Electromyographic indices, orofacial myofunctional status and temporomandibular disorders severity: A correlation study

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Abstract

This study examined whether there is an association between surface electromyography (EMG) of masticatory muscles, orofacial myofunction status and temporomandibular disorder (TMD) severity scores. Forty-two women with TMD (mean 30 years, SD 8) and 18 healthy women (mean 26 years, SD 6) were examined. According to the Research Diagnostic Criteria for TMD (RDC/TMD), all patients had myogenous disorders plus disk displacements with reduction. Surface EMG of masseter and temporal muscles was performed during maximum teeth clenching either on cotton rolls or in intercuspal position. Standardized EMG indices were obtained. Validated protocols were used to determine the perception severity of TMD and to assess orofacial myofunctional status.

TMD patients showed more asymmetry between right and left muscle pairs, and more unbalanced contractile activities of contralateral masseter and temporal muscles (p < 0.05, t-test), worse orofacial myofunction status and higher TMD severity scores (p < 0.05, Mann–Whitney test) than healthy subjects. Spearman coefficient revealed significant correlations between EMG indices, orofacial myofunctional status and TMD severity (p < 0.05).

In conclusion, these methods will provide useful information for TMD diagnosis and future therapeutic planning.

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1. Introduction

The stomatognathic system performs many physiologic functions, such as mastication, speech, suction, deglutition, which generate mechanical forces that are dissipated by the skeletal tissues associated with the temporomandibular joint (TMJs) (Hinton and Carlsson, 1997). In all these functions, coordinated by the central nervous system and under the influence of peripheral inputs, there are mandibular motor requests and, at the same time, movements of the tongue, hyoid, soft palate, lips and other structures, involving several muscle groups (Douglas et al., 2010).

A relatively common problem of the stomatognathic system is the temporomandibular disorder (TMD); approximately 7–15% of the adult population is affected, with higher prevalence in women at reproductive ages. TMD is usually defined as a collective term embracing several clinical problems that involve the masticatory muscles, the TMJ and the associated structures. The most frequent complaints reported by subjects with TMD are pain in the TMJ and/or masticatory muscles, TMJ sound and difficulty to chew (Cooper and Kleinberg, 2007; Kurita et al., 2001; Lim et al., 2010; Michelotti and Iodice, 2010).

Due to the multiplicity of factors that may cause or contribute to TMD manifestation or worsening, multiple treatments have been employed, although the pathophysiology is not fully understood and the mechanisms of action of the treatments may be not clear (Cairns et al., 2010; Michelotti and Iodice, 2010).

The classic dental and skeletal etiologic theories of TMD have been challenged and refuted by studies conducted around the world (Klasser and Greene, 2009), and the relationship between malocclusion and TMJ is still far from being clearly understood (Michelotti and Iodice, 2010). The new approaches show a less restrictive understanding of TMD, and there is great interest in the relationship between oral motor function and TMD (Ardizone et al., 2010; Douglas et al., 2010; Koutris et al., 2009; Lobbezoo et al., 2006; Peck et al., 2008).
In normal conditions, the stomatognathic system shows neuro-muscular harmony. Harmony may be disrupted, and alterations/ dysfunctions of the appearance, posture and/or mobility of the lips, tongue, mandible and cheeks may occur. A collective label for these alterations is orofacial myofunctional disorders (OMDs) (Felício and Ferreira, 2008).

OMDs may disequilibrate TMJ function (Gelb and Bernstein, 1983), or may be a consequence of TMD since the nociceptive stimuli may generate compensatory muscle behaviors (Bianchini et al., 2008; Casanova-Rosado et al., 2006). For instance, pain may influence the characteristics of masticatory sensory–motor system (Kouris et al., 2009), and TMJ pain, especially when long-standing, is associated with marked functional impairment (Bakke and Hansdottir, 2008).

So, together with pain relief, the goals of TMD treatments should include function improvement (Michelotti and Iodice, 2010), reestablishing the possibility to chew (Kurita et al., 2001), swallow, and speak without pain and without exacerbating the problem (Felicio et al., 2010). Otherwise, deterioration can progress into a self-perpetuating chronic condition with increasing dysfunction and pain (Cooper and Kleinberg, 2007). Nevertheless, there is a scarcity of studies about the relationship between TMD and OMD. For this purpose, clinical and instrumental examinations should allow to discriminate subjects with and without TMD, but also to provide data about the orofacial myofunctional status and neuro-muscular impairments that influence the global quality of life. A better therapeutic intervention may thus be planned. Therefore, the detection of relationships between the various diagnostic tools is one of the fundamental steps for the assessment of their validity and clinical performance.

Accordingly, we selected three assessment protocols for the present study:

1. Surface electromyography (sEMG), according to Ferrario et al. (2000).
2. ProTMDmulti-Part II, a questionnaire validated to determine the perception severity of TMD (Felício et al., 2009).
3. Orofacial Myofunctional Evaluation with Scores Protocol (OMES Protocol) that provides information about the components and functions of the stomatognathic system (Felício and Ferreira, 2008; Felício et al., 2010).

The purposes of this study were to assess the characteristics of the stomatognathic system in a group of patients with TMD as compared to those of normal subjects, and to examine the relationship between the data obtained by sEMG of masticatory muscle, those gained by orofacial myofunction assessment, and the TMD severity scores, for future clinical use.

2. Materials and methods

2.1. Subjects and clinical examination

Forty-two women with TMD (TMD group, mean 30 years, SD 8) and 18 women without signs or symptoms of TMD (C group, mean 26 years, SD 6) participated in the study. All participants were Brazilian women. The project was approved by the Human Research Ethics Committee of the Institution and all subjects gave written informed consent to participate.

TMD subjects were consecutive patients for orofacial pain and TMD treatment on the Faculties of Medicine and Dentistry of Ribeirão Preto, University of São Paulo, whose duration of TMD ranged from 6 to 108 months (long lasting TMD), and the C group were students and community volunteers invited to participate in the study.

The inclusion criterion for TMD group was to present TMD, muscle diagnosis (group Ia or Ib) plus disk displacements with reduction (group Ila), according to the Research Diagnostic Criteria for TMD, axis I (RDC/TMD (Dworkin and LeResche, 1992)). All the TMD patients had a permanent dentition, with at least one molar maxillary–mandibular contact per dental hemiarch, and without dental pain or parodental problems.

The inclusion criteria for C group were to present full natural permanent dentition (28 teeth at least), Angle Class I, overbite and overjet between 2 and 4 mm, absence of periodontal problems no TMD based on the RDC/TMD.

The exclusion criteria, for both groups, were: neurological or cognitive deficit, previous or current tumors or traumas in the head and neck region, current or previous orthodontic, orofacial myofunctional or TMD treatment, current use of analgesic, anti-inflammatory and psychiatric drugs.

During data collection, each assessment/examination was performed by independent examiners, blinded to the outcome of the other ones. In all, four examiners participated.

Subjects were examined while sitting on a dental chair in a room with appropriate lighting.

2.2. Electromyographic (EMG) recordings and measurements

sEMG recordings and analyses were performed according to Ferrario et al. (2000) and Tartaglia et al. (2011). Briefly, the masseter and anterior temporal muscles of both sides (left and right) were examined. Disposable silver/silver chloride bipolar surface electrodes (diameter 10 mm, interelectrode distance 21 ± 1 mm; Duo-Trode; Myo-Tronics Inc., Settle, WA, USA) were positioned on the muscular bellies parallel to muscular fibers. A disposable reference electrode was applied to the forehead. The electrodes were located according to the recommendations of SENIAM [Surface EMG for Non-Invasive Assessment of Muscles (Hermens et al., 2000)].

EMG activity was recorded using a computerized instrument (Freely, De Götzien srl; Legnano, Milano, Italy). The analog EMG signal was amplified and digitized (gain 150, peak-to-peak input range 28 mV, that is ±14 mV, 12 b resolution, 2220 Hz A/D sampling frequency, theoretical resolution 16 μV) using a differential amplifier with a high common mode rejection ratio (CMRR = 105 dB in the range 0–60 Hz, input impedance 10 GΩ), and filtered (analogue filtering: lowpass filter with a bandwidth in the frequency range 0–580 Hz; digital filtering: range 30–400 Hz; band-stop for common 50 Hz interference with a notch filter, approximate range 47–53 Hz). The signals were recorded for further analysis. Very low frequency (<10 Hz) artefacts were limited by the use of the reference electrode (forehead). Previous bench assessments found that the peak-to-peak input range measured by the instrument was larger than the offset values obtained by the surface electrodes positioned according to the current protocol. The signals were averaged over 25 ms, with muscle activity assessed as the root mean square (RMS) of the amplitude (unit: μV). EMG signals were recorded for further analysis.

In all subjects, sEMG of the right and left masseter and anterior temporal muscles was performed during maximum voluntary teeth clenching (MVC) (Sforza et al., 2010; Tartaglia et al., 2011). All subjects underwent two sets of tests: a standardization recording (clench on cotton rolls) and a test recording (clench in intercuspal position) (Ferrario et al., 2000).

To standardize the EMG potentials of the analyzed muscles with tooth contact, two 10-mm thick cotton rolls were positioned on the mandibular second premolars/first molars of each subject, and a 5-s MVC was recorded.

sEMG activity was then recorded during a MVC in intercuspal position. For both recordings, the subject was invited to clench as
hard as possible, and to maintain the same level of contraction for 5 s; during tests performance, the subjects were verbally encouraged to perform at their best. All subjects repeated the MVC test twice. The tests were explained and shown to the subjects, who practiced before actual data acquisition.

For all tests, the subjects sat with their head unsupported and were asked to maintain a natural erect position. To avoid any fatigue's effect, a rest period of at least 3 min was allowed between each test.

For all tests, the 3-s period with the most constant RMS EMG signal was automatically selected by the software and used for all subsequent analysis, that were automatically performed by the computer software (Tartaglia et al., 2011).

For each subject, the EMG potentials recorded during the MVC tests were expressed as percent of the mean potential recorded during the MVC on the cotton rolls (unit: μV/μV × 100). All following calculations were made with the standardized potentials.

Subsequently, several EMG indices were computed: POCTemporal, POC Masseter, Torque Coefficient and total standardized activity (Ferrario et al., 2000). To assess muscle symmetry, within each subject the EMG waves of left and right masseter and temporal anterior muscles were compared by computing a percentage overlapping coefficient (POC, unit: %). POC is an index of the symmetric distribution of muscular activity; it ranges between 0% (no symmetry) and 100% (perfect symmetry).

To assess potential lateral displacing components given by unbalanced contractile activities of contralateral masseter and temporal muscles, the Torque Coefficient (unit: %) was assessed. TC ranges between 0% (absence of lateral displacing force) and 100% (maximum lateral displacing force).

The mean (masseter and temporal) total standardized muscle activity (unit: μV/μV/s %), was computed as the integrated area of the EMG potentials over time (Ferrario et al., 2000; Sforza et al., 2010; Tartaglia et al., 2008, 2011).

The test–retest recordings were made for a 76% subset of the sample; 25 subjects were assessed during the same session (C group = 3, TMD group = 22 subjects) and 13 subjects after a 3-month interval (C group). For the same session repeatability, new electrodes were repositioned on the analyzed muscles, and the subjects repeated the same measurement protocol.

2.3. Self-judgment of severity

The ProTMDmulti-part II questionnaire was used to determine the perception of severity of TMD signs and symptoms by the subjects. They were asked to indicate the severity of nine signs and symptoms according to the situation, i.e., when waking up, during mastication, when speaking, and at rest. Severity was indicated on a printed 11 point numerical scale where zero corresponded to the complete absence of the symptom, and 10 corresponded to the highest possible severity. The severity score was the sum of the scores attributed to each sign and symptom in the four questioned situations (range 0–40). The total severity score varies between zero (absence) and 360 (the highest possible severity). The reliability and validity of this measure was demonstrated previously (Felício et al., 2009).

2.4. Orofacial myofunctional evaluation

The components of the stomatognathic system were evaluated in terms of appearance/posture, mobility and performance during the functions, according to the Orofacial Myofunctional Evaluation with Scores – OMES Protocol (Felício and Ferreira, 2008; Felício et al., 2010). Recently the OMES protocol was validated for young and adult subjects, among them patient with TMD, with both sensitivity and specificity of 0.80. The criterion validity was determined by concurrent validity with the Nordic Orofacial Test-Screening (NOT-S) (Bakke et al., 2007), and showed a good correlation (r = –0.86, p < 0.01). The OMES Protocol was applied by experienced speech pathologist, unfamiliar with the subjects, with 0.98 test–retest reliability, and 0.92 reliability between examiners.

2.5. Statistical analysis

Descriptive statistics were computed for the analyzed variables. The EMG indices reproducibility was calculated by Student’s t-test for paired samples, considering 76% of the sample. The Technical Error of Measurement (random error) was also calculated as \( \frac{\sum(D^2)}{2 \times N}^{0.5} \), where D is the difference between the two repeated measurements, and N is the number of subjects.

Categorical variables were analysed by non-parametric statistic, Mann–Whitney test, and continuous data by parametric statistic, Student t-tests for unpaired samples. The Spearman Correlations test was used to analyze the correlations between the data of the EMG, OMES and ProTMDmulti. Each EMG index was analyzed in relation to the scores of the categories of OMES (appearance/posture; mobility and functions) and to the total sum of the ProTMDmulti scores. The scores of the categories of OMES were analyzed in relation to the total sum of the ProTMDmulti scores. The calculations were made using the Statistica data analysis software. Significance was set at 5% (p < 0.05).

3. Results

3.1. Data reproducibility

There were no statistically significant differences between EMG indices obtained in test and retest values, assessed during the same session or after a 3-month interval (p > 0.05). For all indices, the test–retest random error was lower than or close to the intragroup standard deviation, showing the good reproducibility of the indices (Table 1).

3.2. Groups comparison

Significant inter-group differences were found for temporal muscle POC (p = 0.03) and masseter muscle POC (p = 0.01). The C group had a larger symmetry in their temporal and masseter muscles than the TMD group. Significantly larger unbalanced contractile activities of contralateral masseter and temporal muscles (TC) were observed in the TMD group than in the C group (p = 0.04). The total standardized muscle activity was larger in C group than TMD group, but the difference was not significant (p > 0.05) (Fig. 1). There were no age differences between control and TMD groups (p < 0.05).

Perception of the severity of all TMD signs and symptoms, according to ProTMDmulti – part II questionnaire, was significantly worse in TMD patients than in C subjects (Fig. 2, p < 0.05).

The C group showed mean values in orofacial myofunctional evaluation close to the maximum scores (normal) of the OMES protocol. There were significant differences between C and TMD groups in appearance/posture of jaw, tongue and facial symmetry; jaw mobility; deglutition and mastication (Table 2, p < 0.05).

3.3. Correlation analysis

sEMG indices and scores of OMES protocol (appearance/posture and functions), and total sum of the ProTMDmulti scores were significantly correlated (Table 3, p < 0.05, Spearman correlation). Overall, the larger the sEMG standardized symmetry (POC) and the total muscular activity, the larger the scores of the OMES.
Table 1
Comparison between EMG indices in test–retest exams.

<table>
<thead>
<tr>
<th></th>
<th>POC temporal %</th>
<th>POC Masseter %</th>
<th>TC %</th>
<th>Standardized activity μV/μVs %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Test</td>
<td>80.24</td>
<td>15.87</td>
<td>82.02</td>
<td>7.75</td>
</tr>
<tr>
<td>Retest (N = 25)</td>
<td>79.82</td>
<td>16.87</td>
<td>81.52</td>
<td>9.64</td>
</tr>
<tr>
<td>TEM</td>
<td>3.19</td>
<td></td>
<td>5.24</td>
<td></td>
</tr>
<tr>
<td>p (Paired sample)</td>
<td>0.65</td>
<td></td>
<td>0.74</td>
<td></td>
</tr>
<tr>
<td>Test (N = 13)</td>
<td>88.30</td>
<td>1.97</td>
<td>85.78</td>
<td>2.70</td>
</tr>
<tr>
<td>TEM</td>
<td>2.01</td>
<td>3.27</td>
<td>1.72</td>
<td>3.43</td>
</tr>
<tr>
<td>p (Paired sample)</td>
<td>0.40</td>
<td>0.84</td>
<td>0.54</td>
<td>0.50</td>
</tr>
</tbody>
</table>

POC: percentage overlapping coefficient (index of left–right muscular symmetry). TC: torque coefficient (potential lateral displacing component). TEM: Technical error of measurement. p: Probability of a Student’s t test. Significant values for p < 0.05.

Table 2
Descriptive statistics of the orofacial myofunctional evaluation in the control subjects and TMD patients.

<table>
<thead>
<tr>
<th>Appearance/posture</th>
<th>Maximum scores</th>
<th>Control N = 18</th>
<th>TMD N = 42</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Lips</td>
<td>3</td>
<td></td>
<td>2.56</td>
</tr>
<tr>
<td>Jaw</td>
<td>3</td>
<td></td>
<td>2.67</td>
</tr>
<tr>
<td>Checks</td>
<td>3</td>
<td></td>
<td>2.83</td>
</tr>
<tr>
<td>Facial symmetry</td>
<td>3</td>
<td></td>
<td>2.39</td>
</tr>
<tr>
<td>Tongue</td>
<td>3</td>
<td></td>
<td>2.67</td>
</tr>
<tr>
<td>Hard palate</td>
<td>3</td>
<td></td>
<td>2.61</td>
</tr>
<tr>
<td>Mobility</td>
<td>12</td>
<td></td>
<td>11.67</td>
</tr>
<tr>
<td>Tongue</td>
<td>18</td>
<td></td>
<td>14.83</td>
</tr>
<tr>
<td>Jaw</td>
<td>15</td>
<td></td>
<td>13.56</td>
</tr>
<tr>
<td>Checks</td>
<td>12</td>
<td></td>
<td>11.89</td>
</tr>
<tr>
<td>Functions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Breathing</td>
<td>3</td>
<td></td>
<td>2.89</td>
</tr>
<tr>
<td>Deglutition</td>
<td>15</td>
<td></td>
<td>14.44</td>
</tr>
<tr>
<td>Mastication</td>
<td>10</td>
<td></td>
<td>9.61</td>
</tr>
<tr>
<td>SUM</td>
<td>103</td>
<td></td>
<td>94.62</td>
</tr>
</tbody>
</table>

Probability of Mann–Whitney test for unpaired samples. Maximum scores (normal) of the OMES protocol.
* 0.05 Levels of significance.
** 0.01 Levels of significance.
*** 0.001 Levels of significance.

Despite criticism about the clinical use of EMG in the diagnosis and treatment of TMD (Klasser and Okeson, 2006; Suvinen and Kemppainen, 2007), the standardized EMG data have been reported to have good repeatability (Ferrario et al., 2000; Tartaglia et al., 2011; Teco et al., 2011), as confirmed by current results. Indeed, technological advances in signal detection and processing have improved the quality of the information extracted from the EMG and furthered our understanding of the anatomy and physiology of the stomatognathic apparatus (Castroflorio et al., 2008).

Current EMG mean values of the C group were in agreement with previous data (Botelho et al., 2010; Ferrario et al., 2000, 2007; Sforza et al., 2010; Tartaglia et al., 2008, 2011) and significantly differed from the TMD group (Ferrario et al., 2007). Additionally, the current TMD group showed more asymmetry between the standardized activity of muscle pairs (POC temporal and masseter) and larger unbalanced contractile activities of contralateral masseter and temporal muscles (TC) in comparison to Tartaglia et al. (2008, 2011), that did not include patients with myogenous plus arthrogenous TMD (group I plus group II), and Botelho et al. (2010), who did not specify TMD classification or duration. However, the lack of significant difference on total muscle activity was also observed in patients with long lasting arthrogenous TMD (Tartaglia et al., 2011).

4. Discussion

The assessment of patients in dentistry currently includes quantitative evaluations, like sEMG of masticatory muscles (Ardizone et al., 2010; Tartaglia et al., 2008).
In contrast to the C group, the TMD group reported TMD-related signs and symptoms, with significantly higher severity. The most severe signs/symptoms were muscular pain, TMJ pain, and TMJ noise, in accord with the literature (Cooper and Kleinberg, 2007; Felício et al., 2009, 2010; Lim et al., 2010).

Also, the C group had a better status of the components and functions of the stomatognathic system, and almost half of the scores were significantly higher than in the TMD group. Subjects with TMD frequently have OMD, among them, disorders of the oral phase of deglutition, and prevalence of unilateral mastication (Bianchini et al., 2008; Felício et al., 2010; Gelb and Bernstein, 1983; Kurita et al., 2001), which involves a greater risk of pain and more TMD signs and symptoms (Casanova-Rosado et al., 1983; Ardizone et al., 2006) and other functions.

The functional performance of the stomatognathic system is influenced by several variables, including dental occlusion, jaw elevator muscles contraction, lips and tongue (Bakke and Hansdottir, 2008; Kays et al., 2010). A healthy masticatory system, characterized by the absence of pain at rest and during functional movement of the mandible, is a prerequisite for chewing (Lobbezzo et al., 2006) and other functions.

Based on results, the relationship of the elevator muscles and components and functions of the stomatognathic system includes symmetry between right and left muscle pairs and balanced activities of contralateral masseter and temporal muscles. In addition, EMG, beside allowing differentiation among different diagnostic categories defined according to the RDC/TMD (Tartaglia et al., 2008), matches that established by TMD severity test (Ardizone et al., 2010).

The mobility category scores were correlated with ProTMDmulti, but not with EMG, presumably because the indices are obtained through static tasks involving jaw elevator muscles.

The results, taken together, reinforced that in cases of TMD, the change in muscle recruitment may be a compensatory mechanism for pain relief, or asymmetrical muscle recruitment may precede the muscle pain symptoms (Lobbezzo et al., 2006). The strategy of differential activation, which is influenced by the functional complexity of the sensory–motor system and by the multidimensional nature of pain (Peck et al., 2008), protects the injured muscle while simultaneously maintaining optimal function (Koutris et al., 2009).

In case of depletion or insufficiency of such adaptive capacity, the system will produce a failure in some point, which will be manifested as a sign or a symptom (Douglas et al., 2010). In addition, the chronic pain seems to limit movement duration, speed, and variability which could be protective in the short term but also counterproductive over time (Cote and Hoeger Bement, 2010). The sequence of factors and events may vary but, once the TMD sets in, the stomatognathic system is no longer able to withstand the functional loads without the occurrence of some discomfort, pain and/or compensation.

According to literature, in certain situations, an adequate muscular training may allow a better function, reducing pain and disability (Sforza et al., 2010). The orofacial myofunctional therapy has demonstrated positive effects on the reduction of symptoms and clinical signs of TMD, as well as improved swallowing and chewing functions (Felício et al., 2010).

Thus, it seems important to understand the link between pain-related injury and muscular status. Furthermore, studying coordination patterns under normal and pain circumstances may be possible to uncover ‘efficient’ versus ‘inefficient’ movement strategies, which knowledge can in turn be integrated into training and rehabilitation strategies (Cote and Hoeger Bement, 2010).

The EMG analyses, the self-judgment of severity of the TMD signs and symptoms and the orofacial myofunctional evaluation, allowed differentiating female control subjects and TMD patients, which ensures the construct validity of the instruments. Moreover, the EMG as a neuromuscular functional analysis appears to be able to deliver additional diagnostic and therapy-relevant information (Hugger et al., 2008), and the OMES provide data that could supplement clinical examination and support the intervention. Future studies should be designed to confirm these possibilities, using other outcome measures for comparison.

The principal limitation of the study is the number of analyzed control subjects. The inclusion criteria for control group led to the exclusion of many adults. Additionally, only women were examined: indeed, even if TMD is more frequent in women than in men (Lim et al., 2010; Bakke and Hansdottir, 2008), TMD male patients can be found.

5. Conclusion

The EMG, OMES and ProTMD protocols allowed discriminating TMD and health women. The results support the importance of clinical and instrumental examination of the stomatognathic system, as well as questionnaires with numerical scales combined for TMD diagnosis: all of them will provide useful information for diagnosis. Furthermore, understanding how evaluation methods are related is an important step toward diagnosis and future therapeutic planning.

Conflict of interest

The authors declare that they have no conflict of interest.

Sources of Support

Acknowledgments

This work was supported by Conselho Nacional de Pesquisa – CNPq, Process N. 300950/2007-1 and N. 470174/2008-0.

References


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