Badel, T., Marotti, M., Kern, J., Laškarin, M. (2009) *A quantitative analysis of splint therapy of displaced temporomandibular joint disc.* Annals of anatomy = Anatomischer Anzeiger, [Epub ahead of print, Corrected Proof]. ISSN 0940-9602 (Print) 1618-0402 (Electronic)

http://www.elsevier.com/locate/issn/0940-9602

http://dx.doi.org/10.1016/j.aanat.2008.12.004

http://medlib.mef.hr/596

A QUANTITATIVE ANALYSIS OF THE SPLINT THERAPY OF DISPLACED TEMPOROMANDIBULAR JOINT DISC

Short title: ANALYSIS OF DISPLACED TMJ DISC

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Summary

Objectives: The effects of the Michigan splint on the change of disc displacement (DD) as well as the position of the condyles were determined by metrical analysis with a magnetic resonance imaging (MRI). Methods: Twenty-five patients with clinical DD symptoms were treated by means of the Michigan splint, and an assessment of the effects of the splint was conducted or verified by MRI before and during the period of therapy, 5 months follow-up. The positions of the condyles and the disc were calculated from the MRI in the parasagittal plane. Results: There was no change in the positions of the disc and condyles in the physiological joints of the patients (n=23) prior to and during the time the splint was in place (p>0.05). The splint achieved a DD decrease (p<0.05), and pain was eliminated in 69.2% of the DD joints with reduction (n=13). As far as the DD joints without reduction (n=13) are concerned, pain was eliminated in 74.9% of the joints, that is, without any change in the positions of the disc and condyles (p>0.05). Conclusions: The evaluation of the Michigan splint therapy showed that it has no influence in the repositioning of the DD joints without reduction, but the DD joints with reduction have a limited positive effect. In both forms of these displacements conditions for the elimination of the clinical symptoms are created.

Key words**:** temporomandibular disorder, temporomandibular joint, disc displacement, magnetic resonance imaging, Michigan splint

1. Introduction

Temporomandibular disorder (TMD) designates a cluster of descriptive diagnoses of the temporomandibular joint (TMJ) and/or masticatory muscle disorders from the musculoskeletal disorders group. As far as the diagnostically important clinical signs and symptoms of TMDs are concerned, the most uncomfortable for the patient is the temporomandibular pain, followed by the limitation of the mandibule (Türp et al., 2006; Palla 2003; Dworkin and LeResche, 1992).

The anterior disc displacement (DD) is the most frequent form of disc malpositioning of TMJ. DD can only occur in the intercuspal occlusion position (DD with reduction) or during condyle movements when opening the mouth (DD without reduction). Magnetic resonance imaging (MRI) is a noninvasive diagnostic method for the analysis of arthrogenic TMDs that enables a qualitative as well as a quantitative analysis of the structures within the joint, as well as the soft tissues, especially those of the disc (Hugger 2002; Larheim 2005).

Occlusal splint therapy is the most frequent form of initial TMD treatment, despite the fact that all of the effects of the different types of splints on the treatment of TMD symptoms are controversial (Dao and Lavigne, 1998; Dylina, 2001; Clark and Minakuchi, 2006). The most frequently used permissive splint in TMD and bruxism therapy is the Michigan splint (Ash Jr and Ramfjord, 1998; Ekberg et al., 1998; Baldissara et al, 1998; Ekberg and Nilner 1999; Ekberg and Nilner, 2002; Jokstad et al., 2005; Fayed et al., 2004; Babadağ et al., 2004; Ohnuki 2006). Of the nonpermissive types, the anterior repositioning splint is also much in use. It is exclusively indicated for DD conditions, with the goal of achieving physiological relationships between the disk and the condyles by positioning the mandible into the therapeutic anterior position (Kurita et al., 1998a; Kurita et al., 1998b; Dylina, 2001; Eberhard, 2002).

The purpose of this study is to determine the effects of the Michigan splint therapy on the change of the disc position as well as the position of the condyles through the use of metrical analysis, with an MRI-confirmed clinical diagnosis of DD. The hypothesis was that during initial Michigan splint therapy there were no differences between the position of an anteriorly DD and the position of the condyles.

2. Materials and Methods

2.1. Subjects

The subjects of this study, 25 patients, aged between 18 and 71 years (mean: 38 years; 1:5 ratio men to women), were selected from the total number of 40 patients with DD (between 15 and 82 years of age, mean 37; 23.3% men and 76.7% women) seeking treatment for TMD at the Department of Prosthodontics at the School of Dental Medicine in Zagreb in the period of 2001 to 2004. The selected patients included in this study voluntarily agreed to an additional MRI assessment when the splint was applied (Figs 1 and 2).

The clinical parameters were pain and/or clicking in the TMJ region, and limited mouth opening. The DD diagnoses were set based on MRI-confirmed clinical diagnostics. All patients were informed of the type and purpose of diagnostic procedures and gave their written consent for participation, and the execution of the study was approved by the Ethics Committee of the School of Dental Medicine in Zagreb.

2.2. Clinical Method

The patients were diagnosed with a DD with or without reduction in congruence with the Research diagnostic criteria (RDC)/temporomandibular disorders diagnostics system (Axis I) (Dworkin and LeResche, 1992). In the clinical examination Bumann and Groot Landeweer's techniques of manual functional analysis were also used (Bumann and Lotzmann, 2002). The Michigan splint therapy was indicated for these patients, which was then performed. In this study Michigan splint was made as an occlusal bite plane stabilization splint with cuspid rise and freedom in centric in an articulator SAM 2P (Präzisiontechnik, Gauting bei München, Germany). A face bow was used (SAM Axioquick, Präzisiontechnik, Gauting bei München, Germany) and all splints were fabricated by one dental technician (Witt, 1998).

Patients were instructed to wear the splint during the night. During the period of wearing the splint the patients were regularly checked so that it could be seen that the splint was successfully accepted and the subjective and objective conditions of the patient were improving. The effects of the splint treatment on the positions of the disc and the condyles were checked in addition to clinical condition, also by TMJ analysis during the initial treatment, by repeating the MRI with the splint applied. Because all patients had artrogenic disorder, it was expected that those need relative longer period of splint wearing to improved functional oral status. In this study, a 5-month interval to MR evaluation was chosen, because 6 months of treatment were considered an optimal period for evaluation, and, if necessary, treatment modality could have been changed (Conti et al., 2006; Ottl, 1997). The clinical state of the patient's individual joints was monitored, so that the subjective result of the splint therapy was evaluated as: a state without discomfort, a state without pain, but with clicking present, a state of reduced pain, and a state of still significant pain.

2.3. MRI Protocol

The bilateral MRI of TMJs was performed using a super-conductive device, the "Harmony" magnet by Siemens AG (Erlangen, Germany), magnetic field strength of 1 T. Gradient magnets of 20 mT/ms with quick system reboot time and radio frequent system for the head coil. The coil included digitalized transmitters and antennae with frequency signals of 42 MHz – the resulting resolution was 100 ns.

The angle of the parasagittal imaging is individually determined by the angle showed on the individual angulated layers of the axial and coronar slice. TMJs of the patients were scanned in intercuspal occlusion with their mouths closed. The open mouth position was fixated with an interincisal individual fixator (Optosil ® P plus, Heraeus Kulzer, Hanau, Germany). The layers in the position of an open or closed mouth could be compared well. In all, seven slices of 3 mm thick were scanned, with a 256 x 192 matrix, and field of view of 160 x 160. Scanning sequences included a T_1 weighted image with a repetition time of 450 ms, and an echo time of 12 ms.

2.4. Metric evaluation

The patient's joint with asymptomatic DD without reduction was excluded. The rest of the patients' joints were distributed according to the disc position. Only one patient had a bilateral DD, with reduction in one joint and no reduction in the other. The disc's physiological position in the parasagittal plane was defined according to the placement of its intermedial zone between the articular eminence and the shortest distance of the bone contours of the condyles' ventrocranial part. The *pars posterior* of the disc was located on the condylar head (Orsini, 1998; Bumann and Lotzmann, 2002).

The quantitative analysis of the position and the relationship between the disc and the condyles was described using Kurita et al.'s method of measuring the relative and absolute distances of reference points (Kurita et al, 1998b). A tangent was drawn between the lowest part of the articular eminence (T) and the highest edge of the external auditory canal (P). A line was drawn perpendicular to the tangent, touching the back edge of the disc, and their intersection was marked as point D. Another perpendicular, touching the back edge of the condyle was also drawn, and point C marked the intersection of this line and the tangent. The distances between points T and P were taken as measurement reference values and individual distances on the tangent - distances between points T and C, and points T and D (Fig. 3) were also measured. Absolute values (TP, TC and TD) were measured in millimeters to one decimal place using Adobe® Photoshop® 7.0. Millimeter values were calculated based on the measurement scale shown in the MRI. The disc and condyle positions were calculated as TC/TP and TD/TP and expressed in one-hundredths of the distance between points T and P. A lower value indicates a more anterior condyle, or disc position.

2.5. Statistical analysis

The statistical analysis was performed by using STATISTICA and SAS programs. The measured values of the metric evaluation are displayed as box-and-whisker plots. The box with the marked median encompassed the values between the 25%- to the 75%-quantile, and all the measured values were shown in the limits of the whisker, except the outliers (therefore, all the values are in the non-outlier range).

The left and the right TMJs of each person were presented as two separate entities within the data analysis. The properties of joints with DD (DD with reduction and DD without reduction) were observed separately. A control group consisted of joints of the same patients without clinical signs and symptoms of TMD. In this case, the physiological position of the disc is confirmed by MRI. The Wilcoxon pair test was used to compare data before the insertion of the Michigan splint and after it was applied. The significant difference for statistical testing was 5% and 1%.

The reliability of MRI assessment was evaluated on the basis of two researchers' (a radiologist's and a dentist's) inspection, which was conducted independently of the patient's clinical signs on MRI images prior to the insertion of the Michigan splint. The Kappa index of reliability was between 0.8 and 1.0 for all variables. The MRI assessment was judged to be extremely reliable.

The reliability of results for the metrical variables was tested by calculating the error according to Dahlberg (Houston, 1993). When no measurement error exists then the Dahlberg error equals *0*. To calculate the method error (ME) according to Dahlberg, the following formula was used: $ME = \sqrt{\frac{\sum d^2}{2n}}$, where *d* is the difference between two measurements, and *n* is the number of measured MRI images.

For the purpose of determining the reliability of the measurements, a metrical analysis was conducted on 12 patients twice on the same MRIs of both joints (24 measurements in all). The comparison results for the two measurements of metrical variables are shown in Table 1. There is a great possibility of a reproduction of the metrical analysis reference points.

3. Results

In 23 patients' joints the physiological position of the disc was established. The quantitative relationship of the patients' joints was compared with the physiological disc position during the period when the occlusal splint was worn. There was no statistically significant change to the relative disc position (Wilcoxon's pair test z=0.821 with p=0.412; Figure 4A), or to the relative condyle position (Wilcoxon's pair test z=0.568

with p=0.570; Figure 4B) before the insertion of the Michigan splint and after it was applied.

In 13 joints a DD with reduction was noted. The metrical analysis showed a statistically significant decrease in anterior DD during splint therapy when the relative disc position in the mouth (Wilcoxon's pair test z=2.795 with p<0.005) was compared with the dorsal relative condyle positioning (Wilcoxon's pair test z=2.510 with p=0.012) before and after splint application (Figure 5).

The DD without reduction was diagnosed in 13 joints. Based on the Wilcoxon pair test, there was no decrease in the anterior DD during the splint therapy, when the relative disc position (z=0.489) with p=0.625 and the relative position of condyles (z=0.384) with p=0.701 were compared before and after splint application (Figure 6).

4. Discussion

In this study the criteria applied for determining the physiological position of the disc in the parasagittal plane include the steep forms of the articular eminence (Drace and Enzmann, 1990; Bumann and Lotzmann, 2002). Using Kurita et al's (1998b) method of measurement, the values were calculated with regards to the reference distance, which dependent on the slice is selected for scanning as well as the patient's individual anthropological measurements. The difficulties of estimating the position of the measurement points in, for example, the middle of the articular eminence and the condyles, or the middle of the intermediate disc zone between the anterior and the posterior edge, were avoided. With the best known 12 o'clock position method (Drace and Enzmann, 1990) the reference plane is not defined by points in the joint display, but by positioning the patient's head in the Frankfurt horizontal plane during scanning.

For the technical reasons, the best relationship between the layers was obtained with 3 mm thickness of MRI scans (all three parts of each TMJ in the parasagittal plane: medial, central, and lateral), as well as an optimal volume resolution of each scan, and duration of scanning which was not too long. This thickness was most common in MRI scanning of TMJ-s and was used in very sensitive MRI metric analysis, for example by Bumann and Lotzmann, 2002.

The highest prevalence of TMD is to be found in the adult population aged between 20 and 45 years. Also, TMD occurs more commonly in women (75–80%) than in men, which was confirmed in this study. The reason for this very high sex difference is unknown; probable reasons could be: biological and physiological, behavioural, and genetic differences (Warren and Fried, 2001). There are some musculoskeletal disorders with females outnumbering males, like fibromyalgia (Plesh and Gansky, 2006).

The occlusal splints successfully reduce the signs and symptoms of TMD regardless of the characteristics of their construction, and were commonly clinically monitored and evaluated based on the elimination of clinical symptoms, and by MRI (Baldissara et al, 1998; Kurita et al., 1998a; Kurita et al., 1998b; Ekberg et al., 1999; Ekberg et al., 2002; Eberhard et al., 2002; Fayed et al., 2004; Babadağ et al., 2004; Jokstad et al., 2005; Ohnuki et al., 2006). Research is available which provides the possibility of a quantitative evaluation of the changes that take place while the occlusal splint is worn, both for the purposes of DD diagnosis and therapy (Ekberg et al., 1998; Fayed et al., 2004; Kurita et al., 1998a; Kurita et al., 1998b).

The Michigan splint is a therapeutic means of choice for arthrogenic and miogenic TMDs, as well as bruxism. Although small in number, randomized controlled clinical studies show that the Michigan splint lessens the arthralgia (Ekberg et al., 1998;

Baldissara et al., 1998; Ekberg et al., 1999; Ekberg et al., 2002; Babadağ et al., 2004; Jokstad et al., 2005; Fayed et al., 2004). Proff et al. (2007) used modified Michigan splint for patient with DD. Even though the Michigan splint is very commonly used, and is very successful in achieving clinical improvement; there are limited numbers of studies on its biomechanical effects on the disc and condyle positions that could be corroborated by metrical analysis (Ekberg et al., 1998; Bergé et al., 2000; Fayed et al., 2004).

In this study the Michigan splint caused a decrease of the anterior DD with reduction, as well as the dorsal repositioning of the condyles. Rammelsberg (1997) and Incesu et al. (2004) speak of a possible connection between the dorsal condyle movement and the anterior DD. In the joints of patients with DD without reduction the splint had no significant effect on the phase of DD, or the condylar position, despite the fact that there was a great improvement in the clinical condition.

The results of this study showed that the Michigan splint did not change the disc or condylar positions in healthy joints. Only in joints with DD with reduction, a reduction of the anterior disc position, and a dorsal repositioning of the condyles in the glenoid fossa took place. In a previous study by Ekberg et al. (1998) the results suggested that the stabilization splint changed the condyle-fossa position and they assumed that a positive treatment effect could be the unloading of the TMJ. These results partially confirm that Michigan splint allows the placement of the condyles inside the glenoid fossa, or the settling of the condyles into a more physiologically stable position – a centric relation (Ash Jr. and Ramfjord, 1998; Witt, 1998).

There is multidimensional area to investigate influence Michigan splint, not on only intraarticular TMJ structures relationship, also neuromuscular and brain activities.

Kordass et al. (2007) suggested that Michigan splint could reduce cerebral activation in order to relax muscle activation. But the splint was used only by asymptomatic persons.

Ohnuki et al. (2006) reported no significant difference in the rates of joints that showed DD without reduction, as well as in the degree of DD with or without reduction between pre-treatment and post-treatment MRI. This study suggests that the various treatments (including stabilization splint) do not necessarily improve the displaced disc, but is important for the improvement of signs and symptoms.

The goal of the anterior repositioning splint therapy is to produce some measure of invasive, irreversible change, that is, to improve the possibility of disc reduction, or the achievement of a physiological relationship between the disc and the condyle (Kurita et al., 1998a; Eberhard et al., 2002; Fayed et al., 2004). Kuritta et al. (1998a) have by an identical metric method showed a successful repositioning of the disc to the physiological position to the condyle. The metrical analysis with MRI on the base the small sample size by Fayed et al. (2004) showed that disc recapture was better by stabilization splint than anterior repositioning splint, but appliances were effective in eliminating pain and clicking.

It is important to emphasize the differences in the biomechanical effects of these two types of splint therapy, because joint analyses of asymptomatic subjects re-evaluate the clinical importance of the position or displacement of the disc in TMD patients. Because of the significant prevalence (20–33%) of asymptomatic DD, the anterior anatomic disc position cannot be said to be an exclusive cause of TMJ pain (Haiter-Neto et al., 2002; Larheim et al., 2001).

Conclusions

This study shows, regardless of its limits, that the Michigan splint has no effect on the changing of the disc or condylar positions in healthy joints. Joints with DD without reduction also have a smaller possibility of reduction, and the splint was an effective therapeutic means, even though no changes occurred with that group of joints either. In joints with DD with reduction, a reduction of the anterior DD, and a dorsal repositioning of the condyles in the glenoid fossa took place.

Acknowledgements

This study was performed through the support of the Croatian Ministry of Science, Education and Sports, numbers 065-0650448-0438 and 134-1080232-1494.

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TABLES

Table 1. Measurement of the method error (ME) by Dahlberg (in millimeters), and the average difference of two measurements

Variable(inmm)	ME	Mean	SD	min.	max.
Distance T–P	0.100	0.108	0.093	0	0.3
Distance T–C	0.076	0.100	0.042	0	0.2
Distance T–D	0.095	0.096	0.095	0	0.3

SD – standard deviation, min. – minimum, max. – maximum.

FIGURE LEGENDS

Figure 1. MRI of the physiological disc positions with the mouth closed (left) and open (right).

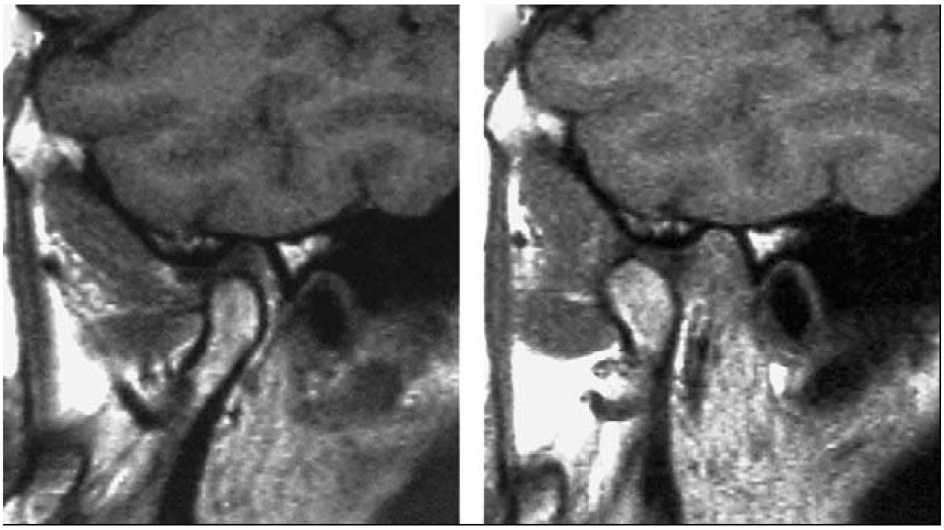

Figure 2. MRI of DD with reduction with the mouth closed (left) and open (right).

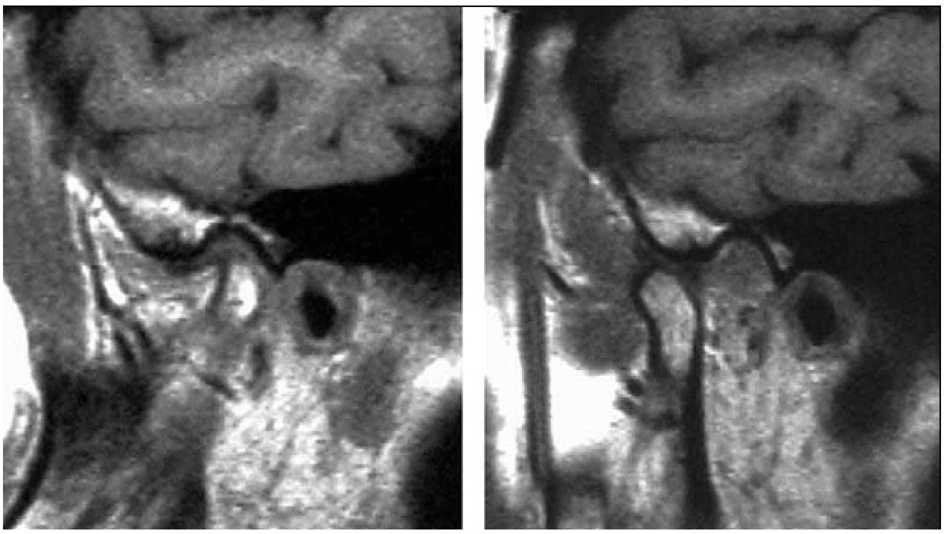

Figure 3. The disc and condyles position measuring in the parasagittal plane using Kurita et al's method (1998b). The TP, TC and TD distances are measured in millimeters.

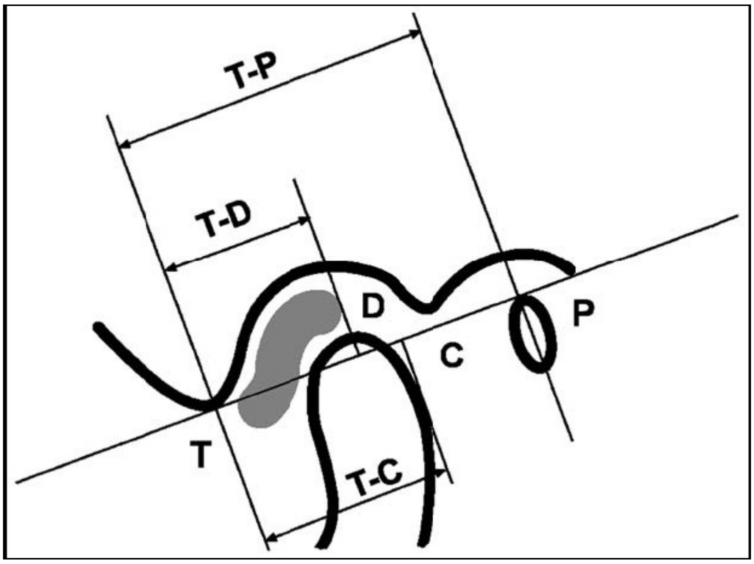

Figure 4. Box-plot comparison of the calculated disc (A) and condyles (B) position (y-axis, expressed in one-hundredths between points T and P) for TMJs (x-axis) with a physiological position of the disc prior to treatment (a), and with the splint applied (b). Thick black horizontal line in the box=median value; the box encompassed 50% of the results.

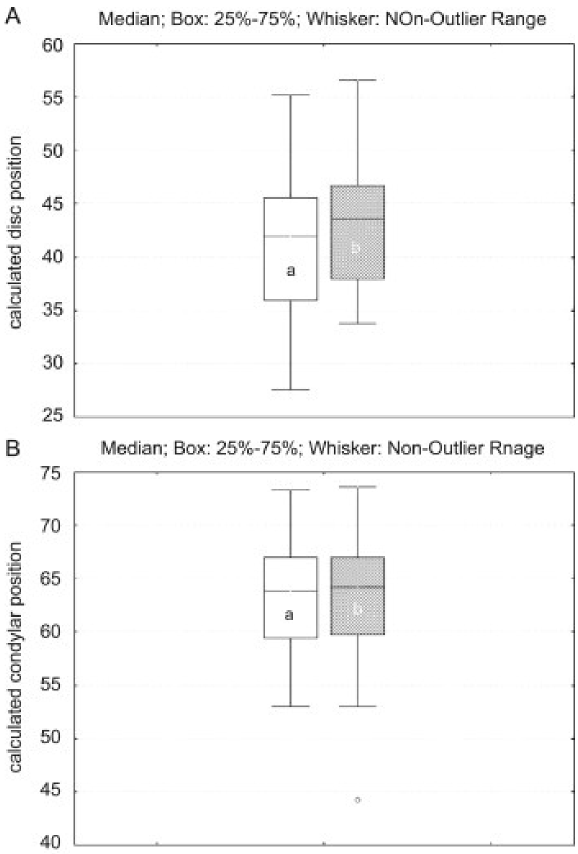

Figure 5. Box-plot comparison of the calculated disc (A) and condyles (B) position (y-axis, expressed in one-hundredths between points T and P) for TMJs (x-axis) with a DD with reduction prior to treatment (a), and with the splint applied (b).

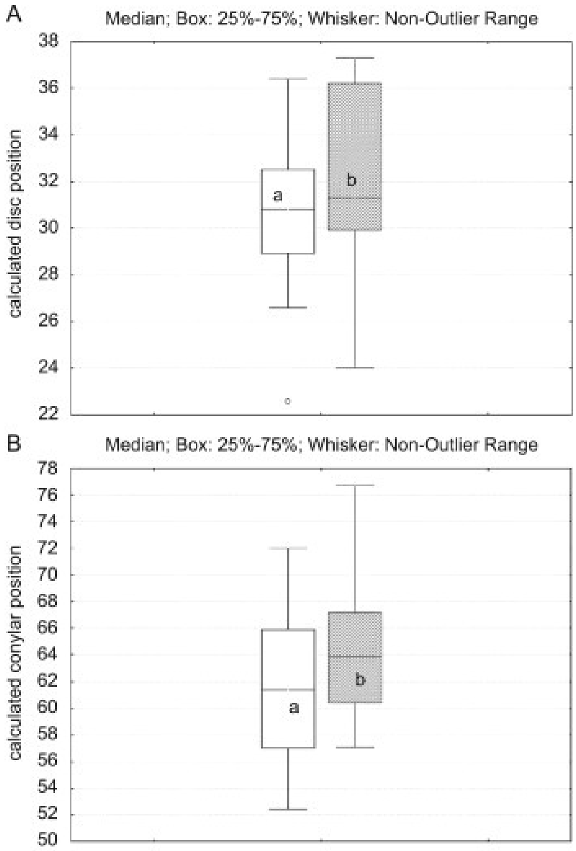

Figure 6. Comparison of the calculated disc (A) and condyles (B) position (y-axis, expressed in one-hundredths between points T and P) for TMJs (x-axis) with a DD without reduction prior to treatment (a), and with the splint applied (b).