Influence of Stabilization Splint Thickness on Temporomandibular Disorders

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Purpose: To assess the effect of stabilization splint (SS) thickness on temporomandibular disorders (TMDs). Materials and Methods: Participants were selected from patients who applied to the clinic with a complaint of temporomandibular disorders (TMDs). Symptoms were evaluated with the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD). Regarding the treatment plan, patients were divided into two groups: the 2-mm–thick splint group (2-mm TSG) and the 4-mm–thick splint group (4-mm TSG). They used SSs at night (8 hours) and were recalled 1, 2, 3, and 6 months after splint insertion. At the end of the study, 72 patients (2-mm TSG = 39, 4-mm TSG = 33) had completed the 6-month follow-up. The SPSS program was used for statistical analysis. The results of the analysis were evaluated at a significance level of .05. Results: Pain in the muscles decreased significantly in the muscle disorders and combined groups (both 2- and 4-mm TSG) after 6 months of treatment (P < .05). In the combined group, TMJ sounds significantly decreased after 6 months of treatment, and there was a statistically significant difference between the 2-mm TSG and the 4-mm TSG (P = .045). Also, in the combined group, maximum unassisted opening (MUO) values of patients treated with 2-mm–thick splints decreased after 6 months of treatment (P = .022). Conclusion: Both 2-mm–thick and 4-mm–thick splints were effective in the treatment of muscle disorders and disc displacements, especially in muscle-related pain and TMJ sound symptoms. Int J Prosthodont 2022;35:163–173. doi: 10.11607/ijp.6923
Some of these studies examined the activity and chewing forces of masticatory muscles using electromyographic (EMG) values. Also, the effect of splint thickness on orofacial pain, headaches, myofascial pain-dysfunction syndrome, and chewing performance were studied. As a result of these studies, a consensus on splint thickness could not be reached. The aim of this study was to assess the effect of the 2-mm–thick and 4-mm–thick splints on myofascial pain, disc displacement disorders, and a combination of these disorders. Based on clinical experience, 2 mm thick was chosen for the thin splint group (2-mm TSG), and 4 mm thick was chosen for the thick splint group (4-mm TSG). The null hypothesis of this study was that there is no difference between the 2-mm TSG and the 4-mm TSG in terms of treatment success and important clinical parameters for myofascial pain, disc displacement disorders, and a combination of these disorders.

MATERIALS AND METHODS

Study Design, Patient Selection, and Randomization

This study was approved by the Istanbul Medipol University Non-Interventional Clinical Research Ethical Committee (10840098-62), and the protocol was registered with clinicaltrials.gov (NCT04524806). Recruitment for this clinical trial took place between July 2013 and January 2015. Patients were selected from the individuals who applied to the Department of Prosthodontics at the Faculty of Dentistry with complaints regarding their TMDs. The inclusion criteria for the study were as follows: (1) patients diagnosed with muscle disorders (Axis I, group 1) and/or disc displacements (Axis I, group 2) based on the RDC/TMD diagnostic criteria; (2) patients with no need for orthodontic treatment; (3) patients with a lack of general systemic conditions that can affect the TMJ and masticatory muscles, such as rheumatoid arthritis; and (4) a minimum age of 18 years.

The exclusion criteria for the study were as follows: (1) patients diagnosed as other common TMJ disorders (Axis I, group 3); (2) patients currently taking any medications (analgesics, anti-inflammatory drugs, muscle relaxants, corticosteroids, antidepressants) that may affect the results of the study; (3) patients previously treated with stabilization splints; (4) patients with complete or partial edentulism; and (5) patients not able to attend follow-up appointments regularly. Patients were informed about the study, and if the patient agreed to participate in this study voluntarily, informed consent was signed. TMD diagnoses were performed using Axis I of the RDC/TMD. The examination of anatomical regions and patient orientation were performed as recommended in the RDC/TMD by one experienced clinician (H.K.). Patients who only conformed to the criteria of Axis I, group 1 were evaluated as the muscle disorders group, and patients who only conformed to the criteria of Axis I, group 2 were evaluated as the disc displacements group. Patients who conformed to the criteria of both groups 1 and 2 were evaluated as the combined group.

Power analysis was conducted with a dedicated software (G*Power v3.1.9.2). The sample size of the groups was calculated to be 21 to achieve the study objectives (α = .05, 1 – β = 0.95), but the number of the patients was increased in case patient loss occurred in the follow-up appointments. The distribution of the 2-mm TSG and the 4-mm TSG was made by randomization. Simple randomization was performed by the toss of a coin. The first patient was assigned to the 2-mm TSG group, and the next patient to the 4-mm TSG group.

Construction of Stabilization Splints

All stabilization splints were constructed by a single clinician (H.B.) who did not know the diagnoses of patients. Impressions were taken from the maxillary arch of patients. Irreversible hydrocolloid impression material (Tropicalgin, Zhermack) was used for the impression. Maxillary full-arch SSSs were preferred because they are more stable, more retentive, and less fractural than mandibular splints. Hard gypsum (Elite Stone, Zhermack) was poured immediately, and the stone cast model was prepared. Clear hard sheet pressure molding material (2 mm thick, Duran Biocryl, Scheu-Dental) was placed on the vacuum adapter (Biostar, Scheu Dental). After the hard sheet pressure molding material was sufficiently heated, the stone cast model was placed on the device, and the vacuum of the device was activated. The borders of the splints were marked and cut off with a cutting disc (NTI Superflex Disc, Kerr); then, the splint was removed from the stone cast. The borders of the anterior and posterior buccal areas were adjusted, and excessive acrylic in the palatal side was abraded. Edges and sharp areas were rounded. After checking the fit of the splint in the mouth, the borders of the splint were shortened when necessary (Fig 1a).

A small amount of autopolymerizing acrylic resin (Temdent Classic, Schütz Dental) was mixed and placed in the anterior region of the splint. After the polymerization process, the acrylic part was used as an anterior stop. The contact points of the mandibular anterior teeth on the anterior stop were marked using articulating paper (Bausch articulating paper) and were then abraded perpendicularly to the long axis of the mandibular teeth (Fig 1b). The musculoskeletal stable position of the patients was determined. According to the recommendations of Okeson, the patients were guided to close on the posterior teeth while the splint was in the mouth using the bilateral manual manipulation technique. This position was considered as a stable mandibular position. The correct position was checked by trying several times, and the contact points were marked.
Arrangement of Stabilization Splint Thickness

A horizontal line was drawn with a permanent marker on the first premolars while the teeth were in centric occlusion. The distance between the lines was measured with a digital caliper (Standart type, Insize; Fig 1c). The SS was placed inside the mouth, and adjustments were made on the anterior stop to retain 2 mm or 4 mm of space in the first premolar region (Fig 1d). After that, the SS was removed from the mouth, and the autopolymerized acrylic was added to the occlusal surface without affecting the anterior stop. Before the SS was mounted, free monomers were eliminated by air spray. The patient closed the mouth until the mandibular incisors contacted the point, which was signed on the anterior stop. After removing the SS from the mouth, the top point of the buccal cusps of all mandibular teeth was marked with a...
pencil (Fig 1e). The acrylic around the contact points was abraded to provide freedom during eccentric movements. Only the canine regions were left. The SS was reinserted into the patient’s mouth, and centric relation contacts were marked with articulating paper (Fig 1f). Anterior and posterior contacts were distributed homogenously. According to the eccentric and protrusive movements, the canine area on the SS was inclined up to 30 to 45 degrees. In this way, canine-guided occlusion was provided. The SS was polished using a polishing kit (Set HP 125, EVE Ernst Vetter) and a polishing paste (Universal Paste, Ivoclar Vivadent) according to manufacturer instructions. After that, the patient was asked to check the cheeks and tongue for any discomfort areas. When necessary, the splint was readjusted. Figure 2 shows splints from the 2-mm TSG and the 4-mm TSG.

**Blinding and Evaluating the Outcomes**

This study was double-blinded, as follows: Patients did not know whether they were in the 2-mm TSG or the 4-mm TSG. Follow-ups were made by one researcher (H.K.) who determined the diagnoses using RDC/TMD Axis I at baseline. Until the end of the study, this researcher did not know which splint group the patients were in. Splints were constructed by the other researcher (H.B.). Until the end of the study, this researcher did not know the patients’ diagnoses.

After SS was delivered to the patient, follow-up appointments were scheduled for 1, 2, 3, and 6 months. RDC/TMD forms were used again in these follow-up appointments. The outcomes of the muscle disorder group were the rate of treatment success, the amount of maximum unassisted opening (MUO), the number of painful muscles, and the scores of painful muscles. The outcomes of the disc displacement group were the rate of treatment success, the amount of maximum unassisted opening (MUO), and the presence of TMJ sounds when opening or closing the mouth. The outcomes of the combined group were the rate of treatment success, the amount of MUO, the number of painful muscles, the scores of painful muscles, and the presence of TMJ sounds when opening or closing the mouth.

**Treatment Success**

Treatment success was determined with those who partially recovered and fully recovered after 6 months of treatment. For the muscle disorders group, those who returned from myofascial pain with limited opening to myofascial pain were determined as partially recovered; and those who recovered completely were determined as fully recovered. Both were included when calculating treatment success in the muscle disorders group. For the disc displacements group, those who returned from disc displacement without reduction with limited opening to disc displacement without reduction and without limited opening were determined partially recovered; and those who recovered completely were determined as fully recovered. Both were included when calculating treatment success in the disc displacement group. For the combined group, if one of the muscle disorder or disc displacement diagnoses
recovered, it was considered partially recovered, and fully recovered if both recovered. Both were included when calculating treatment success in the combined group.

Amount of MUO
When calculating the MUO, patients were told to open their mouth to the point where they could open the most, even if they had pain. The distance between the incisal edge of the maxillary central incisor and the incisal edge of the mandibular central incisor was measured with a ruler in millimeters. The amount of overbite was added to this distance.

Number of Painful Muscles and Scores of Painful Muscles
The index and middle fingers of clinicians were used for the palpation of the muscles. A digital scale was used for the calibration of the clinician. Before the palpation of each muscle, the application of 2 lbs of pressure at least three consecutive times by the clinician was confirmed with a digital scale. For the palpation of the posterior mandibular region and the submandibular region, the pressure was changed to 1 lb. The temporalis (posterior, middle, anterior), the masseter (origin, body, insertion), the posterior mandibular region, and the submandibular region were palpated. The patients were asked about pain or pressure after palpations. If the patient reported feeling no pain or pressure, then the muscle was scored as 0 (no pain). If the patient reported feeling pain, the muscle was scored according to the patient’s rating of pain as 1 (mild), 2 (moderate), or 3 (severe). The painful muscle score was obtained by summing these scores and dividing by the number of muscles palpated. The number of painful muscles was found by summing up how many of the palpated muscles had pain.

Presence of TMJ Sounds
The clinician’s right index finger was placed on the left preauricular area of the patient, and the left index finger was placed on the right preauricular area to evaluate the joint sounds. Patients were told to open as much as they could, even if they felt pain. During each closure, patients were told to touch all their teeth. Patients were told to open and close three times. If a click was noted on two of three opening or closing movements, it was considered positive for TMJ sounds.

Statistical Analysis
Data were analyzed with SPSS version 23 (IBM). Kolmogorov-Smirnov test was used for the normality distribution. Chi-square test and Fisher exact test were used to compare categorical variables according to group. Mann-Whitney U test was used to compare quantitative variables with respect to the binary group for nonnormally distributed data. Friedman test was used for nonnormally distributed variables to examine the changes of within-group parameters over three or more times. Cochran Q test and Friedman test were used to examine the changes of categorical parameters within the group over three or more times. Analysis results are presented as mean ± SD for quantitative data, and as deviation and median (minimum–maximum) and frequency (percentage) for categorical data. Significance levels were evaluated at $P < .05$ in all analyses.

RESULTS
The study was conducted between July 2013 and January 2015. A total of 150 patients with TMDs enrolled in this study, and 104 met the inclusion criteria and were randomized to the 2-mm TSG and the 4-mm TSG. At the end of the study, a total of 72 patients; 39 patients in the 2-mm TSG (35 women, 4 men, mean age: 27.31 ± 8.88 years) and 33 patients in the 4-mm TSG (28 women, 5 men, mean age: 32.72 ± 12.20 years), attended all follow-ups (Fig 3).

As shown in Table 1, 23.6% ($n = 17$) of the patients were in the muscle disorders group (Axis I, group 1), and 15.2% ($n = 11$) in the disc displacement group (Axis I, group 2). More than half of the patients (61.2%, $n = 44$) were in the combined group (Axis I, groups 1 and 2 together). There was predominantly myofascial pain (64.7%) in the group of muscle disorders; also, in almost one-third of the muscle disorders, patients were diagnosed with having myofascial pain with limited opening (35.3%). All patients in the disc displacement group were diagnosed as having disc displacement with reduction. In the combined group, patients were diagnosed with mainly myofascial pain (63.6%) in terms of muscle disorders and predominantly disc displacement with reduction (84.1%) in terms of disc displacements. There was a statistical difference in the disc displacement part of the combined group ($P = .048$).

Outcome of Muscle Disorders Group
In the muscle disorders group, the rate of treatment success in the 2-mm TSG was 28.6% and 30% in the 4-mm TSG (Table 2). There was no statistically significant difference between 2-mm TSG and 4-mm TSG in terms of treatment success in the muscle disorders group ($P = 1.000$). The treatment of all patients in the 2-mm TSG was partially successful, the treatment of 20% of patients in the 4-mm TSG were completely successful, and of 10% of the patients in the 4-mm TSG were partially successful.

Although the MUO values increased from baseline toward the end of treatment in both groups, these increases were not statistically significant for the 2-mm TSG ($P = .050$) and the 4-mm TSG ($P = .922$). There was no statistically significant difference between the 2-mm
### Table 1  Distribution of TMDs According to RDC/TMD at Baseline

<table>
<thead>
<tr>
<th></th>
<th>2-mm TSG (n = 39)</th>
<th>4-mm TSG (n = 33)</th>
<th>Total (N = 72)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Muscle disorders (Axis I, group 1)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Myofascial pain</td>
<td>5 (71.4)</td>
<td>6 (60)</td>
<td>11 (64.7)</td>
<td>1.000</td>
</tr>
<tr>
<td>Myofascial pain with limited opening</td>
<td>2 (28.6)</td>
<td>4 (40)</td>
<td>6 (35.3)</td>
<td></td>
</tr>
<tr>
<td><strong>Disc displacements (Axis I, group 2)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disc displacement with reduction</td>
<td>3 (100)</td>
<td>8 (100)</td>
<td>11 (100)</td>
<td></td>
</tr>
<tr>
<td><strong>Combined</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Myofascial pain</td>
<td>17 (58.6)</td>
<td>11 (73.3)</td>
<td>28 (63.6)</td>
<td>.336</td>
</tr>
<tr>
<td>Myofascial pain with limited opening</td>
<td>12 (41.4)</td>
<td>4 (26.7)</td>
<td>16 (36.4)</td>
<td></td>
</tr>
<tr>
<td>Disc displacement with reduction</td>
<td>25 (86.2)</td>
<td>12 (80)</td>
<td>37 (84.1)</td>
<td></td>
</tr>
<tr>
<td>Disc displacement without reduction</td>
<td>0 (0)</td>
<td>2 (13.3)</td>
<td>2 (4.5)</td>
<td>.048*</td>
</tr>
<tr>
<td>Disc displacement without reduction with limited opening</td>
<td>4 (13.8)</td>
<td>0 (0)</td>
<td>4 (9.1)</td>
<td></td>
</tr>
<tr>
<td>Disc displacement without reduction without limited opening</td>
<td>0 (0)</td>
<td>1 (6.7)</td>
<td>1 (2.3)</td>
<td></td>
</tr>
</tbody>
</table>

Data are reported as n (%) unless otherwise specified.

*Significant (P < .05) according to chi-square test.

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**Fig 3** Flowchart of the study protocol.
TSG and the 4-mm TSG from baseline to 6 months of treatment for MUO values. The painful muscle scores and the number of painful muscles decreased from baseline to 6 months of treatment in both groups (2-mm TSG; \( P = .019 \) and 4-mm TSG; \( P < .001 \)). There were no statistically significant differences between the 2-mm TSG and the 4-mm TSG in terms of treatment success in the 4-mm TSG (Table 2). There was no statistically significant difference between the 2-mm TSG and the 4-mm TSG from baseline to 6 months of treatment for the painful muscle scores or the number of painful muscle values (Table 3, Fig 4).

Outcome of Disc Displacement Group
In the disc displacement group, the rate of treatment success in the 2-mm TSG was 0% and 37.5% in the 4-mm TSG (Table 2). There was no statistically significant difference between the 2-mm TSG and the 4-mm TSG in terms of treatment success in the disc displacement group (\( P = .491 \)). The treatment of all patients in the 4-mm TSG was completely successful.

There were no statistically significant differences between baseline and 6 months of treatment for the 2-mm TSG (\( P = .050 \)) and the 4-mm TSG (\( P = .922 \)) in terms of MUO values. There was no statistically significant difference between the 2-mm TSG and the 4-mm TSG from baseline to 6 months of treatment for MUO values.

Although TMJ sounds decreased at some follow-ups in the 2-mm TSG, it remained the same after 6 months of treatment. In the 4-mm TSG, TMJ sounds decreased during the 6-month treatment, but this decrease was not statistically significant (\( P = .092 \)). There was also no statistically significant difference between the 2-mm TSG and the 4-mm TSG from baseline to 6 months of treatment for TMJ sounds (Table 4 and Fig 5).

Outcome of the Combined Group
In the combined group, the rate of treatment success in the 2-mm TSG was 62.1%, and in the 4-mm TSG was 40% (Table 2). There was no statistically significant difference between the 2-mm TSG and the 4-mm TSG in terms of treatment success in the combined group (\( P = .210 \)). The rate of the treatment success of completely recovered patients was 20.7%, and the rate of the treatment success of partially recovered patients was 41.4% in the 2-mm TSG. The treatment in the 4-mm TSG was partially successful (40%).

The MUO values were decreased from baseline toward the end of treatment in the 2-mm TSG, and there was a statistical difference between baseline and the 6-month follow-up (\( P = .022 \)). Although the MUO values increased from baseline toward the end of treatment in the 4-mm TSG, these increases were not statistically significant for the 4-mm TSG (\( P = .156 \)). There was no statistically significant difference between the 2-mm TSG and the 4-mm TSG from baseline to the 6-month follow-up for MUO values.

### Table 2
Comparison of Treatment Success Rates of 2-mm and 4-mm TSG

<table>
<thead>
<tr>
<th></th>
<th>2 mm (n = 39)</th>
<th>4 mm (n = 33)</th>
<th>( P^a )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muscle disorders</td>
<td>2 (28.6)</td>
<td>3 (30)</td>
<td>1.000</td>
</tr>
<tr>
<td>Disc displacement</td>
<td>0 (0)</td>
<td>3 (37.5)</td>
<td>.491</td>
</tr>
<tr>
<td>Combined</td>
<td>18 (62.1)</td>
<td>6 (40)</td>
<td>.210</td>
</tr>
</tbody>
</table>

\( P < .05 \) was considered significant.

\(^a\) Fisher exact test.

\(^b\) Chi-square test.

The painful muscle scores and the number of painful muscles decreased from baseline to 6 months of treatment in both groups (2-mm TSG; \( P = .019 \) and 4-mm TSG; \( P < .001 \)). There were no statistically significant differences between the 2-mm TSG and the 4-mm TSG from baseline to 6 months of treatment for the painful muscle scores and the number of painful muscle values (Table 5 and Fig 6).

There was a statistically significant difference between baseline and 6 months for both the 2-mm TSG (\( P < .001 \)) and 4-mm TSG (\( P = .024 \)) in terms of TMJ sounds. There was also a statistical difference between the 2-mm TSG and the 4-mm TSG at 2 months of treatment (\( P = .009 \)) and 6 months of treatment (\( P = .045 \)) in terms of TMJ sounds (Table 5 and Fig 6).

**DISCUSSION**

In the present study, the effect of thin and thick SSs on treatment success and symptoms of TMD healing was investigated. The null hypothesis of this study is that there is no difference between the 2-mm TSG and the 4-mm TSG in terms of the rate of treatment success and the important clinical parameters for myofascial pain, disc displacement disorders, and the combination of these disorders. There was a statistically significant difference between the 2-mm TSG and the 4-mm TSG only in TMJ sounds in the combined group after 6 months of therapy. As a result, the null hypothesis was accepted, except for the TMJ sounds parameters in the combined group.

As in many studies,\(^{10,12–14,16–19}\) the thicknesses of the groups were determined by the help of previous studies and clinical experience. Kostrzewa-Janicka et al\(^{15}\) used a cephalometric analysis to determine the ideal splint thickness for their study. Hegab et al\(^{11}\) used magnetic resonance imaging (MRIs) with splints having five different thicknesses. Although these two studies determined the thickness of splints based on more quantitative data, the first study should be evaluated in terms of the amount of...
### Table 3  Comparisons of 2-mm and 4-mm TSG from Baseline to 6 mo for Maximum Unassisted Opening (MUO), Painful Muscle Scores, and Number of Painful Scores in Muscle Disorders Group

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>1 mo</th>
<th>2 mo</th>
<th>3 mo</th>
<th>6 mo</th>
<th>(\chi^2)</th>
<th>(P^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MUO (mm)</strong></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>2-mm TSG</td>
<td>40.43 ± 3.87</td>
<td>44.71 ± 4.15</td>
<td>44.14 ± 5.70</td>
<td>44.14 ± 2.91</td>
<td>44.43 ± 3.15</td>
<td>11.250</td>
<td>.050</td>
</tr>
<tr>
<td>4-mm TSG</td>
<td>37.80 ± 9.83</td>
<td>39.60 ± 9.18</td>
<td>40.80 ± 11.50</td>
<td>40.60 ± 11.77</td>
<td>43.00 ± 4.27</td>
<td>0.917</td>
<td>.922</td>
</tr>
<tr>
<td>(P^b)</td>
<td>.921</td>
<td>.193</td>
<td>.488</td>
<td>.769</td>
<td>.277</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Painful muscle scores</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-mm TSG</td>
<td>17.71 ± 7.04</td>
<td>6.29 ± 2.69</td>
<td>8.14 ± 5.61</td>
<td>9.43 ± 7.79</td>
<td>4.00 ± 0.82</td>
<td>11.765</td>
<td>.019*</td>
</tr>
<tr>
<td>4-mm TSG</td>
<td>18.00 ± 8.89</td>
<td>4.80 ± 2.44</td>
<td>4.80 ± 2.35</td>
<td>5.80 ± 2.62</td>
<td>4.40 ± 2.37</td>
<td>22.043</td>
<td>&lt; .001*</td>
</tr>
<tr>
<td>(P^b)</td>
<td>.767</td>
<td>.485</td>
<td>.323</td>
<td>.694</td>
<td>.610</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>No. of painful muscles</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-mm TSG</td>
<td>13.57 ± 5.32</td>
<td>6.29 ± 2.69</td>
<td>8.14 ± 5.61</td>
<td>7.14 ± 4.41</td>
<td>4.00 ± 0.82</td>
<td>11.765</td>
<td>.019*</td>
</tr>
<tr>
<td>4-mm TSG</td>
<td>11.60 ± 4.35</td>
<td>4.60 ± 2.27</td>
<td>4.60 ± 2.17</td>
<td>5.60 ± 2.55</td>
<td>4.20 ± 2.44</td>
<td>20.043</td>
<td>&lt; .001*</td>
</tr>
<tr>
<td>(P^b)</td>
<td>.200</td>
<td>.364</td>
<td>.326</td>
<td>.694</td>
<td>1.000</td>
<td></td>
<td></td>
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</tbody>
</table>

Data are reported as mean ± SD unless otherwise indicated.

*\(P < .05\).*

\(^a\)Friedman test.

\(^b\)Mann-Whitney \(U\) test.

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**Fig 4** Change in amount of maximum unassisted opening (MUO), painful muscle scores, and number of painful muscles for 2-mm TSG and 4-mm TSG from baseline to 6-month follow-up in muscle disorders group.

### Table 4  Comparisons of 2-mm and 4-mm TSG from Baseline to 6 mo for Maximum Unassisted Opening (MUO) and Presence of TMJ Sounds in Disc Displacement Group

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>1 mo</th>
<th>2 mo</th>
<th>3 mo</th>
<th>6 mo</th>
<th>(\chi^2)</th>
<th>(P^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MUO, mean ± SD (mm)</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>2-mm TSG</td>
<td>38.33 ± 8.08</td>
<td>37.33 ± 6.35</td>
<td>39.67 ± 10.97</td>
<td>37.00 ± 6.93</td>
<td>36.00 ± 5.20</td>
<td>(\chi^2 = 2.143)</td>
<td>.710</td>
</tr>
<tr>
<td>4-mm TSG</td>
<td>40.38 ± 8.26</td>
<td>39.13 ± 6.60</td>
<td>37.38 ± 8.30</td>
<td>38.88 ± 3.80</td>
<td>42.00 ± 5.55</td>
<td>(\chi^2 = 8.286)</td>
<td>.082</td>
</tr>
<tr>
<td>(P^b)</td>
<td>.678</td>
<td>.678</td>
<td>.678</td>
<td>.667</td>
<td>.213</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TMJ sounds, no. of patients</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-mm TSG</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>Q = 5.333</td>
<td>.255</td>
</tr>
<tr>
<td>4-mm TSG</td>
<td>8</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>5</td>
<td>Q = 8.000</td>
<td>.092</td>
</tr>
<tr>
<td>(P^d)</td>
<td>NC</td>
<td>1.000</td>
<td>1.000</td>
<td>.491</td>
<td>.491</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NC = not computed. \(P < .05\) was considered significant.

\(^a\)Friedman test.

\(^b\)Mann-Whitney \(U\) test.

\(^c\)Cochran Q test.

\(^d\)Fisher exact test.
Table 5  Comparison of 2-mm TSG and 4-mm TSG from Baseline to 6 mo for Maximum Unassisted Opening (MUO), Painful Muscle Scores, Number of Painful Scores, and Presence of TMJ Sounds in Combined Group

<table>
<thead>
<tr>
<th></th>
<th>MUO</th>
<th>Painful muscle scores</th>
<th>No. of painful muscles</th>
<th>TMJ sounds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline 1 mo 2 mo 3 mo 6 mo</td>
<td>Baseline 1 mo 2 mo 3 mo 6 mo</td>
<td>Baseline 1 mo 2 mo 3 mo 6 mo</td>
<td>Baseline 1 mo 2 mo 3 mo 6 mo</td>
</tr>
<tr>
<td></td>
<td>2-mm TSG 42.07 ± 7.43 37.28 ± 8.20 38.03 ± 6.80 37.41 ± 5.10 39.86 ± 7.08 11.480 .022*</td>
<td>2-mm TSG 41.53 ± 5.45 43.93 ± 7.98 42.53 ± 10.15 41.67 ± 9.48 42.40 ± 9.16 6.643 .156</td>
<td>2-mm TSG 9.21 ± 4.81 5.90 ± 3.65 4.28 ± 3.47 4.97 ± 2.78 5.03 ± 4.12 37.218 &lt; .001*</td>
<td>2-mm TSG 27 19 19 10 15 Q = 26.441 &lt; .001*</td>
</tr>
<tr>
<td></td>
<td>4-mm TSG 41.53 ± 5.45 43.93 ± 7.98 42.53 ± 10.15 41.67 ± 9.48 42.40 ± 9.16 6.643 .156</td>
<td>4-mm TSG 41.53 ± 5.45 43.93 ± 7.98 42.53 ± 10.15 41.67 ± 9.48 42.40 ± 9.16 6.643 .156</td>
<td>4-mm TSG 7.67 ± 3.99 3.93 ± 2.05 4.40 ± 4.32 5.00 ± 4.07 5.27 ± 4.76 20.883 &lt; .001*</td>
<td>4-mm TSG 15 15 13 10 13 Q = 11.200 .024*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>χ²</td>
<td>P</td>
<td>χ²</td>
<td>P</td>
</tr>
<tr>
<td></td>
<td>.558 .089 .205 .073 .611</td>
<td>.558 .089 .205 .073 .611</td>
<td>.558 .089 .205 .073 .611</td>
<td>.558 .089 .205 .073 .611</td>
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<td>.326 .128 .950 .881 1.000</td>
<td>.326 .128 .950 .881 1.000</td>
<td>.326 .128 .950 .881 1.000</td>
<td>.326 .128 .950 .881 1.000</td>
</tr>
<tr>
<td></td>
<td>.54</td>
<td>.009*</td>
<td>.171</td>
<td>.059</td>
</tr>
</tbody>
</table>

*P < .05.
bFriedman test.
Friedman test.
Mann-Whitney U test.
Cochran Q test.
Fisher exact test.

Fig 5  Change in amount of maximum unassisted opening (MUO) and presence of TMJ sounds for 2-mm TSG and 4-mm TSG from baseline to 6-month follow-up in disc displacement group.

Fig 6  Change in amount of MUO, painful muscle scores, number of painful muscles, and presence of TMJ sounds for 2-mm TSG and 4-mm TSG from baseline to 6-month follow-up in combined group.
radiation, and the second study should be evaluated in terms of the difficulty of taking MRIs with splints having five different thicknesses.

The duration of the treatment for the SS was not established properly. In a meta-analysis, Kuzmanovic Pficer et al.\(^{23}\) evaluated the short-term (≤ 3 months) and long-term (> 3 months) effects of the SSs. It was observed that pain reduction, muscle tenderness reduction, and the increase in mouth opening were better in short-term treatment, while the long-term SS was not superior to other treatments. In another study, Romero-Reyes and Uyanik\(^{24}\) recommended making arrangements every 3 to 6 months, as there might be changes in the contacts or function of the SS due to chronic bruxism. In this study, the duration of the treatment was determined as 6 months to observe long-term treatment results. Also, follow-ups were arranged at 1, 2, and 3 months. Thus, in addition to observing the effect of SSs in the short-term treatment periods, the difference in short-term and long-term treatment was observed.

Some forms have been developed to standardize evaluation in TMD research. The RDC/TMD\(^{20}\) and the Fonseca Anamnestic Index (FAI)\(^{21}\) are the most frequently used forms. A visual analog scale (VAS), a numeric rating scale (NRS), characteristic pain intensity (CPI), and pain severity scores (PSS) were also used for evaluating pain intensity.\(^{23}\) The RDC/TMD is reliable and valid for TMD diagnosis\(^ {26}\) and is more comprehensive compared to other forms.\(^ {27}\) The RDC/TMD was updated in 2014, and the new name for the diagnosis form is the DC/TMD.\(^ {28}\) In the current study, patients were evaluated with the RDC/TMD at baseline and the 1-, 2-, 3-, and 6-month follow-up appointments because the DC/TMD was not reported when this study started.

Myofascial pain is in the subgroup of chronic orofacial pain in the classification of the International Association for the Study of Pain (IASP) Special Interest Group on Orofacial Pain.\(^ {29}\) Some studies\(^ {10, 11}\) show that myofascial pain is associated with excessive use of masticatory muscles, and, as a result, the EMG values of these muscles are high. EMG values decrease as the teeth move from the contact position to the rest position.\(^ {32–34}\) In the study of Pita et al.,\(^ {19}\) no differences were found between 3-mm–thick and 6-mm–thick splints in the terms of EMG values of masticatory muscles. Also, Olothoff et al.,\(^ {18}\) who measured the performance of the masticatory muscles in three different vertical dimensions (2 mm, 4 mm, and 6 mm), found no difference among the groups. In the present study, both 2-mm TSG and 4-mm TSG had a similar effect in reducing painful muscle scores, and the number of painful muscles in the muscle disorders group and the combined group were inconsistent with these studies. However, both splint groups were highly effective in relieving muscle pain after 6 months of treatment in the muscle disorders group and the combined group.

In the present study and other studies\(^ {10, 11}\) related to splint thickness, full-arch SSs were used, but anterior repositioning splints (ARS) are used to recapture the disc by the condyle to specifically improve the TMJ sounds.\(^ {5, 35}\) ARSs are generally used in patients with longer-term disc displacement with reduction. Lin et al.\(^ {10}\) and Hegab et al.\(^ {11}\) found that thin and thick splints did not have superiority to one another in the treatment of the TMJ sounds. In the present study, both 2-mm TSG and 4-mm TSG were effective in reducing the TMJ sounds, and the 2-mm TSG showed superiority over the 4-mm TSG regarding TMJ sounds in the combined group. The reduction of sounds in patients may be due to recapture of the disc or to remodeling of the retrodiscal tissues. In the present study, the magnetic resonance images were not taken from patients at baseline or 6 months of treatment. Although the real reason for the reduction of the TMJ sounds cannot be certain, it could be said that the use of a splint increases the adaptation capacity of the patients’ tissues.

In the present study, no difference was found between the 2-mm TSG and the 4-mm TSG in the muscle disorders group or the disc displacement group in terms of MUO values. In accordance with this study, Lin et al.\(^ {10}\) did not find any difference in their studies when they evaluated MUO in the 3-mm splints and the 5-mm splints. At the end of the 6-month treatment, the 2-mm–thick splints had a negative effect on the MUO values compared to baseline, and the 4-mm–thick splints had no effect in the combined group. Hegab et al.\(^ {11}\) found that thick splints were more successful than thin splints in terms of MUO. Thick splints may be recommended in terms of MUO values for patients with combined disorders.

One limitation of the present study was the small number of patients in the group with disc displacement. This may be because TMJ disorders were often combined. Further work with an increased sample size is recommended to provide generalizable conclusions for the disc displacement group. The thickness adjustment of the splints from the premolar region was another limitation of the current study. The thicknesses of the splints were thicker in the incisal region due to movement of the mandible on the hinge axis, and this method has made it more difficult to compare the results to previous studies, which used the incisal region for thickness measurements.

**CONCLUSIONS**

From this study, the following conclusions were drawn after 6 months of treatment:

1. Two-mm–thick and 4-mm–thick splints are not superior to each other in terms of treatment
success in muscle disorders, disc displacement, and combined groups.
2. Both splint groups are extremely successful in relieving symptoms of muscle-related pain.
3. Although both splint groups are effective in reducing TMJ sounds in the combined group, the 2-mm–thick splints are more successful.

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REFERENCES