# A novel neuromotor reprogramming treatment modality for temporomandibular disorders: a pilot retrospective observational study

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Case report

# Abstract

## Background

The purpose of this investigation was to determine if neuromotor programming using the ALLYANE® process would significantly improve mouth-opening capacity in patients suffering from temporomandibular disorders (TMD).

## Methods

A total of 21 adult patients (20 females and 1 male; mean age = 44 years) who underwent a rehabilitation session with neuromotor reprogramming were included. Maximal mouth opening (MMO) was measured before and just after neuromotor reprogramming session.

## Results

The results showed a statistically significant ($p < 0.001$) mean gain of 4.95 mm (+ 13%) after neuromotor reprogramming. Furthermore, this preliminary study showed that the gain registered in patients with a lower-than-normal mouth opening and improvement of lateral movements were greater than the one obtained with the other patients.

## Conclusions

Although these preliminary results need confirmation, the study suggests that the use of neuromotor reprogramming in patients suffering from TMD could present new possibilities for enhanced outcomes, in particular to relax the stomatognathic system with a noninvasive, reversible therapy without known side effects, providing open new perspectives in the area of joint diseases.

## Background

Temporomandibular disorders (TMD) is a collective term that embraces a variety of temporomandibular joint (TMJ) disorders, masticatory muscle disorders, headache disorders, and disorders affecting the associated structures (Peck et al., 2014; Schiffman et al., 2014). Its common features are regional pain in the face and preauricular area, limitations in jaw movements, and noises from the TMJs during jaw movements. The prevalence of temporomandibular disorders ranges from 20–50% (Lee et al., 2013; Vojdani et al., 2012). In studies where there was a clear age pattern, the age range where TMJs was more prevalent was between 35 and 45 years (Nadershah, 2019). The variability in prevalence may be attributed to differences in the race of the population, and in the sampling design and criteria. Patient populations are characterized by relevant psychosocial impairment, which is often unrelated to the physical diagnosis. Majority of pain reported by patients is located in masticatory muscles and/or pre-

auricular region, this can be easily exacerbated by chewing or other jaw activity (Baig et al., 2019). Other symptoms include, but are not limited to joint noises, jaw movement asymmetry, commonly described as clicking, popping, grating, or crepitus (Bitiniene et al., 2018), painless masticatory muscles hypertrophy, and muscle fatigue (Baig et al., 2019). Associated to these symptoms, there is a wide variety of consequences including headache, bruxism, tenderness upon palpation and difficulty opening the mouth due to limited range of movement (Bitiniene et al., 2018).

TMD can have a wide variety of causes, among which, most common are parafunctional habits, occlusal disharmony, stress, anxiety, trauma and microtrauma, mandibular instability, postural imbalance, and abnormal physiological conditions (Mortimer-Jones et al., 2018). Macrotrauma may occur following injuries or after prolonged mouth opening, such as during dental treatment or intubation (Ohrbach et al., 2013). Microtrauma may occur after parafunctional habits such as bruxism (tooth clenching and/or grinding), bracing the jaw, tongue thrusting, fingernail biting, or pencil/pen chewing (Lobbezoo et al., 2013). Orthodontic treatment alters occlusion, which suggested considering it a risk factor for developing TMD. The most commonly reported comorbid painful conditions in persons with TMD-pain are headache, neck pain, and back pain (Dominick et al., 2012). Individuals with TMD-related pain show higher levels of stress, anxiety, depression, somatic awareness, pain catastrophizing, and kinesiophobia compared to controls (Carlson et al., 1993). Studies have also demonstrated that psychological comorbidities contribute to the persistence of TMD-pain, regardless of the presence of painful comorbidities (Velly et al., 2010, 2011).

Management of orofacial pain and TMD is customized for a multifaceted and initially conservative working diagnosis using the skill sets of both conventional and alternative disciplines. These include acupuncture, internal medicine, naturopathy, neurology, osteopathy, physical and massage therapy, psychology, rheumatology, and traditional Chinese medicine (Armijo-Olivo et al., 2016; Greene and Obrez, 2015).

The aim of the present retrospective non-comparative observational study of patients suffering from a deficit of oral opening and clenching of teeth (bruxism) was to show that an action through neuromotor reprogramming using the ALLYANE® process can help to improve the mouth opening by relaxing the manducatory muscles by giving them back the notion of physiological tone.

# Methods

# Study design

This was a retrospective observational cohort study performed in a dental office and in a physiotherapy and osteopathic practice. The retrospective study was initiated by the investigators and self-coordinated. Investigators from the dental office and from the physiotherapy and osteopathic practice designed the study, collected, and managed the data, and a PhD student from Lyon I University performed the statistical analyses.

# Participants

Participant recruitment was carried out on patients treated first at the dental office in Lyon (France) and then oriented at the physiotherapy and osteopathic practice in Lyon (France) for a joint care over a period of 10 months (from September 2019 through June 2020).

A total of 21 adult clinical cases (≥ 18 years of age) presenting mouth opening restriction with X-rays of normal temporomandibular joints resulting from trauma (chin shock or tooth extraction) or clenching due to stress were included. Exclusion criteria were patients with cophosis (total deafness), patients with major mechanical injury, and those with severely impaired cognitive or psychiatric abilities (inability to understand and/or communicate).

# Treatment / Interventions

The Alphabox® is medical device (Fig. 1), which is part of the ALLYANE method. The human hearing frequency range of a healthy young person is about 20 to 20 000 Hz. This device is a generator which emits specific low frequency sounds from 50 to 400 Hertz (Hz) through headphones (LFS: low frequency sounds). These sounds are emitted with different sequences and modes during the rehabilitation period. Alphabox® allows to emit two types of sounds: pulsed sounds and associated sounds (Byrne, 2017).

According to the ALLYANE® process, the session took place in a treatment room including the Alphabox®, a massage table, video analysis and specific software (Visible Body©). These tools allow the patient to become aware of his motor pattern as well as the visualization of the patient's progress by the investigator during the sessions.

MMO was defined as the maximal interincisal distance on unassisted active mouth opening. Measurement of maximal mouth opening capacity reflects mandibular range of motion. It is simple but important clinical parameter for follow-up and outcome of diverse affections of the stomatognathic system. MMO was measured using a TheraBite® Range of Motion Scale (Atos, Sweden) (Fig. 2). Each participant's mouth opening was measured before and immediately after intervention. The participants were positioned supine on a flat therapy table in an examination room. The investigator instructed the participants to slowly and comfortably open their mouths as wide as possible. The TheraBite® Range of Motion Scale was passively placed between the edges of upper and lower central incisors. The measurement was read and recorded to the nearest millimeter (Fig. 3). Measurements of right and left lateral deviation were also included. The results were entered into an Excel datasheet.
Results were divided into three groups:

- All the 21 tested patients.
- Group with "limitation of mouth opening": number of millimeters measured from the incisal edge of the upper anterior teeth to the incisal edge of the lower anterior teeth with the TeraBite ruler (opening limitation < 40mm).

- Group without "limitation of mouth opening": number of millimeters measured from the incisal edge of the upper anterior teeth to the incisal edge of the lower anterior teeth with the TeraBite ruler (opening limitation > 40mm).

Participants underwent a rehabilitation session with neuromotor reprogramming. At the beginning of the session, we track the patient's medical and complaint history (anamnesis). Then we took videos (iPad AIR© and iPad PRO©) of all patients to follow their evolution but more important to allow the patient to be conscious of his/her mouth opening. At this stage, MMO and lateral deviations were measured.

Visible Body© application (Muscle Premium 2018) is a detailed guide to understanding how muscles and bones interact. Thanks to this application and the explanations provided by the practitioner, the patient can visualize the anatomical position of the masticatory muscles responsible for the clenching of the teeth which, through their contractions, prevent the proper development of the mouth opening (masseters, temporal, medial and lateral pterygoid muscles).

Neuromotor reprogramming used with the ALLYANE process is a tripod-based method including proprioception, mental imaging, and low frequency sounds (Fig. 4).

*Proprioception*, also referred to as our 6th sense, is today the subject of many scientific studies in the field of rehabilitation (Jahn and Krewer, 2020; Roll, 2003; Smith, 2011). Dependent on mechano-receptors located at the level of muscles, tendons, joints, ligaments, and support tissues, it is directly involved in the apprehension of the position of our body in space, our movements (coordination, movements), and balance. During the neuromotor reprogramming, the patient has to be conscious of his environment and his movement based on somatosensory information.

In a stable environment, healthy people rely approximately 70% on somatosensory information (proprioception), 10% on vision and 20% on vestibular information (Le Goïc et al. 2013). The masticatory system (orofacial sensory receptors, bones, masticatory muscles, temporomandibular joints) also plays a role in postural control (Tardieu et al., 2009).

*Motor imagery (MI) is* "the mental representation of an action without executing it physically. It stimulates the brain's motor networks and promotes motor learning after a spinal cord injury" (Di Rienzo et al., 2015). MI is known to engage overlapping cerebral substrates with physical practice of the same action (functional equivalence principle). MI shares many similarities with the actual execution of movements with regard to the processes that take place in the central nervous system. For instance, it leads to similar activations of brain regions as planning, preparation and execution of movements (Decety and Boisson, 1990; Grafton et al., 1996; Mellet et al., 1998). To imagine a movement is to stimulate a large part of the areas that allow the gesture (Jeannerod, 2001; Jeannerod and Frak, 1999). For this reason, patient is asked to focus his attention on visual and kinesthetic motor imagery for a few minutes during neuromotor reprogramming.

*Relaxation with low frequency sounds.* This stage consists in a general relaxation protocol performed after installing the Alphabox® with a duration between 3 and 10 minutes. From this step, the pulsed sounds emitted by the Alphabox® aims at placing the patient in a state of hypo-vigilance allowing sensory isolation from external stimuli.

Outcome parameters

Personal and anthropometric data were evaluated at baseline (before treatment). The outcome parameters described hereafter were evaluated at baseline (before treatment) and after treatment neuromotor reprogramming: TMD parameters (maximum mouth opening and deduction movements (right and left)).

Data handling and data analysis

All data were confidentially secured by storing it on a password-protected computer attainable only by the principal investigators. All individual details were replaced with ID codes. At the end of the data collection, all data were transferred securely to a server and stored without any time limitation.

Statistical analysis

Statistical analysis was carried out using R Statistical Software (version 3.6.3; R Foundation for Statistical Computing, Vienna, Austria). The level of significance was set at $p < 0.05$ for all statistical tests. Descriptive statistical methods were used for calculating the means and standard deviation of the means. Paired t-tests on the differences of scores obtained before and after sessions were used to compare the pre- and post- neuromotor reprogramming results. The Cohen's d effect size was used to study the effect size.

# Results

# Patients' characteristics

Patients were more frequently female (20/21), with a median age of 44 (30−73) years. All patients underwent physical examination and specialized functional examination of the masticatory system. Approximately half of the patients were admitted due to TMD (9/21). The other pathologies were fibromyalgia (3/21), bruxism (3/21), muscular tension on the right TMJ (2/21), oromandibular dystonia (1/21), blocking of the left TMJ (1/21), tension in the musculus masseter (1/21), and referred pain (1/21).

### Mouth opening capacity and lateral movements.

The mean MMO range was 38,71 mm [25,0; 45,0] at baseline and 43.67 [35.0; 53.0] after treatment. A mean gain of 4.95 mm (+ 13%) was registered after neuromotor reprogramming with a maximal gain of 13 mm (+ 52%). The results of the paired t test showed MMO range were significantly different between before and after session, associated with "large" effects sizes (t = -7.16; p < 0.001; d = 1.56).

Furthermore, no amelioration was observed in one patient with muscular tension on the right TMJ. Table 1 summarizes the measurements of MMO in all 21 subjects at baseline and after neuromotor

reprogramming.

Table 1
Summary of measurements of maximum mouth opening at baseline and after neuromotor reprogramming.

|  | MMO in mm Before session | MMO in mm After session | MMO improvement in mm |
|---|---|---|---|
| Mean ± SD | 38.71 ± 4.99 | 43.67 ± 4.38 | 4.95 ± 3.09 |
| Minimum | 25.00 | 35.00 | 0.00 |
| Maximum | 45.00 | 53.00 | 13.00 |
| *All measurements in millimeters (mm). SD; standard deviation.* | | | |

The left and right lateral movements were measured in 20 patients. For the left side, the mean was significantly different (t = − 5.59; p < 0.0001) before the session (7.40 mm [4.0; 11.0]) and after the session (10.45 mm [5.0; 15.0]), corresponding to an increase of 3.05 mm (+ 41%).

On the right side, the movement was significantly similar to the one on the left side with a mean of 7.45 mm [3.0; 15.0] before the session and 10.30 mm [6.0; 15.0] after the session (t = − 6.43; p < 0.001), *i.e.* an increase of 2.85 mm (+ 38%). Nevertheless, 3 patients out of 20 (15%) did not experienced any improvement on both sides and 1 patient did not experienced any improvement on the left side. The maximum enhancement was 180% with a gain of 9 mm on the left side and the 200% with a gain of 6 mm on the right side. Table 2 summarizes the measurements of lateral movements (left and right) in 20 subjects at baseline and after neuromotor reprogramming.

Table 2
Summary of measurements of lateral movements (left and right) at baseline and after neuromotor reprogramming.

|  | Left side in mm Before session | Left side in mm After session | Improvement in mm | Right side in mm Before session | Right side in mm After session | Improvement in mm |
|---|---|---|---|---|---|---|
| Mean ± SD | 7.40 ± 2.89 | 10.45 ± 3.53 | 3.05 ± 2.38 | 7.45 ± 3.50 | 10.30 ± 3.11 | 2.85 ± 1.93 |
| Minimum | 4.00 | 5.00 | 0.00 | 3.00 | 6.00 | 0.00 |
| Maximum | 11.00 | 15.00 | 9.00 | 15.00 | 15.00 | 6.00 |
| *All measurements in millimeters (mm). Measures were not performed in Patient 18 because of a poor understanding of the instructions. SD; standard deviation.* | | | | | | |

The same analysis was performed on the sub-group of patients with an abnormal mouth-opening at baseline (MMO lower than 40 mm). In our study, we had 8 participants with mouth-opening

measurements < 40 mm before treatment. All patients improved, with gains ranging from 2 mm (+ 6%) to 13 mm (+ 52%). The mean improvement was 6 mm (+ 18%) with an average MMO of 33.38 mm [25.0; 38.0] before treatment and 39.38 mm [35.0; 43.0] after the session with neuromotor reprogramming. The gain in mouth-opening measured in these patients with a lower-than-normal opening was greater than that obtained in the other 13 patients, which was 4.31 mm (+ 10%) (Fig. 5). The same difference was observed for the improvement of lateral movements. Table 3 and Fig. 5 summarize the measurements of MMO in sub-groups of subjects (MMO < 40 mm or group INF and MMO > 40 mm or group SUP) at baseline and after neuromotor reprogramming.

Table 3
Summary of measurements of MMO at baseline and after neuromotor reprogramming.

| Subject group | MMO in mm Before session | MMO in mm After session | Improvement in mm |
|---|---|---|---|
| MMO < 40 mm | 33.38 ± 3.81 | 39.38 ± 2.45 | 6.00 ± 3.54 |
| Mean ± SD | 25.00 | 35.00 | 2.00 |
| Minimum | 38.00 | 43.00 | 13.00 |
| Maximum | | | |
| MMO > 40 mm | 42.00 ± 1.71 | 46.31 ± 3.00 | 4.31 ± 2.58 |
| Mean ± SD | 40.00 | 42.00 | 0.00 |
| Minimum | 45.00 | 53.00 | 9.00 |
| Maximum | | | |
| All subjects | 38.71 ± 4.99 | 43.67 ± 4.38 | 4.95 ± 3.09 |
| Mean ± SD | 25.00 | 35.00 | 0.00 |
| Minimum | 45.00 | 53.00 | 13.00 |
| Maximum | | | |
| All measurements in millimeters (mm). SD; standard deviation. | | | |

# Discussion

The present study was retrospectively undertaken to obtain initial useful information about the short-term clinical effects of neuromotor reprogramming. Since limitations in jaw movements is one of the most pressing problem facing people with TMD, a significant improvement in 52% of mouth opening capacity indicates the potential of the proposed non-invasive treatment. We also report on enhanced global efficacy of this treatment on laterally range of motion (deduction left and right) although results need to be interpreted with caution owing to the small number of patients.

It is now well established that temporomandibular joint has neurological impact, it follows that TMD plays a role in developing a distorted pattern of neural organization (Yin et al., 2007). Treatment usually relies on physical therapy showed mixed results regarding long-term biomechanical effects after one session and their clinical effectiveness in relieving pain (Martins et al., 2016), suggesting that inconsistencies could be due to the interaction between biomechanical and neurophysiological mechanisms. Additionally, patients with TMD seem to be associated with increased activity in brain areas involved in emotional processing (Weissman-Fogel et al., 2011), suggesting that individuals with this pathology may be more sensitive to music. Among the different technics that can be used for TMD, Imbriglio et al. recently demonstrated if adequate music is selected, passive music listening might have positive effects in TMD (Imbriglio et al., 2020). Interestingly, there is evidence of a link between auditory and motor systems in the brain (Chen et al., 2008). While major of studies investigated TMD treatment pointing biomechanical effect, these findings showed the importance to include other technic implying passive listening to sounds to have the possibility to act on neurological influences. Furthermore, there is growing evidence advocating the efficacy of using motor imagery during rehabilitation (clinical trial in process), not excluding the association between motor imagery and listening to sounds considering TMD involves a multidisciplinary management (Cabinet de Kinesitherapie SCM Saint-Alexandre, 2020).

Although the interventions in this pilot were a single session of mobilization with very short-term follow-up, certain criteria are in accordance with other studies. For example, epidemiological data indicate that TMDs are most prevalent in the age group of 17–45 years old, which is coherent with the age of the subjects in the study ranging from 30 to 73 years. What is more, in the present study, a female predilection was noted with 20/21 females (i.e., 95% of the patients studied). This is in accordance with most of the studies which have reported that the incidence of TMDs is up to four times more frequent in women, and they tend to seek treatment for their TMJ problems three times more often than males (Gamsa, 1990).

There are some limitations to our retrospective study that merit discussion. First, the incompleteness of data entered in the patients' records and the assessment of mouth opening based on one measure before and after the neuromotor reprogramming session. More accurate measurements could have included the assessment of mouth opening level before and after each session. Second, inclusion criteria were considerably heterogeneous, and conclusions could not be made to a specific diagnostic of TMD; a randomized controlled pilot trial is imperative. In addition to confirm these results, further studies are needed to examine long-term effects of this neuromotor reprogramming session.

## Conclusion

This preliminary study suggests that the use of neuromotor reprogramming in patients suffering from TMD could present new possibilities for enhanced outcomes, in particular to relax the stomatognathic system with a noninvasive, reversible therapy without known side effects. Although these preliminary results need confirmation in a randomized clinical trial, our study should supply the basis for scientific

arguments for the use of the non-invasive neuromotor reprogramming in patients suffering from TMD, providing open new perspectives in the area of joint diseases.

# Abbreviations

LFS: low frequency sounds

MI: motor imagery

MMO: maximal mouth opening

TMD: temporomandibular disorders

TMJ: temporomandibular joint

# Declarations

### Author's contributions

All authors read and approved the final manuscript.

### Author's information

Not applicable.

### Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

### Ethics approval and consent to participate

Not applicable.

### Consent for publication

Not applicable.

## Competing interests

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# Figures

**Figure 1**

The Alphabox®. Legend: The Alphabox® is a generator specially designed and patented by the creators of the ALLYANE process which provides LFS through headphones.
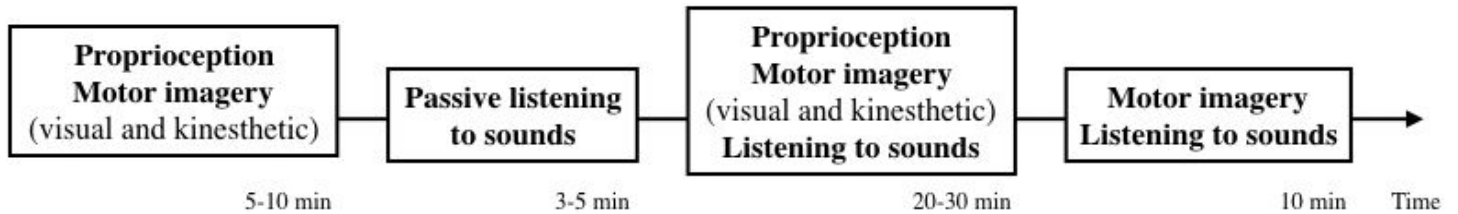


**Figure 2**

The TheraBite® Range of Motion Legend: The TheraBite® Range of Motion are disposable paper measuring scales, specifically designed to allow patients and providers to measure the opening, movement and function of the mouth and jaw.
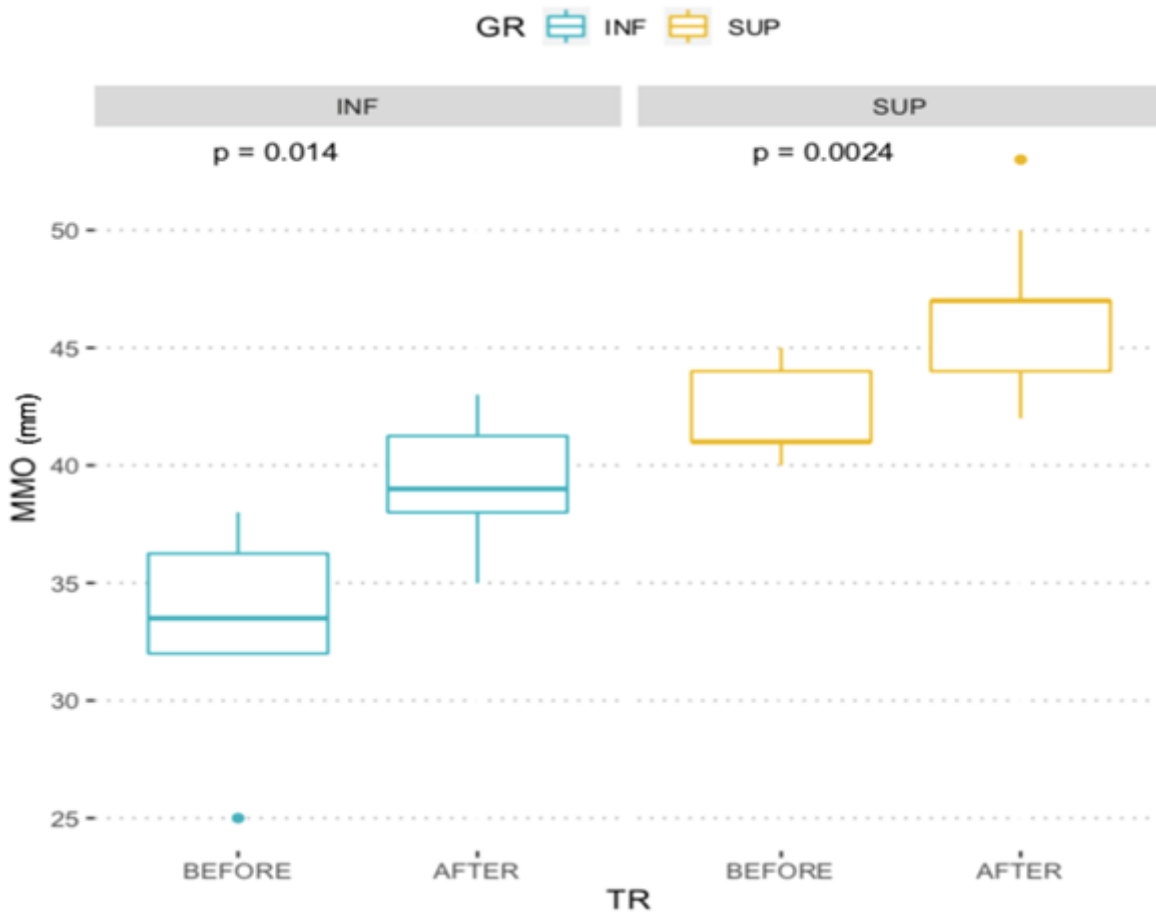
# Figure 3

Measurement of mouth opening using a range of motion ruler. Legend: When measuring mouth opening, the notch at the lower left portion of the scale is stabilized on the superior aspect of the lower incisors. Once stabilized, the instrument is rotated up toward the inferior aspect of upper incisors until contact is made between the scale and the upper incisors. The instrument's scale is then read, and the opening range obtained.



# Figure 4

Description of the neuromotor reprogramming.



# Figure 5

Box plots showing 1.5 times the interquartile distance. Legend : The horizontal line in the middle of each box indicates the median, and the points beyond the whiskers are outliers. The box plots of both indexes showed significant difference between INF group (MMO lower than 40 mm) and SUP group (MMO greater than 40 mm) before and after neuromotor reprogramming treatment (TR).