

## A Comparison of Electromyographic Activity Between Anterior Repositioning Splint Therapy and a Centric Relation Splint

Eugene H. Williamson, D.D.S., M.S., E. Zulay Navarro, D.D.S., M.S.,  
Jack D. Zwemer, D.D.S., Ph.D.

**ABSTRACT:** The purpose of this study was to compare the electromyographic activity of masticatory muscles (temporal and masseter) with the use of an anterior repositioning splint and a centric relation superior repositioning splint. Twenty-six consecutive patients, who referred with the chief complaint of temporomandibular pain and/or headache were selected from one of the author's practices. All these subjects were diagnosed as having internal derangement of the temporomandibular joint. Ten normal subjects were used as controls. Surface electromyographic recordings were taken of each subject prior to the beginning of clinical therapy for the patients. The results show significantly less masseter and temporal muscle activity with anterior repositioning splint therapy compared to the centric relation superior repositioning splint therapy.

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Address for reprint requests: Eugene H. Williamson, D.D.S., M.S. P.O. Box 569 4250 Washington Road Evans, Georgia 30809

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*Dr. Eugene H. Williamson is in private practice specializing in orthodontics in Evans, Georgia, and is past chairman of orthodontics at the Medical College of Georgia in Augusta, Georgia. He is presently a clinical associate professor at M.C.G.A. and also teaches sequenced courses and conducts research in his educational facility in Evans. Dr. Williamson was the editor and publisher of the monthly journal Facial Orthopedics and Temporomandibular Arthrology and is a Diplomate of the American Board of Orthodontics.*

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*Dr. E. Zulay Navarro received her D.D.S. degree in 1984 and her M.S. degree in orthodontics in 1989 from the Central University of Venezuela. She is a consultant in the Department of Orthodontics at Central University of Venezuela and is in private practice in Caracas, Venezuela, specializing in orthodontics.*

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In the last two decades, the management and treatment of temporomandibular disorders (TMD) has received widespread attention. Many different therapies have been advocated for patients presenting with TMD. Several types of splints are routinely utilized in treatment, and this is possibly the most controversial issue among clinicians and researchers. Most recently, the question of joint loading or pressure exerted within the glenoid fossa by different splints has been of interest. There is much concern over an association of avascular necrosis as the result of undue pressure caused by splints placing the jaw in various positions.<sup>1</sup>

Current research indicates that the temporomandibular joint (TMJ) is load-bearing with function. Studies by Hylander<sup>2</sup> and Hylander and Bays<sup>3,4</sup> found the jaw joint to receive pressure during chewing in *Macaca mulatta fascicularis* monkeys. They deduced TMJ loading from strain gauges cemented in the condylar neck. In a more recent paper, Boyd et al.<sup>5</sup> implanted piezoelectric foil transducers over the anterior superior surface of the condyle in two *Macaca arctoides* monkeys. Their results also showed the TMJ to be load-bearing.

It is generally believed that pathologic destruction of the articular tissues occurs whenever articular remodeling does not maintain a balance between its structure and the function demanded upon it.<sup>6</sup> If the mechanical forces are within the physiologic tolerance of the articular structures, cellular repair will keep up with destruction to protect the joint from deformation.

With respect to other body joints, Bollet,<sup>7</sup> Radin et al.,<sup>8</sup> and Telhag<sup>9</sup> state that the single most important factor

known today with regard to osteoarthritis or localized degenerative remodeling is increased mechanical loading. Radin et al.<sup>8</sup> stated that a great deal of force may be produced within a joint by muscle contraction. Carlsson et al.,<sup>10</sup> in their study, agree with this, as they assert that long-standing increased compressive forces in the TMJ lead to thinning of the disk, cell necrosis, intercellular matrix degradation, and eventual perforation.

Since Ahlgren and Owall<sup>11</sup> showed that integrated electromyography (EMG) is directly proportional to the force of biting, and it has been established that the TMJ receives increased pressure with biting, EMG seems a proficient method with which to assess the comparative amounts of force produced within the joint by function. The purpose of this study was to compare the relative EMG activity of temporal and masseter muscles with the use of anterior repositioning splints (ARS) and centric relation or superior repositioning splints (SRS) when the subjects were asked to clench their teeth together.

### Materials and Methods

The experimental group consisted of 26 consecutive patients (22 females and 4 males), the average age being 34 years (ranging from 12-66 years), who presented with pain or limited function in the jaw joints and headache. All these patients were judged to be suffering from internal derangement of the TMJs. This diagnosis was based upon stethoscopic auscultation and palpation of the joints through the external auditory meatus. The required criteria for such a diagnosis were pain to palpation of the joints and joint clicking during movement.<sup>12, 13</sup>

The control group consisted of 10 individuals (7 females and 3 males), the average age being 29 years (ranging from 22-46 years), who had no history or evidence of TMD complaints. Records were made, consisting of history, mounted models, lateral, frontal, submental vertex cephalograms and panoramic radiographs.

A mandibular centric relation splint (SRS) was constructed for each subject with bilateral posterior equal contacts and anterior guidance in order to separate posterior teeth with eccentric jaw movements. Mandibular manipulation was utilized for the SRS, with the best possible superior-anterior condylar position attained.

Anterior repositioning splints (ARS) were also constructed. They were made with the mandible positioned forward and/or laterally to a relationship where the joint noise and the least pain to palpation of the joints occurred simultaneously for the experimental group.

The ARS position for the control group was the incisor edge-to-edge relationship, with the maxillary and mandibular midlines coinciding. Splint construction tech-

niques have been published previously.<sup>14-17</sup>

The maxillary ARS was made without contact of the mandibular premolars or molars. (The maxillary anterior repositioning splint is hereafter referred to as "max/ARS," and the mandibular anterior repositioning splint is hereafter referred to as "man/ARS.")

Integrated and rectified EMG recordings were made using the Myotronics EM 2 computerized system.\* Following skin cleansing, bipolar surface electrodes were placed bilaterally over the temporal and masseter muscles. Each patient was seated upright and comfortably in a chair and the recordings were made in the following sequence:

1. Rest position without any splint
2. Maximum bite in the intercuspal position without any splint
3. Maximum bite in centric relation with the SRS
4. Maximum bite in the forward position with the max/ARS in place
5. Maximum bite in the forward position with the man/ARS in place

All recordings were made prior to the beginning of clinical therapy for each patient in the control group and the experimental group. The patients were instructed to clench firmly and maintain pressure against the splint during the recordings. In order to simulate a true clinical situation where the patients might be clenching and, therefore, loading the joints periodically, a standardized clench was not determined for each subject. During the interval between tests, the individuals were able to relax in order to prevent muscle fatigue and joint pressure.

EMG data was measured in microvolts and a three-trial factor and one grouping factor repeated measured ANOVA. This was performed using the MANOVA program in Statistical Packages for the Social Sciences (SPSS) for the following:

1. Control compared to experimental group
2. Rest position treatment
3. Intercuspal position treatment
4. SRS treatment
5. Max/ARS treatment
6. Man/ARS treatment

### Results

Analysis of the data combining the left and right sides did not show differences between the controls and the experimental groups. However, analysis did show the following significant differences:

1. The max/ARS EMG recordings were lower than all others:  $F(4, 136) = 33.85, p < 0.001$ ;

\*Myotronics Research, Inc., Seattle, Washington.

2. With interaction between treatment by side, the max/ARS EMG recordings were lower than all others:  $F(4, 136) = 14.1, p < 0.001$ .

Follow-up analysis of the left and right sides using the Fisher protracted least significant differences (LSD) procedure at the  $p < 0.05$  level showed:

1. No difference between the control and the experimental groups
2. Rest position is lower than other positions on both sides
3. Intercuspal, SRS and man/ARS are not significantly different on both sides
4. Max/ARS is significantly lower than intercuspal, SRS and man/ARS on the left side
5. Max/ARS is significantly lower than intercuspal and SRS on the right side
6. Max/ARS is not significantly lower than man/ARS on the right side

Analysis of the data for both sides showed:

1. Max/ARS is significantly lower than intercuspal position, SRS and man/ARS on the left side:  $p < 0.0001$
2. Max/ARS is significantly lower than intercuspal position and SRS on the right side:  $p < 0.0001$
3. Rest position is significantly lower than other positions on both sides
4. Intercuspal positions, SRS and man/ARS are not significantly different on both sides
5. Max/ARS is not significantly lower than the man/ARS on the right side
6. Rest position is significantly greater on the right side than on the left side for this group:  $p < 0.05$
7. Intercuspal position and SRS are significantly greater on the left side than on the right side:  $p < 0.05$
8. Max/ARS and man/ARS are not different on the right and left sides

There were no differences between controls and experimentals, age or gender.

Means and standard deviations for all muscles in microvolts are shown in Table 1. The percent of max/ARS activity compared to the SRS and man/ARS activity is shown in Tables 2 and 3.

## Discussion

To support the evidence that the jaw joints are load-bearing with function, Storey<sup>18</sup> attempted to directly measure whether the TMJ receives pressure when the teeth are intercuspat. The studies were carried out on decerebrated cats in which the mandibular elevators were activated by bilateral electrical stimulation of the mesen-

**Table 1**  
Means and Standard Deviations  
For All Muscles in Microvolts\*

|                | Intercuspal Position |       | Superior Repositioning Splint |       | Maxillary Anterior Repositioning Splint |       | Mandibular Anterior Repositioning Splint |       |
|----------------|----------------------|-------|-------------------------------|-------|---|-------|--|-------|
|                | X                    | SD    | X                             | SD    | X                                       | SD    | X  | SD    |
| Right Temporal | 73.00                | 55.09 | 79.41                         | 56.67 | 29.83                                   | 41.85 | 56.86                                    | 53.24 |
| Left Temporal  | 90.69                | 64.87 | 90.72                         | 59.85 | 33.50                                   | 31.44 | 66.22                                    | 54.78 |
| Right Masseter | 60.63                | 61.30 | 72.33                         | 63.61 | 41.27                                   | 37.63 | 68.83                                    | 48.47 |
| Left Masseter  | 62.47                | 61.89 | 73.50                         | 62.71 | 43.54                                   | 47.85 | 70.66                                    | 56.11 |

\*Controls and experimentals were combined since there was no significant difference between groups:  $N = 36$ .

cephalic nuclei. The joint was approached through the middle cranial fossa, the roof of the glenoid fossa of the TMJ was removed, and a linear force transducer was placed against the superior aspect of the condylar head. The joint was found to be vertically loaded in these experiments.

In addition to Ahlgren's work indicating EMG to be a reliable source in determining bite force, Milner-Brown and Stein.<sup>19</sup> have shown that peak-to-peak amplitude, the number and the duration of the interference pattern provide measures of the strength of muscle contraction. Furthermore, Yanagisawa et al.<sup>20</sup> found a linear relationship between the number of spikes in EMG recordings

**Table 2**

% Maxillary Anterior Repositioning Splint (ARS)  
Muscle Activity Compared to Mandibular ARS\*

$$\% = \frac{x \text{ Maxillary ARS activity}}{x \text{ Mandibular ARS activity}} \times 100$$

| Muscle | Experimental | Control |
|--------|--------------|---------|
| RT     | 52%          | 52%     |
| LT     | 51%          | 49%     |
| RM     | 58%          | 63%     |
| LM     | 66%          | 52%     |

\*The Maxillary ARS was x% of the Mandibular ARS.

**Table 3**

% Maxillary Anterior Repositioning Splint (ARS)  
Muscle Activity Compared to Superior  
Repositioning Splint (SRS)\*

$$\% = \frac{x \text{ Maxillary ARS activity}}{x \text{ SRS activity}} \times 100$$

| Muscle | Experimental | Control |
|--------|--------------|---------|
| RT     | 35%          | 41%     |
| LT     | 35%          | 41%     |
| RM     | 51%          | 74%     |
| LM     | 58%          | 63%     |

\*The Maxillary ARS was x% of the SRS.

and biting force during clenching. In 20 masseter muscles of 10 subjects, the correlation coefficients were all higher than 0.96.

MacDonald and Hannam,<sup>21</sup> in a sample of 10 subjects, found that when the size and number of tooth contacts were increased, a generalized increase in the jaw muscle activity could be seen with EMG. Biomechanical simulation of the craniomandibular apparatus by Nelson and Hannam<sup>22</sup> have also displayed that clenching may be assumed to create proportionately more reactive force in the TMJ.

Since anterior repositioning splints (ARS) show a statistically significant decrease in EMG activity compared to either the centric relation superior repositioning splints (SRS) or maximum intercuspation of the natural teeth, it seems logical that less pressure is created in the joints with ARS. Avascular necrosis is a condition most often seen in the femoral head, and its etiology is said to be a decrease in subcondylar blood supply which results in regressive remodeling of the bone surface. Trauma or increased pressure to the femoral head is reported to be the initiating insult.<sup>23</sup> "Degenerative joint disease" is the term applied to this phenomenon.

Based upon the results of this study, it seems unlikely that anterior repositioning therapy would initiate avascular necrosis. On the contrary, one could hypothesize that decreased muscle activity resulting in less pressure within the joints would have a tendency to relieve and rest the tissues similar to the concepts of orthopedic treatment for other joints in the human body.

Moller et al.<sup>24</sup> demonstrated a highly significant correlation between bite force and intramuscular pressure. They investigated blood flow through the muscles of mastication and found that during sustained contraction, circulatory obstruction was almost unanimously demonstrated. This study's results indicate a decrease in muscle activity with ARS which implies that blood flow is not inhibited.

Sessle et al.<sup>25</sup> showed a decrease in the EMG activity of the superior and inferior heads of the lateral pterygoid muscles with anterior repositioning when using fixed functional appliances in monkeys. The decreased postural activity persisted for six weeks with a gradual return toward pre-appliance levels. The electrodes were chronically inserted into the muscles. Concomitantly, the masseters and anterior digastrics also displayed a decrease in function.

In a study on Class II patients, Pancherz and Anehus-Pancherz<sup>26</sup> found that anterior repositioning of the mandible, using the fixed Herbst appliance without posterior teeth in contact and at the incisal edge-to-edge position, resulted in the markedly reduced EMG activity of

the temporal and masseter muscles compared to maximum intercuspation. It has been shown that blood supply to the mandibular condyles is from the lateral pterygoids, as well as from the medullary portion of the bone and periosteum.<sup>27</sup> Hence, if blood supply is interrupted with muscle contraction, it would not seem to occur with anterior repositioning. Furthermore, if avascular necrosis is the result of decreased blood supply, it would not seem to be the result of ARS therapy since muscle function is decreased and blood supply is not compromised.

The synovial organ functions as a source of synovial fluid that provides lubrication and nutrition to the articular tissues and as a semi-permeable membrane to adjust pressure within a joint.<sup>28</sup> Helmy, Bays and Sharawy,<sup>29, 30</sup> demonstrated an intimate relationship between synovial tissue and healing processes in perforated TMJ disks in monkeys and humans.

Increases in intracapsular pressures have been associated with pathologic alterations of articular tissues. Strenuously exercised rabbit knee joints have demonstrated increased synovial fluid volumes that correlated with alterations in the shape of surface cells of the articular cartilage.<sup>31</sup> Consistently higher synovial fluid pressures in patients with rheumatoid arthritis compared to controls were found by Jayson and Dixon.<sup>32-34</sup> Patients with chronic knee problems had higher intra-articular pressures in a study by Caughey and Bywater.<sup>35</sup>

With regard to anterior repositioning of the mandible, Ward, Behrents and Goldberg<sup>36</sup> recently found that forward positioning in pigs resulted in an initial increase in synovial fluid pressure that decayed within two hours to baseline levels. Posterior positioning of the mandible affected a larger increase in pressure that partially decayed over two hours, but did not return to baseline levels over the entire eight week course of the experiment.

Scapino<sup>37</sup> studied the function of the intracapsular structure with arthrography and magnetic resonance imaging (MRI). With the condyle in a forward position, he observed the synovium to increase in thickness over the expanded posterior attachment to the disk and to be filled with synovial fluid. Hence, this would allow for better nutrition to the joint surfaces and would seem to create an environment for better repair and regeneration. Scapino notes that the findings of decreased intra-articular pressure with forward condylar positions are consistent with his findings of increased joint spaces.

The max/ARS was made without posterior tooth contacts and consistently displayed less EMG activity from masseters and temporal muscles than any other. The man/ARS did have posterior indentations for the maxillary teeth to allow stabilization for daytime wear. It did

not result with statistically significant decreases in the temporal and masseter muscles compared to the SRS, but mean values were less with the man/ARS (Table 1). The high group standard deviations may, in part, be testimony to the variability in bite force between patients.

It is noteworthy that it has been the experience of one of the authors that anterior repositioning therapy, although followed by centric stabilization, may result in an irreversible change in the occlusion. However, this condition is not unexpected when one observes the results of surgical reconstructive arthroplasty (for example, disk plication procedures). With reduction of the internal derangement surgically, there is an immediate change in occlusion which tends to remain long term. This would agree with Kazuhiro, Tsuga and Yasumasa<sup>38</sup> who suggest beginning treatment with a centric stabilizing splint. For the first 12-years of practice, this approach was utilized by one of the authors. Although good results were obtained with this approach, patients did not respond as quickly and treatment was more time consuming and tedious. For the last 13 years, the ARS has been the initial treatment for patients presenting with internal derangement and has resulted in more immediate relief of symptoms.<sup>16</sup> It is followed by an SRS centric relation stabilizing splint to allow mandibular seating. A comment is appropriate concerning the possibility of mandibular posterior teeth supra erupting since they are not in contact with the maxillary ARS. This condition has not been problematic because the patient wears the mandibular splint during the day.

### Conclusions

There is significantly less masseter and temporal muscle activity with the use of the maxillary ARS, which does not have posterior teeth in contact, compared to the SRS.

It seems unlikely that ARS therapy could be an etiology of avascular necrosis of the mandibular condyle or articular eminence.

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*Dr. Jack D. Zwemer received his D.D.S. degree from the School of Dentistry, University of Illinois. He also received his M.S. degree (Pedodontics) and Ph.D. degree (Bacteriology, Biochemistry) at the same University. Dr. Zwemer is presently a professor in the Department of Community Dentistry, School of Dentistry, Medical College of Georgia, and Special Project Coordinator for the Office of Institutional Research and Information. Dr. Zwemer has been active in international health with a consultantship to the Peace Corps.*

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