group.

The fabrication of the stent was made as follow:

- An impression of both maxillary and mandibular arches was made using alginate\* in a proper sized stock tray. Then poured immediately using stone.
- The maxillary cast was mounted on the semi-adjustable articulator\*\* by means of a face bow\*\*\* record and centric occlusion record was used to mount the mandibular cast. Vertical opening of the articulator was done, to gain 2mm space between the posterior teeth, representing the thickness of the future splint.
- A protrusive record done and both the protrusive and lateral condylar guidance were adjusted on the articulator.

### Group A:

For the hard splint, self-curing transparent acrylic resin was used to fabricate the splint in the form of a flat anterior bite plane with a thickness of

2–3 mm, which separated the posterior teeth while allowing contact between the anterior teeth using vaccum machine .(fig 2)

### Group B:

Patients in this group received hard occlusal stabilization splint constructed on the maxillary teeth of 2mm thickness by 3D digital printing. (7)

- An intraoral scanner\*\*\*\* was used to scan both casts on the articulator mounted at the desired thickness of the splint, then both protrusive and lateral values (bennet angle) taken from the articulator was introduced to the software\*\*\*\*\* on the virtual articulator (fig. 3).

- On the virtual maxillary model, the undercut areas were blocked out, then the edges of the splint shell were drawn so that they include the incisal edges of the anterior teeth slightly more than 2 mm and across the equator of the buccal surfaces of the posterior teeth, the palatal border follows the dental arch, including the hard palate in the shape of a horseshoe to finish behind the last molar (fig. 4). (15)

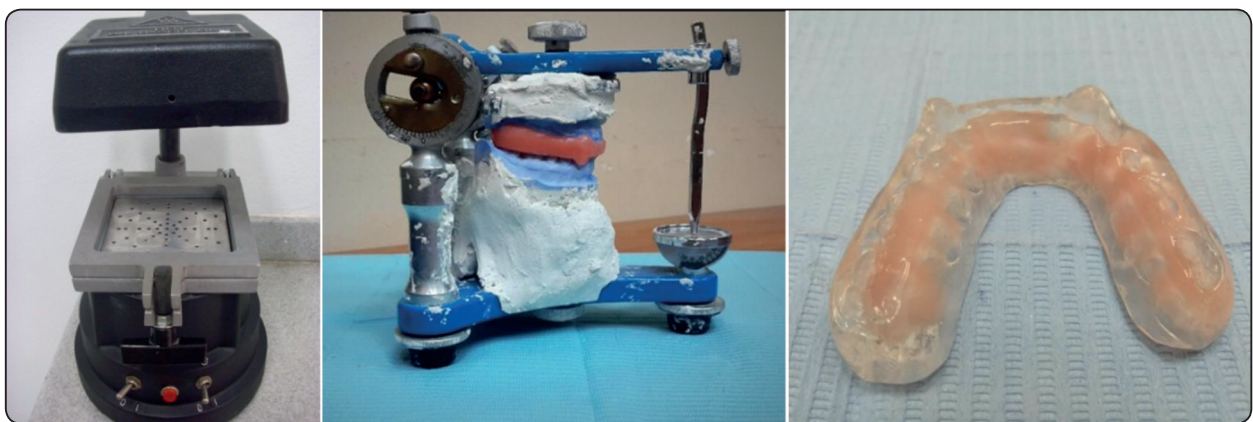


Fig. (2) Splint made by vaccum machine

\* Cavex alginate, Cavex, Holland

\*\* Dentatus, Dentatus AB, Sweden.

\*\*\* Dentatus, DentatusAB, Sweden.

\*\*\*\* Planmeca plan scan, 650 International Parkway, Richardson, Texas 75081, USA.

\*\*\*\*\* 3Shape CAD, 3Shape A/S • HolmensKanal 7, 4. 1060 Copenhagen K Denmark

- A bar was added to the splint shell virtual cast, where the occlusal surface was adjusted to be flat, and achieve contact with the working cusps of all the mandibular premolars and molars(fig.5).<sup>(15)</sup>
- Ramps created at the canine region, to create disocclusion of the posterior teeth during lateral and protrusive movement (fig. 3,4).<sup>(16)</sup>
- The virtual articulator simulate the protrusive and lateral movement based on the date introduced for lateral and protrusive movements, to check that ramps cause un interrupted disocclusion of posterior teeth represented by the continuous

v-shape on the ramp (fig.6).

- Smoothing and finishing of the final splint was done, areas representing contact with lower functional cusps were created.
- The splint was printed using 3D printer\*.
- The splint was checked in the patient mouth for retention, and proper disocclusion of the posterior teeth during lateral and protrusive movements using an articulating paper placed at the area of the canine ramps, and asking the patient to protrude the mandible and move from one side to other side, interrupted v-shape was produced(fig.7).



Fig. (3): Planmeca intraoral scanner.

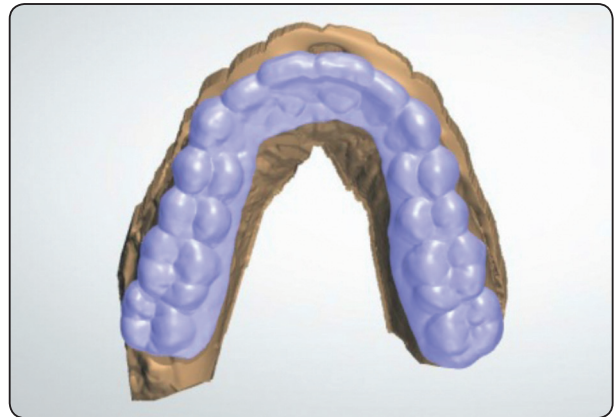


Fig. (4): Shell constructed virtually to the desired extensions on the virtual maxillary cast.



Fig. (5): Flat bar with ramps in the canine region constructed over the shell to achieve a flat surface to contact only with the buccal cusps of the lower teeth.



Fig. (6): Using the virtual articulator to ensure that the canine ramps cause complete disocclusion of the posterior teeth during lateral and protrusive movements represented by the uninterrupted V shape on the ramp.

\* Perfactory Desktop Digital Dental 3D Printer (DDDP), envisionTec.,



Fig. (7): Michigan splint from frontal, and lateral view inside the patient's mouth.

- The patient was reviewed after 7 days, to check the occlusion and re-adjust it if necessary.

The patient gradually weaned off the splint after 6 months, but told to wear it if their discomfort returns which is often at times of stress.

The muscular activity was evaluated by electromyogram.

Four EMG records were performed for each patient in the three groups at the following timings:

- Preoperative record, before starting the treatment.
- Post operative , 3 months after beginning of the treatment.

- After 6 months of the beginning of the treatment.

**RESULTS**

All the patients in the two groups attended the follow up periods, then the obtained data were statistically analyzed, and graphically illustrated.

**Electromyogram records**

Statistical analysis was performed by Anova for repeated measuring tests and post Hock test during follow up periods, data were presented as mean and standard deviation (SD).

**Group A (vaccum machine)**

**Effect of Michigan splint (vaccum machine) on masseter muscle in during follow up period:**

TABLE (1): Effect of time on masseter muscle in group A

	Preoperative		After 3 months		After 6 months		P value
	Mean	SD	Mean	SD	Mean	SD	
Masseter muscle	140.2	13.3	120.8	26.7	101.1	3.8	0.05

The change was statistically significant (P=0.05) as shown in table (1).



**Effect of Michigan splint (vaccum machine) on temporalis muscle during follow up period:**

TABLE (2) Effect of time on temporalis muscle of group A

	Preoperative		After 3 months		After 6 months		P value
	Mean	SD	Mean	SD	Mean	SD	
Temporalis muscle	253.3	9.2	155.8	44.2	126.2	24.3	0.05

The change was statistically significant ( $P < 0.05$ ) as shown in table (2).

**Group B (Michigan splint printed)**

**Effect of Michigan splint printed on masseter muscle in during follow up period:**

TABLE (3) Effect of time on masseter muscle in group B

	Preoperative		After 3 months		After 6 months		P value
	Mean	SD	Mean	SD	Mean	SD	
Masseter muscle	142.28	41.3	109.78	25.97	98.12	6.84	0.05

The change was statistically significant ( $P = 0.05$ ) as shown in table (3).

**Effect of Michigan splint printed on temporalis muscle during follow up period:**

TABLE (4) Effect of time on temporalis muscle of group B

	Preoperative		After 3 months		After 6 months		P value
	Mean	SD	Mean	SD	Mean	SD	
Temporalis muscle	267.33	99.88	135.88	54.24	111.28	28.23	<0.001

The change was statistically significant ( $P < 0.05$ ) as shown in table (4).

**Comparison between the effect of the two appliances on the masseter muscle :**

TABLE (5) Comparison between mean masseter muscle activity through the follow up periods.

Masseter	Vaccum splint		Splint printed		P value
	Mean	Std.	Mean	Std.	
Preoperative	140.2	13.3	142.28	41.3	
After 3 months	120.8	26.7	109.78	25.97	0.3612
After 6 months	101.1	3.8	98.12	6.84	0.2441

This was statistically insignificant as the ( $p > 0.05$ ) as shown in table (5)

### Comparison between the effect of the two appliances on the temporalis muscle:

TABLE (6): Comparison between mean temporalis muscle activity through the follow up periods.

Temporalis	Vaccum splint		Splint printed		P value
	Mean	Std.	Mean	Std.	
Preoperative	253.3	9.2	267.33	99.88	
After 3months	155.8	44.2	135.88	54.24	0.3799
After 6months	126.2	24.3	111.28	28.23	0.221

This was statistically insignificant ( $p > 0.05$ ) as shown in table (6) .

### DISCUSSION

Bruxism is believed to be one of the most common parafunctional habits nowadays, that has been suggested to be an initiating factor for TMD, and myofascial pain disorders. <sup>(17)</sup>

In this study patients suffering from bruxism of myogenic origin were selected, they were suffering from one or more from the following signs and symptoms to help in confirming the myogenic origin: pain in the auricular area, tenderness of masseter and / or temporalis muscle, morning headaches, and pain in the temporomandibular joint region associated with eating. <sup>(18)</sup>

Patients in this study had trigger points, which are localized spots of in which tenderness is felt upon manual pressure. Sustained pressure in this area cause tingling or numbness. <sup>(19)</sup>

The patients were free from any pathological condition in the temporomandibular joint or any systemic condition that may affect the efficiency of the masticatory muscles, as patients with past dental or medical history of a pathological condition of nervous or muscular origin may affect the EMG results. <sup>(20)</sup>

Other conditions also was excluded from the patient criteria as they are contraindicated for Botox treatment, like; Pregnancy or breast feeding, prior

Botox treatment, trigeminal neuralgia, pain of dental origin, muscle relaxant use, or aminoglycoside use as it interferes with neuromuscular function, and rheumatoid arthritis. <sup>(21)</sup>

Patients having loss of vertical dimension of occlusion were excluded, as this effects the position of the condyle, leading to excessive load on the TMJ, causing pathological conditions in it, and prevent the jaw muscles from proper functioning due to the change in the distance between the muscles origin and insertion sites especially the masseters and the medial pterygoids muscles. <sup>(22,23)</sup>

Patients age ranges between 18-60, as very old patients were excluded to avoid atrophy in the skeletal muscles due to senility. <sup>(24)</sup>

EMG used to evaluate the efficiency of each treatment modality. <sup>(25)</sup>

Surface electrodes EMG was used as the muscles under study are considered superficial muscles, and also because it is preferred over needle electrodes EMG to eliminate the reflex of pain caused during the insertion of the needle electrodes, which may affect the EMG records.

The anterior fibers of the temporalis muscles, and the superficial fibers of the masseter muscles were the fibers assessed by the EMG because they were easily accessible to the surface electrodes. <sup>(26)</sup>

During making EMG records: A transparent facial template was used to allow for accurate placing and reproducibility of the surface electrodes position each time during muscle assessment by EMG on the trigger point.<sup>(27)</sup>

- Patients were seated in upright position to ensure muscle relaxation, and avoid any postural effect during making the records on the activity of the muscles under study.<sup>(28)</sup>
- The skin at the site where the electrodes were to be placed was cleaned with alcohol to remove the excess oiliness which cause electrical resistance, so this would enhance the contact between the skin and the electrodes producing a good quality signals<sup>(23)</sup>
- A conductive gel was placed on the electrodes to improve its conductivity<sup>(27)</sup>.
- Adhesive strips were used to fix the electrodes in place to avoid errors due to its movements.
- A cube of carrot with standardized thickness was used because the harder the food, the higher the muscular activity, the greater the number of the masticatory cycles, and the longer the duration of mastication allowing for enough time for making EMG records.<sup>(29)</sup>

Michigan splint, is a stabilization splint that has a flat surface that ensures occlusal stability of both dental arches. it is used as it cause relaxation in the masticatory muscle, reposition the disc and the condyle in a physiological position<sup>(15)</sup>

The flat surface of the splint provides freedom in centric, and allow for realization of self positioning of the mandible<sup>(15)</sup>

A Face bow record was done to help relate the arc of closure e.g. hinge axis of the mandible to the cranium. Then the face bow record was transferred to a semi adjustable articulator helps the articulator to simulate the jaw movements more accurately when the casts where vertically separated.<sup>(30)</sup>

The thickness of the splint was 2 mm thickness, as it has been postulated that a stabilization appliance is more effective when fabricated at the vertical dimension where the muscle has minimal surface EMG activity.<sup>(31)</sup>

It was found that the masseter and temporalis muscles have their minimal surface EMG activity at vertical opening ranging from 4.5 to 18 mm. To test this hypothesis, TMD patients were randomized into three groups. One group received stabilization appliances with increased vertical dimension only by 1 mm, the second group received appliances with increased vertical dimension 4.4 mm which is half the opening that produce minimal masseter muscle surface EMG activity, and the third group received appliances with increased vertical dimension 8.2 mm which represents the opening that produced minimal EMG activity. TMD symptoms resolve. It is generally recommended that the appliances should be fabricated at the range from 1 to 4 mm thick.<sup>(31)</sup>

Protrusive and lateral records were introduced to the virtual articulator soft ware to allow for fabrication of the canine ramp in order to produce disocclusion between the posterior teeth in both lateral and protrusive movements. The splint was fabricated on the maxillary cast to enhance its retention and stability<sup>(15)</sup>

The buccal cusps of all the mandibular posterior teeth must be in contact with the flat surface of the splint, to enhance the stability of the splint and to avoid any occlusal changes in the lower arch.<sup>(31)</sup>

### Discussion of results

It was found in the group of 3 Ddigital printed splints that minimal chair side time needed in fitting the appliances and reduced time in adjusting the occlusion. The turn around time for an occlusal splint is 3 to 5 working days and the costs are comparable with splints made by vaccm machine. Most importantly, patients favourably comment on

the comfortable fit and decreased bulk. They have certainly had improved up take and compliance with the wear of occlusal splints and night guard type of appliances and their clinical efficacy has been significantly improved. Intraorally made splints are fabricated by creating a thermoplastic, vacuum formed "suck-down" of the patient's maxillary arch. This is then relined intraorally against the opposing arch with self-cure acrylic resin. This process can be quite uncomfortable for patients, as they have to suffer the unpleasant taste of acrylic resin in their mouth. Further, the chairside time is generally lengthy, as the splint then has to be carved out of the set resin block - a messy clinical/laboratory procedure. Also, occlusal splints require a minimal bulk in order not to fracture during function.

For this reason, they may extend a fair distance onto the palatal tissue and be quite thick. This can result in patient discomfort and failure to wear the appliance. This allows printed occlusal splint to be more durable, lighter, thinner and less bulky, hence improving patient comfort and compliance. <sup>(32)</sup>

For the patients receiving Michigan splint the exact hypothesis for the improvement in muscle is still controversial. Some studies suggest that the splint replace the patient's occlusal disharmonies providing the patient with "interference free" occlusion, others suggest that the appliance makes the patients aware of their habit <sup>(33,34)</sup>.

The cognitive awareness theory suggests that the presence of the splint as a foreign object in the mouth will change the oral tactile stimuli, decrease the oral volume and space for the tongue, and make the patients conscious about the position and potentially harmful use of their jaw. Although it seems reasonable to suppose that this increased awareness would influence the patients' learning to alter or reduce their harmful behavior and therefore contribute to the overall success of the intervention <sup>(35)</sup>.

A third hypothesis was postulated that the increase in the vertical dimension of rest results in muscle relaxation <sup>(36)</sup>

EMG records for the Michigan splint group were in agreement with the findings of Carlsson *et al.*, Christensen *et al.*, Holmgren, Sheikholeslam and Riise, Sheikholeslam *et al.*, Naeije & Hansson, and Visser *et al.*, that there is decrease in EMG activity in both the anterior temporalis and the masseter muscles when using a hard splint in comparison to no splint <sup>(37-41)</sup>

Regarding the muscle activity of conventional and printed splint groups, the results of our study revealed no statistically significant differences as revealed in other studies. <sup>(42)</sup>

## CONCLUSION

It can be concluded that the 3D digital printed occlusal splint improves the patient's satisfaction of TMD patients greater than that of conventional occlusal splint. Moreover, both printed and conventional occlusal splint improves the masseter and temporalis muscle activities. In addition printed occlusal splint decreases to a large extent, the time needed for splint adjustment compared to conventional occlusal splint.

Within the limitations of this study, it could be recommended that 3D digital printed occlusal splint may be suggested as an alternative manufacturing modality for TMD patients who can offer the cost

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