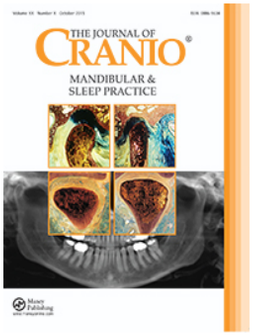

CRANIO®

The Journal of Craniomandibular & Sleep Practice

ISSN: 0886-9634 (Print) 2151-0903 (Online) Journal homepage: http://www.tandfonline.com/loi/ycra20

Fixed Orthodontic Therapy in Temporomandibular Disorder (TMD) Treatment: An Alternative to Intraoral Splint

Simona Tecco, Stefano Teté, Vito Crincoli, Mario Armando Festa & Felice Festa

To cite this article: Simona Tecco, Stefano Teté, Vito Crincoli, Mario Armando Festa & Felice Festa (2010) Fixed Orthodontic Therapy in Temporomandibular Disorder (TMD) Treatment: An Alternative to Intraoral Splint, CRANIO®, 28:1, 30-42

To link to this article: http://dx.doi.org/10.1179/crn.2010.005

Published online: 01 Feb 2014.

Fixed Orthodontic Therapy in Temporomandibular Disorder (TMD) Treatment: An Alternative to Intraoral Splint

Simona Tecco D.D.S., Ph.D.; Stefano Teté, D.D.S.; Vito Crincoli, D.M.D.; Mario Armando Festa, M.A.; Felice Festa, M.D., D.D.S., M.S., Ph.D.

0886-9634/2801-030$05.00/0, THE JOURNAL OF CRANIOMANDIBULAR PRACTICE,

Manuscript received March 12, 2009; revised manuscript received July 28, 2009; accepted September 1, 2009

Address for correspondence:
Dr. Simona Tecco
Via Le Mainarde 26
65121, Pescara
Italy
E-mail: simtecc@unich.it

ABSTRACT: This study evaluated the use of a fixed orthodontic appliance in treatment of temporomandibular disorder (TMD) compared to the use of an intra-oral splint. Fifty (50) adult patients, with confirmed anterior disk displacement with reduction in at least one temporomandibular joint (TMJ), were divided into three groups: 20 patients treated with AR splint (Group I); 20 patients treated with a fixed orthodontic appliance (Group II) and 10 patients who underwent no treatment (Control Group). Joint pain, joint noise, muscle pain, and subjective relief were evaluated monthly before the treatment began (T0) and for six months thereafter. Subjects in Group I and Group II displayed a significant decrease in joint pain ($p<0.01$) from T2 and in muscle pain from T1 ($p<0.01$) to T6. Subjects in Group I showed a higher decrease in the frequency of joint noise ($p<0.05$) from T1 to T6, compared with Group II. At T2 and T3, the patients in Group II reported a significantly lower discomfort level associated with the devices than subjects treated with the AR splint ($p<0.05$). However, at T5 and T6, this observation was inverted. The use of a fixed orthodontic appliance seems to be as efficacious as the use of an AR maxillary splint in the treatment of joint pain and muscle pain, but not in the treatment of joint noise. These results are valid, at least for the short-term clinical results (first six months of treatment). Clinical implications for long-term use are not clarified by these results.

Dr. Simona Tecco *received her D.D.S. degree in 1999 from the faculty of Dentistry, University of Chieti, Italy. Since 1999, she has been a staff member of the Department of Orthodontics and Gnathology, School of Dentistry at the University of Chieti. She is currently working toward a Ph.D. in oral science at the same university.*

Displacement of the disk in one or both of the TMJ is found in a large number of patients with symptoms of temporomandibular disorders (TMD).[1] In these patients, the displaced disk can be held in a normal (reduced) relationship with the condyle by anterior positioning of the mandible, through the use of a splint.[2] With the mandible held in anterior position, clicking and locking are eliminated, and pain relief is usually obtained within a few days.[2] Consequently, anterior mandibular repositioning using maxillary appliances with pull-forward ramps has been used to treat disk displacement.[2-3]

A long-term investigation found that the anterior repositioning splint (AR splint) (**Figure 1**) was superior to flat occlusal splints, when compared to a control group, in reducing or eliminating joint noise (clicking), joint pain, and associated muscle symptoms.[4]

Assuming that the anterior repositioning of the mandible, in some clinical cases, can also be a consequence of a spontaneous movement of the mandible to a forward

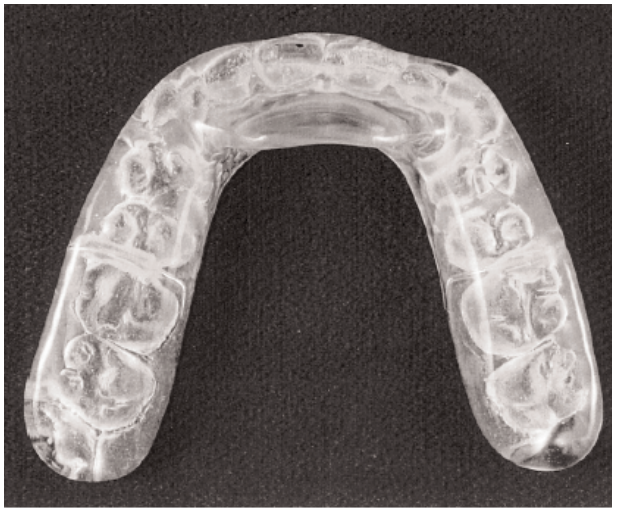

Figure 1
Anterior repositioning splint (AR splint).

position, after the alignment of teeth in the upper arch, the rationale of this study was that fixed orthodontic therapy in patients who need an alteration of their occlusion and are affected by TMD (i.e., a disk displacement) could result not only in aligning the teeth, but also in reducing or eliminating joint noise (clicking), joint pain, and associated muscle symptoms. In such cases, the orthodontic treatment could obtain a reducing of TMD symptoms, as well as an alignment of the teeth.

The interest in the relationship between orthodontic treatment and TMD was prompted in the late 1980s, after litigation that alleged orthodontic treatment as the proximal cause of TMD in orthodontic patients. This litigious climate resulted in an increased understanding of the need for risk management, as well as for methodologically sound clinical studies. The findings of this research can be summarized as follows[5-6]: 1. signs and symptoms of TMD may occur in healthy persons; 2. signs and symptoms of TMDs increase with age, particularly during adolescence, until menopause, and therefore TMDs that originate during orthodontic treatment may not be related to the treatment; 3. in general, orthodontic treatment performed during adolescence does not increase or decrease the chances of development of TMDs later in life; 4. the extraction of teeth as part of an orthodontic treatment plan does not increase the risk of TMDs; 5. there is no increased risk of TMDs associated with any particular type of orthodontic mechanics; 6. although a stable occlusion is a reasonable orthodontic treatment goal, not achieving a specific gnathologic ideal occlusion does not result in signs and symptoms of TMD; and 7. thus far, there is little evidence that orthodontic treatment prevents TMD, although the role of unilateral posterior crossbite correction in children may warrant further investigation.

In 2006, in a "Summary of evidence-based systematic reviews of temporomandibular disorders," Rinchuse and McMinn[7] concluded that the overall quality of the trials was fairly low, because of inadequate blinding, small sample sizes, short follow-up times, great diversity of outcome measures, and numerous control treatments such as acupuncture, ultrasound, and transcutaneous electrical nerve stimulation (TENS), which all lack evidence of effectiveness.

Splint therapy was found superior to three control treatments (ultrasound, palliative treatment, and palatal splint) and comparable with 12 control treatments. Splints were superior to passive control in four studies and comparable with it in another four studies. Occlusal adjustment was found to be equal to control treatment in two studies and inferior to control treatment in one. Occlusal adjustment was equal to passive control in one study. Because of methodological problems, the reviewers concluded that occlusal splints might be of some benefit in the treatment of TMD, that evidence for occlusal adjustment is lacking, and that there is an obvious need for well-designed controlled studies to analyze current clinical practices.

Regarding TMD signs and symptoms during an orthodontic treatment, Alpern,[8] on the basis of an eight-year follow-up study conducted in Florida, discussed simultaneous fixed orthodontics and splint therapy. He said that the TMJ must be protected during orthodontic treatment. Consequently, the orthodontic appliance must be modified to include vertical unloading, using the concept of a full arch, flat plane splint to permit unencumbered joint motion. This simultaneous fixed orthodontics and splint therapy allows the patient's neuromuscular and skeletal apparatus to find the most comfortable joint position. In this condition, orthodontic cusp fossa correction to that position can be accomplished with various appliances, such as porcelainized, light-cured composite overlays on the lingual of the maxillary incisors or the molars. During an orthodontic treatment of patients with TMD, TMJ loading should not be attempted, because it could lead to arthritic degeneration or other joint pathology. Because of this, vertical unloading appliances must be used. These appliances could also decrease a patient's discomfort. This opinion has been put forward by other researchers.[9]

At present, no clinical study has investigated signs and symptoms of TMD during orthodontic fixed treatment of patients with TMD before the beginning of orthodontic treatment. In fact, an appropriate orthodontic fixed device is generally proposed only for finalization of TMD patients—after therapy with splints—since orthodontic

fixed treatment is not fast-acting enough to guarantee a proper advancement of the mandible in a position to allow for disk recapture.[10]

However, the question of whether a fixed orthodontic therapy can be used, instead of an intraoral splint, to resolve a TMD is important, as the psychological and/or physical stress associated with wearing the splint both during the day and at night could lead to increased activity of the masticatory muscles,[11-12] resulting in, or exacerbating, symptoms of craniomandibular disorder.[13]

In addition, the occurrence of patients with TMJ disk displacement has gradually increased in orthodontics, owing to the increasing prevalence of TMJ disk displacement with age and the growing number of adults undergoing orthodontic treatment.[14]

Recently, a cephalometric study was performed to investigate the TMJ before and after an orthodontic fixed treatment in patients with bilateral disk derangement and normal disk position of the TMJ.[15] After the treatment, patients with TMJ anterior disk displacement with reduction exhibited a significant increase in SNB, in the position of Pogonion with respect to N perpendicular, in the SN to mandibular plane angle, in total anterior facial height, in the ramus inclination, and in the effective mandibular length during treatment.

However, in that study, no evaluation was made of signs and symptoms, as all the subjects were treated using splints prior to their orthodontic treatment.

Recently, some new fixed self-ligating appliances have been introduced, called the Damon System (Ormco Corp., Orange, CA) (**Figure 2** and **Table 1**).[16] Apparently, the Damon appliance increases the arch width quickly, due to the lowest friction generated[17] to allow the spontaneous advancement of the mandible in a very comfortable manner. This mechanism has been noted in the orthodontic manuals (**Figure 3**).[18]

The fixed self-ligating appliance is promoted for use instead of an intraoral splint to obtain advancement of the mandible. The use of the self-ligating appliance is designed to guarantee a faster treatment including simultaneous treatment of symptoms and orthodontic finalization.

The current study aimed to investigate whether the use of a fixed self-ligating appliance is as efficacious as the AR splint, in the treatment of TMJ anterior disk displacement with reduction.

Material and Methods

The subjects included in the sample were selected from a group of subjects referred for evaluation of malocclusion and TMJ anterior disk displacement with reduction. Subjects were included based on the following criteria:

1. The subject presented symptoms of TMJ internal anterior disk displacement with reduction: joint pain, joint tenderness, and pain on palpation, joint pain during masticatory movements and abnormal joint noises, such as popping and clicking in at least one TMJ; tenderness and pain in the masticatory muscles during palpation;
2. Suspected internal disk displacement was confirmed on magnetic resonance images (MRI);
3. The subject had no history of rheumatoid arthritis; and
4. There was no history of previous orthodontic treatment.

Fifty (50) subjects were included, 28 males and 22 females (average age 28.8; range from 14.3 to 63.4).

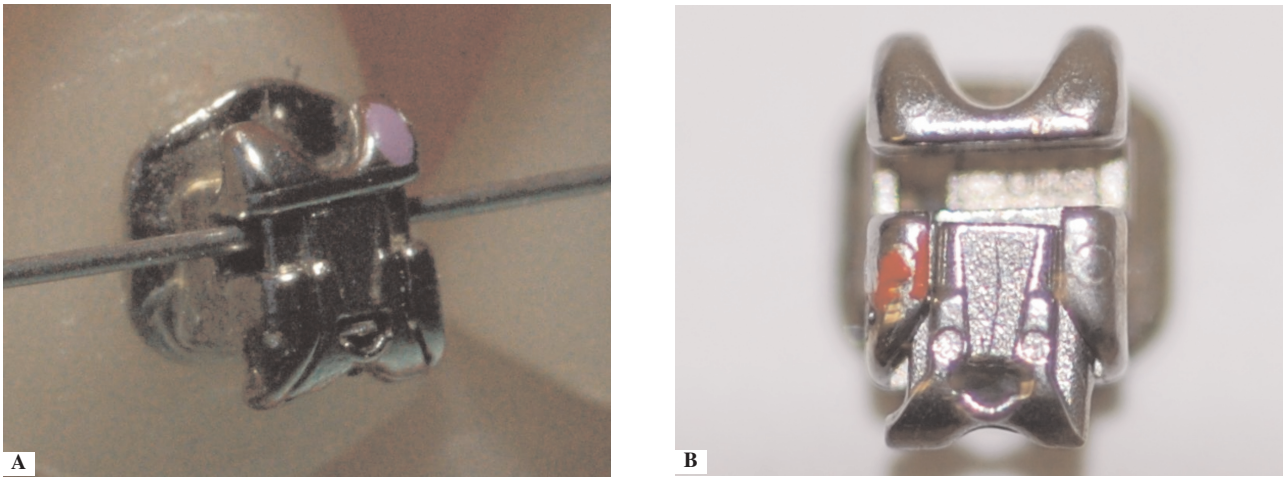

Figure 2
Damon self-ligating bracket. (**A**) closed slot; (**B**) open slot.

Table 1
Prescription of the Orthodontic Brackets Used In the Study

Tooth	Torque	Angulation	Rotation	Bracket type
Maxillary				
Central	7°	5°	0	Twin
Central	12°	5°	0	Twin
Central	17°	5°	0	Twin
Lateral	3°	9°	0	Twin
Lateral	8°	9°	0	Twin
Lateral	10°	9°	0	Twin
Cuspid	0°	6°	0	Twin
Cuspid	7°	6°	0	Twin
Cuspid hook	0°	6°	0	Twin
Cuspid hook	7°	6°	0	Twin
Bicuspid	-7°	2°	0	Twin
Bicuspid hook	-7°	2°	0	Twin
1st molar bondable	-9°	0°	10	Single slot micro tube
2nd molar bondable	-9°	0°	10	Micro tube
Mandibular				
Anterior	-1°	2°	0	Twin
Cuspid	0°	5°	0	Twin
Cuspid	7°	5°	0	Twin
Cuspid hook	0°	5°	0	Twin
Cuspid hook	7°	5°	0	Twin
1st bicuspid	-17°	2°	0	Twin
1st bicuspid hook	-17°	2°	0	Twin
2nd bicuspid	-22°	2°	0	Twin
2nd bicuspid hook	-22°	2°	0	Twin
1st molar bondable	-30°	2°	0	Standard micro tube
2nd molar bondable	-10°	2°	0	Micro tube

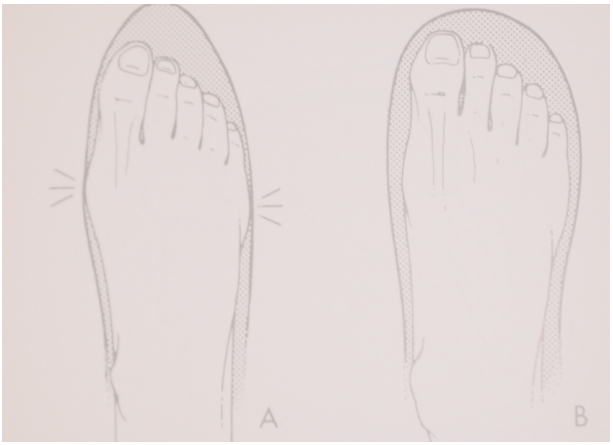

Figure 3
The relationship between the shoe and the foot simulates the advancement of the mandible, when the upper arch increases in diameter: as the shoe is greater, the foot advances in the shoe; for the same reason, when the upper arch increases its diameter, the mandibular arch advances.

Internal disk displacement was assessed using MRI with two sequences, using dual coil capability. The sequences were performed using a proton density image technique. An oral radiologist, who confirmed suspected internal anterior disc displacement with reduction in the subjects, read the MRI. An oral radiologist with TMJ MRI experience interpreted the images without clinical information on the patients. The study was approved by the Human Ethics Committee.

The 50 subjects selected included patients, 10 patients were randomly selected, considering an age distribution homogeneous with the two study groups (based on the criteria of the Kolmogorov-Smirnov test). The patients were considered as an untreated control group (they were treated some months after the investigation) (Control group, N=10).

The other 40 patients were randomly divided into two homogeneous groups, based on the criteria of the Kolmogorov-Smirnov test on age distribution.

No significant difference was found in the variables considered among the three groups before treatment began.

For the management of TMJ anterior disk displacement with reduction, the authors used a fixed self-ligating appliance in Group II (N=20) and an AR splint in Group I (N=20).

In general, the goal of a treatment for TMD is the elimination of pain and noise, although sometimes only the pain is eliminated. In the current study, the objective of treatment was the elimination of both pain and noise.

No drugs or physical therapy were prescribed. The patients were not instructed on exercises or home care and were not told to change their diets. The primary reason for the lack of adjunctive therapies was to assess more accurately the effects of one treatment at a time.

Group I: Anterior Repositioning Splint

An anterior repositioning splint is commonly used in the management of anterior disk displacement with reduction to reestablish the normal condyle-disk relationship (**Figure 2** and **Table 1**). The primary goal in protrusive splint treatment is the elimination of joint pain and the elimination of joint sounds by recapturing the disk. In this way, a smooth, coordinated, painless range of motion can be obtained if the disk is recaptured.[2,19-20] Consequently, mandible deviation, joint noises, and pain may be eliminated.[19-20]

For each patient, a full-coverage AR splint was constructed for the maxillary arch using clear self-curing acrylic resin as described by Okeson.[21] The base of the occlusal splint was prepared on a model and fitted to the maxillary teeth. An acrylic ramp was placed in the anterior palatal area so that during normal occlusion, the mandibular anterior teeth contacted with the protrusive guiding ramp. Occlusal contacts were constructed, positioning the mandible forward to a jaw position that was effective in decreasing pain and in addressing joint noise. The later the opening clicking sound occurred, the less the trend for mandibular protrusion to obtain acceptable condyle-disk position. The subjects were instructed to wear the same splint both during the night and the day. The proper instructions for wearing the AR splint were given during each of the monthly appointments. The importance of wearing the splint at all times, as instructed, was impressed on the patients to guarantee the correct repositioning of the mandibular condyle.

*Group II: Self-Ligating Fixed Appliance (***Figure 2** and **Table 1***)*

The buccal crown surface of each tooth was rinsed and dried after a 15-second polish with fluoride-free pumice slurry. Stainless steel metal self-ligating brackets (Damon SLII, Ormco Corp., Orange, CA) were bonded to the teeth. The buccal enamel surface was etched with 37% phosphoric acid for 30 seconds, rinsed for 15 seconds, and dried with oil and moisture-free air until the enamel had a faintly white appearance.

The Ortho Solo (Sealant and Bond Enhancer, Ormco Corp., Orange, CA) was applied in a thin film to the etched surface and light cured for 10 seconds. The Enlight system (Ormco Corp., Orange, CA) was used to bond the brackets. They were all light-cured with a curing light (XL300; 3M/Unitek Dental Products, Monrovia, CA), calibrated every 10 minutes to ensure consistent light intensity.

The same operator, who was blind to the aim of the study, bonded all brackets and tubes for the first and the second molars. The brackets were bonded first to the upper dental arch and then to the the lower dental arch. Where indicated, two occlusal composite pads were bonded to the central fossa of the upper first molars to allow the bonding of the lower arch, avoiding occlusal contacts between the upper teeth and the lower brackets. After the bonding, a copper NiTi 0.014 round wire (Align SE 200 – Round, (Ormco Corp., Orange, CA) was inserted in the slots.

Variables

When the patients first received their appliances, they were instructed to return to the office only if they noticed some dramatic relief of symptoms within a week. All subjects in the three groups were monitored monthly from the beginning of the treatment (T0) for a total period of six months (Tl, T2, T3, T4, T5, T6).

1. *Joint pain*: The same clinician investigated the presence of joint pain after palpation. Based on clinical evaluation and on the patient's referred history, the patient was listed as having (yes) or not having (no) joint pain each month. Patients with joint pain on only one side during the opening or closing of the mouth were classified as having joint pain.

2. *Joint noise*: The same clinician investigated for the presence of joint noise (clicking or popping) using a stethoscope. Based on clinical evaluation and on the patient's referred history, the patient was listed as having (yes) or not having (no) joint noises each month. Patients with joint noise on only one side during the opening or closing of the mouth were listed as having joint noises. It is known that the evaluation of joint noise with yes-no is not sufficient to assess the effect of treatment. The description of the type of joint noise, such us popping or clicking was added.

3. *Muscle pain*: Muscle pain was rated during palpa-

tion based on a 4-point scale from 0 to 3 (0: no pain; 1: discomfort, aching or suffering; 2: pain; 3: patient shows lachrymation or asks the clinician to not palpate that point. Based on the small samples and to increase the validity of the statistical analysis, patients were classified as having or not having muscle pain upon palpation.

4. *Subjective relief*: The VAS (visual analogical scale) was used to assess subjective disturbance associated with articulation, occlusion, or muscle function. Subjects were asked to estimate their mood of nervousness (i.e., depression or aggressiveness), the comfort they felt wearing splints or the fixed appliance while working or studying, and how they experienced the state of their home life before and during treatment. The VAS was a 100-mm line with the endpoints of no mood of nervousness and the highest possible intensity of nervousness.

Statistical Analysis

This study focused on the distribution and the intensity of pain and joint noises and the influence of the kind of the appliance on these variables. Variables were used to show the influence of using an orthopedic device or an orthodontic fixed appliance and the particular type of device. Age homogeneity in the three groups was ensured using a Kolmogorov-Smirnov test. Simple descriptive statistics were assessed and differences in frequencies (of joint pain, joint noise and muscle pain) among the groups were analyzed using Pearson's chi-square. Nonparametric statistics (Kruskal-Wallis and Dunnett's T3) were computed to test significant differences among the groups according to the VAS score assessment of subjective relief. To investigate the repeated subjective relief in a single group, a Friedman's two-way analysis of variance (ANOVA) among measurements was calculated, and the differences were estimated with the Wilcoxon's signed rank test. All statistical analyses were performed using the SPSS Ver. 9 (SPSS, Inc., Chicago, IL), and the level of significance was set at $p<0.05$.

Results

At the beginning of the study, subjects reported joint pain and joint noise in at least one TMJ on average for the past 24 months at mean (range eight months to 28 months). However, no statistical analyses were performed in this regard. Occlusal features included different types of malocclusion: 39% showed class II molars at one side or bilaterally; 33% showed class III molars at one side or bilaterally; 15% showed the absence of one or more teeth in the posterior zone; and 3% showed agenesis of one or more permanent teeth.

Joint Pain (**Figure 4**)

In patients treated with a fixed orthodontic appliance, the frequency of joint pain decreased from 100% of subjects at T0 to 25% at T6, with a significant difference from the control group at T2, T3, T4, T5, and T6 ($p<0.01$).

Intra-group analysis in Group II revealed that the frequency of joint pain significantly decreased from T1 to T2 ($p<0.05$) from 95% to 50%. Thus, the joint pain disappeared in 50% of patients at T2, after two months from the beginning of the treatment.

In the group of patients treated with the AR splint, the frequency of joint pain decreased from 100% of subjects at T0 to 25% at T6, with a significant difference with the control group at T2, T3, T4, T5, and T6 ($p<0.01$). The joint pain disappeared in 55% of patients at T2, after two months from the beginning of the treatment, with a significant intra-group decrease from T1 to T2 ($p<0.05$).

No significant difference was observed between the two study groups overall at follow-up, but the frequency of joint pain expressed by the control group was significantly higher than the two study groups from T2 to T6.

Intra-group analysis revealed that the frequency of joint pain in the control group remained about the same all throughout follow-up.

Joint Noises (**Figure 5**)

In the AR group, the clinician investigated the frequency of joint noises while the subjects were not wearing a splint. In all the cases, the clinician recognized the joint noise as a click. Popping or crepitation were never noted.

The frequency decreased over time in the two study groups, but with some differences.

In the AR group, the frequency of clicking decreased from 100% of subjects at T0 to 60% of subjects at T5. The clicking disappeared in 30% of subjects after the second month of therapy (T2) and in 35% of subjects after the third month of therapy (T3). In the AR group, the frequency of clicking was significantly lower ($p<0.05$) than the other two groups from T1 to T6.

In patients treated with the fixed appliance, clicking was observed in 100% of subjects at T0; it disappeared in 25% of subjects after the sixth month of therapy (T6). Clicking disappeared in 5% of subjects after the first month of therapy (T1). In Group II, however, the frequency of clicking was significantly higher than the AR group from T1 to T6. The frequency of clicking became significantly lower than the control group only at the T6.

In the control group, clicking was observed in 100% of patients during the entire period of follow-up.

Chi-square analysis revealed that the percentage of subjects reporting clicking was statistically lower in

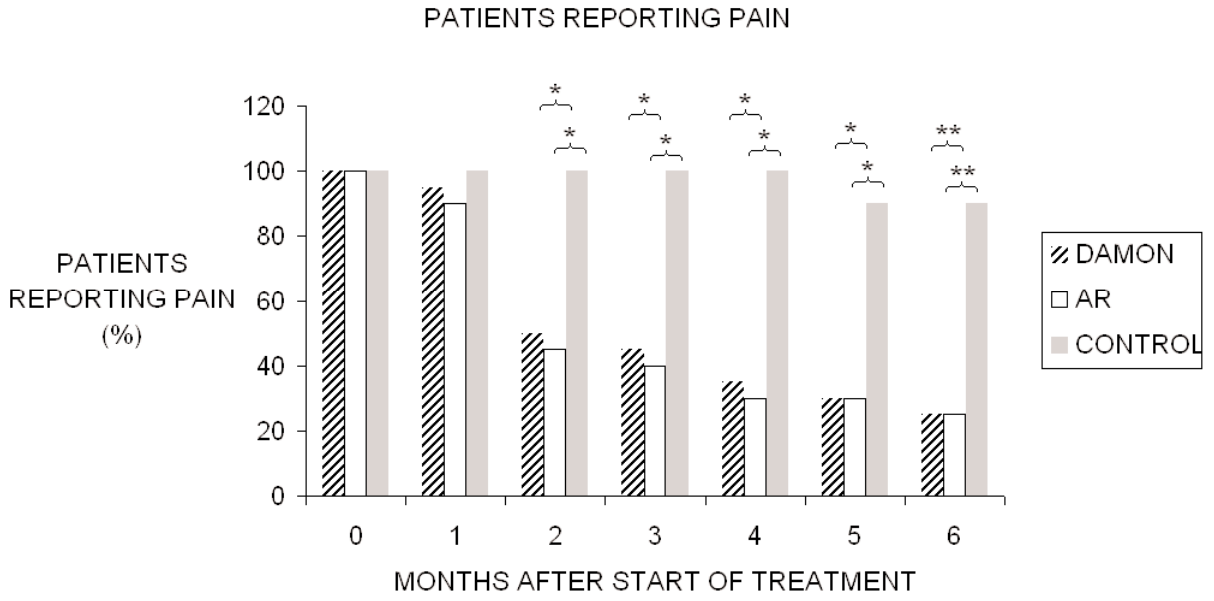

Figure 4
Graphic presentation of patients reporting joint pain (as % of the whole sample) treated using an AR splint (AR: N = 20), Damon appliance (DAMON: N=20) or untreated control patients (CONTROL: N=10), from the baseline recording (T0) to month six (T6) after the start of treatment. Significant differences between groups indicated by clip-brackets and *(p<0.05), **(p<0.01), ***(p<0.001).

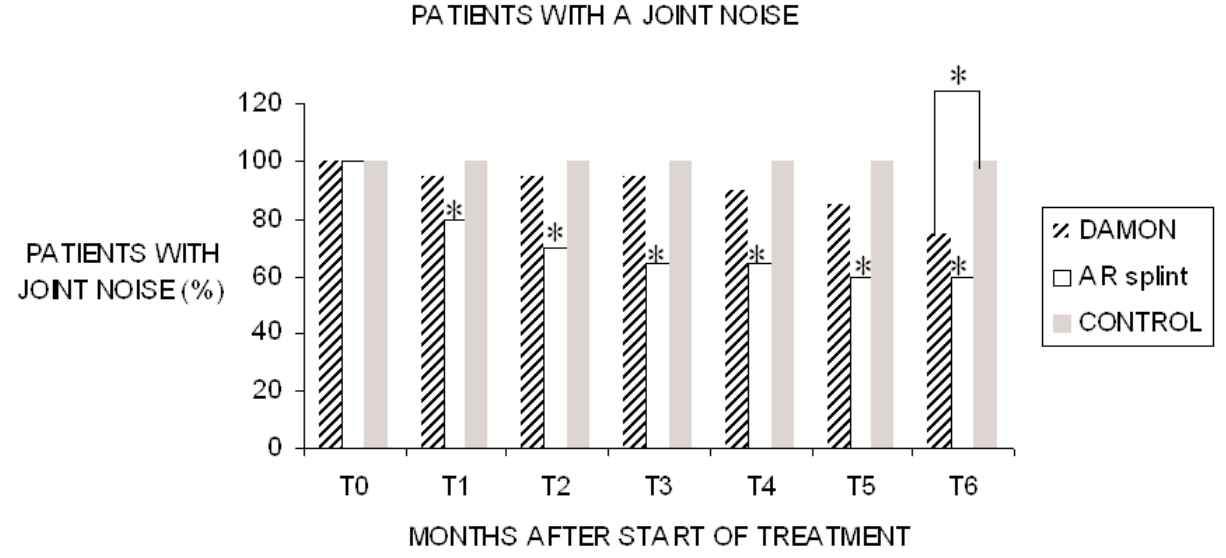

Figure 5
Graphic presentation of patients reporting joint noise (as % of the whole sample) treated using an AR splint (AR: N=20), Damon appliance (DAMON: N=20) or untreated control patients (CONTROL: N = 10), from the baseline recording (T0) to month six (T6) after the start of treatment. Significant differences between groups indicated by clip-brackets and *(p<0.05), **(p<0.01), ***(p<0.001).

Group I compared with Group II at T1, T2, T3, T4, T5, and T6 ($p<0.05$) (**Figure 5**). However, it must be noted that the evaluation of joint noise with only yes-no is not sufficient to assess the effect of the treatment.

Muscle Pain (**Figure 6**)

In both study groups, the frequency of muscle pain was significantly lower than that observed in the control group ($p<0.01$) from T1 to T6. However, no significant difference was observed between the two study groups. In the patients treated with the fixed appliance, the frequency of muscle pain passed from the 85% (T0) to the 75% (T1), then to the 65% (T2), then to the 45% (T3), then to the 40% (T4) and finally to the 20% (T6). In the patients treated with the AR splint, the frequency of muscle pain passed from 80% (T0) to the 70% (T1), then to the 60% (T2), then to the 50% (T3), then to the 45% (T4), then to the 40% (T5) and finally to the 20% (T6). In both study groups, the decrease of muscle pain was so regular during the months, such that there were no statistical significant differences over time, from one control visit to the next.

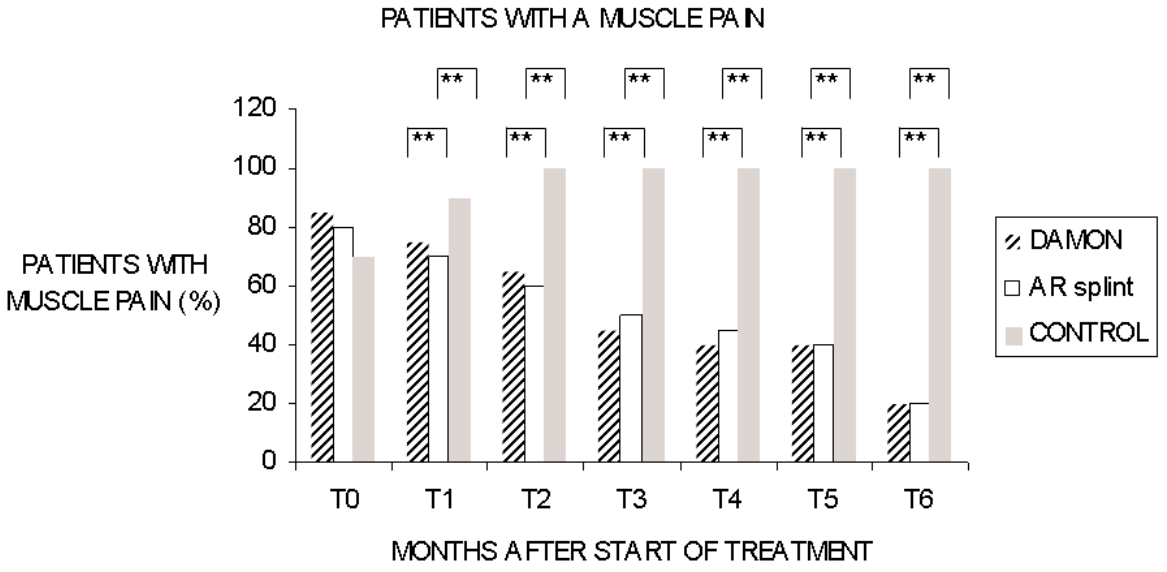

Figure 6
Graphic presentation of patients reporting muscle pain (as % of the whole sample) treated using an AR splint (AR: N=20), Damon appliance (DAMON: N=20) or non treated control patients (CONTROL: N=10), from the baseline recording (T0) to month six (T6) after the start of treatment. Significant differences between groups indicated by clip-brackets and *($p<0.05$), **($p<0.01$), ***($p<0.001$).

Subjective Relief (**Figure 7**)

No significant difference was observed between subjects from the two study groups at T0 and T1 when they had worn the appliances for the first month.

At T2, subjects in Group I reported a severe discomfort (**Figure 7**), mostly associated with difficulty in phonetic function and swallowing. Also, the subjects treated with fixed appliances (Group II) also reported difficulty in maintaining proper oral hygiene. There was a statistically significant higher discomfort in the Group I than in the group treated with the fixed appliance ($p<0.05$). These patients reported a decrease in discomfort (of statistical significance) from T1 to T2 ($p<0.001$).

Also at T3, subjects using the AR splint continued to experience severe discomfort, although at a less intensity from T2 to T3. The discomfort was caused by difficulties while speaking, probably associated with the presence of the anterior ramp on the splint. Subjects treated with fixed appliances described no difficulty in speaking and reported that they felt comfortable with their appliance while working or studying. Because of the improvement of adaptation to the fixed device, subjects in Group II showed a significantly lower discomfort at T3, compared with subjects treated using the the AR splint, **Figure 7**.

From T3 to T4, subjects in the AR group reported a significant decrease in the discomfort associated with their appliance ($p<0.05$). The improvement of signs and

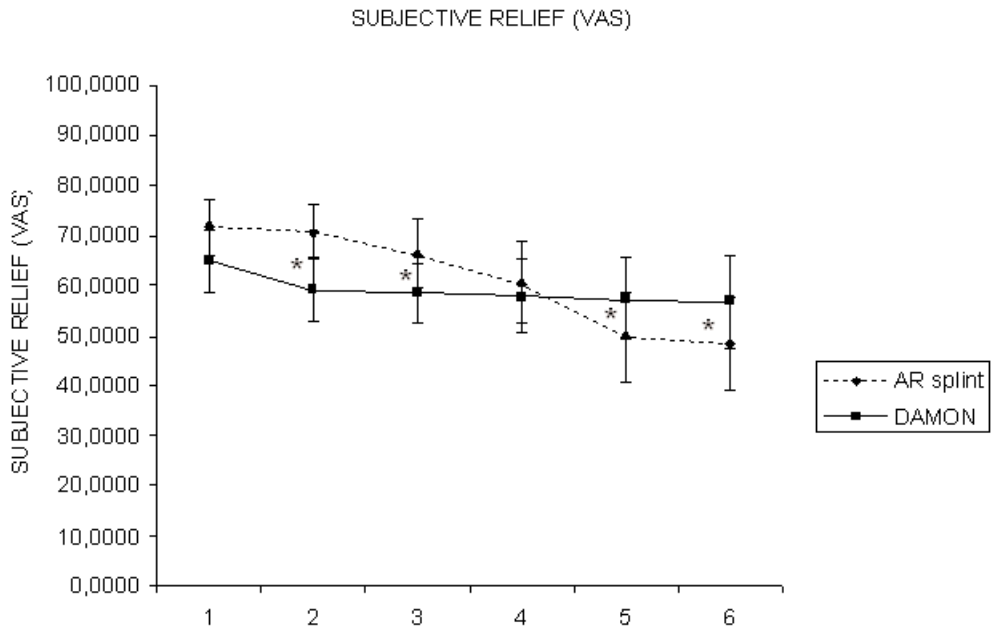

Figure 7
Graphic presentation of subjective relief (as VAS score) (mean value and SD) reported by patients treated by using AR splint (AR; N=20), Damon's appliance (DAMON: N=20) or nontreated control patients (CONTROL: N=10), from the baseline recording (T0) to month six (T6) after the start of treatment. Significant difference between groups indicated by clip-bracket and *(p<0.05), **(p< 0.01), ***(p<0.001).

symptoms of TMD allowed them to wear the splint for less time during the day and, for this, there was no significant difference between the two study groups at T4 in subjective relief. (**Figure 7**)

At T5 and T6, subjects using the AR splint showed a significant decrease of discomfort, ($p<0.05$ between T4 and T3; $p<0.001$ between T5-T4 and T6-T5) (**Figure 7**), due to a decrease of pain intensity and joint noises. Consequently, they began to wear the splints only during the night and for only a few hours during the day. Because of this decrease, patients in Group I reported less discomfort than patients in Group II, at T5 and T6 ($p<0.05$).

Discussion

Joint pain and joint sounds were strongly associated with joint abnormal morphology. The presence of pain was associated with MRI evidence of joint effusion[23] and reciprocal clicking was consistently associated with anterior disk displacement with reduction. In this study all the joint sounds were classified as reciprocal clicking. Pereira, et al.[24] in TMJ autopsy studies (which correlated symptoms before death to anatomical examination of the joints), concluded that the association between pain and/or dysfunction and joint morphology is complex, and that gross morphologic alterations can be present in the absence of TMD symptoms.

However, since the primary symptoms for consulting a clinician are pain and joint noises, the current study simply assessed the existence of pain and joint noises, monitoring over time the presence of symptoms without assessing any morphological alteration of the TMJ observed on MRI.

Eighteen patients with anterior disk displacement with reduction were included in the current study (confirmed only on one side by MRI and with TMJ sounds in both joints). The primary inclusion criteria in the study were the presence of clinical symptoms (sounds and pain), and the 18 subjects showed severe clinical symptoms, although the symptoms were confirmed on MRI on only one side. Additionally, since anterior disk displacement with reduction on one side is often treated with the same therapeutic program as cases with both disks displaced, it was decided to include these patients in our sample.

The results of this study are valid only as short-term results of an orthodontic or a splint treatment, as the

follow-up was only six months. After this time, the ten patients in the control group decided to begin the clinical treatment. Among the patients in Group II, 13 subjects needed, soon after the six months follow-up, a consequential, fixed orthodontic treatment to finalize their splint therapy, and seven subjects wore continued to wear their splints (the number of months varied in the patients, before beginning the fixed orthodontic treatment. The 20 subjects in Group I continued to wear the fixed orthodontic appliance; their TMD's signs and symptoms were reevaluated during treatment, although no comparison was made among the three groups, because the treatment time and sequences were different for each patient and not standardized in the whole sample, avoiding a comparison among the results.

One of the most important findings of this study was regarding the discomfort.

Subjects treated with the fixed appliance (Group II) reported a higher decrease in discomfort at T1 and T2 ($p<0.001$) and showed a significantly lower discomfort than the Group I, at T2 and T3 (**Figure 7**). Apparently, these patients wore the fixed appliance and experienced great therapeutic relief from joint pains and muscle pains. The therapeutic effect was similar in patients treated with the AR splint and in patients treated with a fixed orthodontic appliance, but only if the objective of TMD treatment is the elimination of joint pain and muscle pain. However, since the objective of this TMD treatment also included the elimination of joint noise, the patients treated in the current study with the orthodontic fixed treatment showed a lower therapeutic success compared to the patients treated with splints. In fact, if one considers also the reduction of joint noise, **Figure 5** illustrates that patients treated with the AR splint reported a significantly lower frequency of joint noise from T1 to T6, compared to patients treated with orthodontic fixed appliances.

It should be noted that the control of joint noises as *yes* or *no* is not sufficient to assess the clinical effect of a therapy; the characteristic of joint noise is also important, as, for example, clicking, popping, or crepitation. Our findings showed that the joint noise was always recognized as clicking; not surprisingly, because the subjects were included based on the presence of a TMJ internal derangement.

Regarding joint pain and muscle pain, the results are shown in **Figures 4** and **6**. **Figure 4** shows that patients treated with the fixed appliance (Group II) reported a significantly lower frequency of joint pain, compared with the control group, from T2 to T6. In **Figure 6**, subjects treated with a fixed appliance (Group II) reported a significantly lower frequency of muscle pain, compared with the control group, from T1 to T6.

In the AR group (Group I), the discomfort was probably associated with the presence of the anterior ramp on the AR splint, which can make phonetic function and swallowing difficult, especially if the device is worn during the daytime. Subjects treated using the fixed orthodontic appliance reported no difficulty in speaking, working, or studying. This contrast is demonstrated in the lower discomfort reported in the Group II than in the Group I, at T2 and T3. It is probable that the improvement of symptoms and, consequently, the fact that patients wore the AR splint only during the nighttime, contributed to the decrease in discomfort, during the other months.

This could explain why at T5 and T6, subjects wearing the AR splint (Group I) reported lower levels of discomfort than subjects treated with the fixed appliance (Group II), that is, contrary of to what was observed at T2 and T3.

In terms of the therapeutic effect, the use of a fixed orthodontic appliance seems to be as efficacious as the AR splint in the treatment of joint pain and muscle pain. However, this statement is not valid if we consider the joint noise, because joint noises disappeared only at the sixth month and only in 35% of subjects in Group II. **Figure 5** shows that from T1 to T6, patients treated with the fixed appliance (Group II) reported a significantly higher frequency of joint noises than patients treated with the AR splint (Group I).

This finding with regard to joint noise indicates that the patients treated with the AR splint showed better therapeutic goals compared to patients treated with the fixed orthodontic appliance because they experienced significant reductions in joint pain, muscle pain, and joint noise.

This finding is in accord with previous reviews,[7] which showed that splint therapy was superior to three control treatments (ultrasound, palliative treatment, and palatal splint) and comparable with 12 control treatments, resulting in better treatment.

However, there were also studies to the contrary, which showed an indication to use a simultaneous splint during orthodontic treatment of patients with TMD.[8,9] Those studies stated that TMJ must be protected during the orthodontic treatment. Consequently, the orthodontic appliance must be modified to include vertical unloading using the concept of a full arch, flat plane splint to permit unencumbered joint motion. This simultaneous fixed orthodontics and splint therapy could allow the patient's neuromuscular and skeletal apparatus to find the most comfortable joint position. In this condition, orthodontic cusp fossa correction to that position can be accomplished with the orthodontic fixed appliance. During an orthodontic treatment of patients with TMD, TMJ loading should not be attempted, because it could lead to arthritic degeneration or other joint pathology. For this

reason, vertical unloading appliances must be used; these appliances could also decrease patient's discomfort.

Longitudinal analysis showed that the frequency of joint pain in subjects treated with the AR splint or with the fixed appliance mostly decreased from T1 to T2 (**Figure 4**). It must be noted that no significant difference was found between the two study groups from T1 to T6 in the frequency of joint pain and that subjects in both study groups showed a significantly lower frequency of joint pain compared to the control subjects, from T2 to T6 (**Figure 4**). This finding seems to confirm the validity of the two devices in the treatment of joint pain and muscle pain associated with TMJ anterior disk displacement with reduction, although our findings are based on a six-month follow-up, and it is not possible to propose any clinical implication in the long term. In the group of untreated control subjects, an increased intensity in muscle pain was reported, although it was not statistically significant. There was no significant reduction of joint pain or joint noises, as may be expected in the absence of a therapeutic program.

In terms of joint noise, the following observations must be noted. In the group of patients treated with the fixed appliance (Group II), the frequency of joint noise (**Figure 5**) became significantly lower than the control group only at T6, but it remained significantly higher than Group I patients (treated with AR splint), from T1 to T6. This finding suggests the greater efficacy of the AR splint in reducing the frequency of joint noises, than the fixed appliance, at least during the first six months of treatment. However, it must be noted that the frequency of joint noise decreased over time in each of the two study groups, but only at T1 (although with a significant difference between the two study groups), and remained at 100% until T6 in the control group. Thus, a significant difference between the control group and the group treated with the fixed appliance was also statistically evident, but only at T6. The difference observed from T1 to T6 between the two study groups and the control group suggests that an efficacious therapeutic goal can be obtained soon after the beginning of the treatment, but only by using an AR splint, at least during the first six months of treatment. The fact that no significant difference was observed between Group II and the control group, until T6, could be attributed to the small number of subjects studied.

In terms of clinical relevance, the study notes that subjects treated with the fixed appliance experienced a significantly lower discomfort at T2 and T3, compared with subjects treated with the AR splint (**Figure 5**). Thus, while the therapeutic effect of the two investigated treatments are comparable for the treatment of joint pain and muscle pain, they are not for the treatment of joint noise, while the fixed appliance appears to be more easily acceptable to the patients, especially during the first months of treatment. While the main discomfort with the AR splint arises from the difficulty in speaking and swallowing, the fixed appliance did not interfere with swallowing or phonetic function.

No definite conclusions with regard to the therapy were possible based on a follow-up of only six months and considering that symptoms may arise not from the anatomy or treatment technique, but from a failure of compliance in the treatments. Patients were told they must adhere to a strict protocol for appliance wear. Although they were told to always wear the night appliance to sleep and to not remove it during the day, patients occasionally slept or ate without the appliance. Some of those patients reported that such compliance failure produced a sudden return of symptoms, and they resumed strict compliance. Even though there were some compliance failures, the results still showed improved or normalized symptoms, and no attempt was made to eliminate compliance failures from the study.

Based on this and mostly for the short follow-up period of six months, certain conclusions about the clinical implication of the observations are not possible.

However, it must be noted that generally, successful orthodontic treatment is based on the assumption that the condyle and the TMJ respond normally to various orthodontic treatments, but that structurally damaged joints, such as in TMJ anterior disk displacement with reduction, may respond in an unfavorable and pathological manner because the functional environment of the TMJ and its adaptive capacity are altered.[25-27] This indicates that orthodontic treatment may have a detrimental effect on patients with TMJ disk displacement and vice versa. However, this study showed that by limiting the friction in the treatment, symptoms and signs of TMD can improve during fixed orthodontic therapy, at least during the first six months of treatment.

Limits of the Study

The investigation was concluded when the control subjects decided to begin therapy. Due to the limited period of investigation, this study must be considered preliminary and clinical implications of the findings are not possible. Follow-up was concluded when only some of the subjects were considered asymptomatic. It is not known how many subjects became chronic in pathology or how many completely recovered.

Another limit was that VAS was used to assess the subjective relief. This method was shown to be influenced by

subjective perceived levels of emotions,[28,29] and thus is considered to be a pseudo-scientific diagnostic technique. Finally, no MRI were made during the six months, and the study must be considered as an analysis of the primary symptoms associated with a diagnosed TMD.

In addition, the basic design of this study was flawed, because patients in Group I were treated with only an upper appliance. Although today, the majority of researchers and clinicians think that the use of a unique upper appliance, also during the day, could cause a built-in probability of noncompliance,[30] in this study this type of treatment was selected (using only an AR upper splint) because the use of a unique splint is still very common among orthodontic clinicians.

In the future, the same research protocol could be repeated, comparing the data with a group of patients treated with upper night-time and lower day-time appliances to increase compliance.

Conclusions

In the treatment of TMJ anterior disk displacement with reduction, an anterior repositioning splint seems to be confirmed as an efficacious therapeutic action, since subjects report a significant decrease in joint pain, joint noise, and muscle pain from the first month after the start of therapy.

The use of a fixed appliance in subjects, who need the resolution of a malocclusion, showed a similar therapeutic effect compared with the use of an AR splint in the management of joint pain and muscle pain of patients affected by TMJ anterior disk displacement with reduction.

In the treatment of joint noise, the AR splint proved superior to the fixed appliance. The fixed appliance resulted in greater comfort to the patient during the first three months of treatment, and also an accelerated resolution of malocclusion.

From a clinical point of view, orthodontic treatment is similar in its effect to splint treatment, but only when the objective of therapy is pain relief only (muscle pain or joint pain). If the reduction or elmination of joint noise is the objective of treatment (normalization of disk/condyle relationship), the splint proved superior to orthodontic treatment. If this is the case, then it will be more appropriate to treat the patient with a splint to achieve a stable disk-condyle-fossae relationship first, then finish to that position (finalization or phase II of treatment) with an orthodontic fixed appliance. In order to make a clinical decision, the clinician must decide what is the objective of treatment, and what is the criteria or baseline for success.

Due to the short period of follow-up (six months), any clinical implication observed must be considered as only hypothetical based on the concern over the short-term result of treatment. Long-term implications can be achieved only after studies which will consider a longer follow-up.

References.

1. Paesani D, Westesson P-L, Hatala M, Tallents RH, Kurita K: Prevalence of anterior anterior disk displacement with reduction with reduction in patients with craniomandibular disorders. *Am J Orthod Dentofacial Orthop* 1992; 101:41-47.
2. Farrar WB: Diagnosis and treatment of anterior dislocation of the articular disk. *NY J Dent* 1971; 41:348-351.
3. Farrar WB, McCarty WL: Inferior joint space arthrography and characteristics of condylar paths in anterior anterior disk displacement with reduction with reductions of the TMJ. *J Prosthet Dent* 1979; 41:548-555.
4. Lundh H, Westesson P-L, Kopp S, Tillstrom B: Anterior repositioning splint in the treatment of temporomandibular joints with reciprocal clicking: comparison with a flat occlusal split and an untreated control group. *Oral Surg Oral Med Oral Pathol* 1985; 60:131-136.
5. Egermark I, Magnusson T, Carlsson GE: A 20-year follow-up of signs and symptoms of temporomandibular disorders and malocclusions in subjects with and without orthodontic treatment in childhood. *Angle Orthod* 2003; 73:109-115.
6. McNamara JA Jr.: Orthodontic treatment and temporomandibular disorders. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1997; 83(1):107-117.
7. Rinchusea DJ, McMinna JT: Summary of evidence-based systematic reviews of temporomandibular disorders. *Am J Orthod and Dentofac Orthop* 2006; 130(6):715-720.
8. Alpern MC: TMJ biocompatible orthodontic treatment. *Clinical Review*. *Angle Orthod* 1992; 62(4):299-302.
9. Keller DC. Orthotics and orthodontics. *J Gen Orthod* 1996; 7(3):6-15.
10. Carano A, Leone P, Carano A: Orthodontic finalization strategies in dysfunctional adult patients. *J Craniomandib Pract* 2001; 19:195-213.
11. Yemm R: Neurophysiologic studies of temporomandibular joint dysfunction. *Oral Sciences Rev* 1976; 7:31.
12. Stenn PG, Motherstt KJ, Brooke RI: Biofeedback and cognitive behavioral approach to treatment of myofascial pain dysfunction syndrome. *Behav Ther* 1979; 10:29.
13. Schumann NP, Zwiener U, Nebrich A: Personality and quantified neuromuscular activity of the masticatory system in patients with temporomandibular joint dysfunction. *J Oral Rehabil* 1988; 15:35-47.
14. Artun J, Hollender LG, Truelove EL: Relationship between orthodontic treatment, condylar position, and anterior anterior disk displacement with reduction in the temporomandibular joint. *Am J Orthod Dentofacial Orthop* 1992; 101:48-53.
15. Ahn SJ, Lee SJ, Kim TW: Orthodontic effects on dentofacial morphology in women with bilateral TMJ disk displacement. *Angle Orthod* 2007; 77:288-295.
16. Damon DH: The Damon low-friction bracket: a biologically compatible straight-wire system. *J Clin Orthod* 1998; 32:670-680.
17. Tecco S, Festa F, Caputi S, Traini T, Di Iorio D, D'Attilio M: Friction of conventional and self-ligating brackets using a 10-bracket model. *Angle Orthod* 2005; 75:828-832.
18. Proffitt WR: *Contemporary orthodontics*. London: CV Mosby Co. 1999.
19. Stegenga B: Temporomandibular joint degenerative diseases: clinical diagnosis. In: Stegenga B, De Bont LGM, eds. *Management of temporomandibular joint degenerative diseases*. Basel: Birkhauser-Verlag, 1996:13-25.
20. Kurita K, Westesson P-L, Sternby NH, Eriksson L, Carlsson LE, Lundh H, Toremalm NG: Histologic features of the temporomandibular joint disk and posterior disk attachment: comparison of symptom-free persons with normally positioned disks and patients with anterior anterior disc displacement with reduction with reduction. *Oral Surg Oral Med Oral Pathol* 1989; 67:635-643.
21. Okeson JP: *Management of temporomandibular disorders and occlusion*. 3rd ed. St Louis: CV Mosby Co., 1993:477-479.
22. Travell JC, Simons DG : *Myofacial Pain and dysfunction. The trigger point manual*. Baltimore: William and Wilkins Co., 1983.
23. Westesson P-L, Brooks SL: Temporomandibular joint: relationship between MR evidence of effusion and the presence of pain and disk displacement. *Am J Roentgenol* 1992; 159:559-563.

24. Pereira FJ Jr, Lundh H, Westesson P-L, Carlsson LE: Clinical findings related to morphologic changes in TMJ autopsy specimens. *Oral Surg Oral Med Oral Pathol* 1994; 78:288-295.
25. Stegenga B, deBont LG, Boering G, van Willigen JD: Tissue responses to degenerative changes in the temporomandibular joint: a review. *Oral Maxillofac Surg* 1991; 49:1079–1088.
26. Luder HU: Articular degeneration and remodeling in human temporomandibular joints with normal and abnormal disk position. *J Orofacial Pain* 1993; 7:391-402.
27. Axelsson S: Human and experimental osteoarthrosis of the temporomandibular joint. Morphological and biochemical studies. *Swed Dent J* 1993; 92:1-45.
28. Steigerwald DP, Verne SV, Young D: A retrospective evaluation of the impact of temporomandibular joint arthroscopy on the symptoms of headache, neck pain, shoulder pain, dizziness and tinnitus. *J Craniomandib Pract* 1996; 14:46.
29. McKay DC, Christensen LV: Whiplash injuries of the temporomandibular joint in motor vehicle accidents: speculations and facts. *J Oral Rehabil* 1998; 25:731-746.
30. Tecco S, Caputi S, Teté S, Orsini G, Festa F: Intra-articular and muscle symptoms and subjective relief during TMJ internal derangement treatment with maxillary anterior repositioning splint or SVED and MORA splints: a comparison with untreated control subjects. *J Craniomandib Pract* 2006; 24:119-129.

Dr. Stefano Teté *received his D.D.S. at the University G. D'Annunzio, Chieti/Pescara, Department of Oral Science) and is an associate professor of oral surgery at the same university. He has authored many articles on the relationship between oral surgery and orthodontics.*

Dr. Vito Crincoli *is a researcher at the University of Bari. He also collaborates with the clinical hospital in Bari. He is the author of many scientific articles on the relationship between oral pathology and treatment.*

Dr. Mario Armando Festa *is a student at the University La Saienza Roma. He is an expert in radiographic diagnosis of temporomandibular dysfunction (TMD). He has authored many scientific articles on TMD.*

Dr. Felice Festa *is director of the Department of Orthodontics and Gnathology, School of Dentistry and a professor of orthodontics at the University of Chieti, Italy. He is also director of the postgraduate program in clinical gnathology and orthodontics. He received his M.D. and D.D.S. degrees at the University of Rome in 1979 and 1982 respectively. He earned an M.S. degree in orthodontics in 1985 at the University of Cagliari. In 2001 he was nominated National Referee Professor in orthodontics at the National College of Professors. Dr. Festa has many published research articles in his field.*