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MMP-7 and MMP-9 are overexpressed in the synovial tissue from severe temporomandibular joint dysfunction

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ABSTRACT

Matrix metalloproteinases (MMPs) are tissue-enzymes that play a key role during the remodeling process, such as in inflammatory diseases. MMP-7 and MMP-9 have been shown to be implicated in extracellular matrix homeostasis and in joint disc remodeling. The objective of this study was to determine the relation of MMP-7 and MMP-9 expression with severe temporomandibular joint dysfunction, in particular with anterior disk displacement without reduction (ADDwoR), using an immunohistochemical approach. Therefore, twenty human temporomandibular synovia in the test group and ten in the control group were collected. The results showed there was a statistically significant difference ($P < 0.001$) for morphometric and densitometric analysis of both detected MMPs in control and test groups. In conclusion, MMP-7 and MMP-9 were overexpressed in the synovial tissue of patients with ADDwoR.

Key words: MMP-7; MMP-9; TMJ synovial; TMJ dysfunction.

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Patient consent for publication: Not applicable.

Informed consent: Patients' informed consent had been obtained before tissue collection.

Introduction

Temporomandibular disorders (TMDs) define a number of clinical problems involving masticatory musculature, temporomandibular joint (TMJ), and associated structures. Many TMDs are characterized by similar symptoms described as pain in the joint, noisy interferences during mastication, and movement restrictions.¹

Several studies have investigated the changes in the composition of the articular TMJ disc for understanding the significance of the pathological process of internal derangement (ID) using immunohistochemical approaches.²⁻⁵

A growing body of evidence indicates that matrix metalloproteinases (MMPs) are associated with a family of zinc-dependent endopeptidases, responsible for extracellular matrix (ECM) protein degradation by cleavage of internal peptide bonds.^{6,7} They are involved in physiological tissue remodeling, but in some conditions the overexpression of MMPs result in tissue destruction.⁸

Indeed, the upregulation of some MMPs has been observed in the TMJ synovial fluid pathological conditions, resulting the primary enzymes involved in matrix turnover.⁹⁻¹⁴

Studies about TMJ disc analyzing the synovial fluid (SF) of patients with IDs have shown a relationship between MMPs overexpression and TMJ degeneration, indicating a possible marker for these pathologies.^{8-10,15-18} In particular, MMP-3 is involved in the pathological destruction process of TMJ osteoarthritis combined with disc displacement.¹⁶ High levels of MMP-1, MMP-8, and MMP-13, MMP-2 and MMP-9 have been reported in the TMJ-SF of patients with ID.^{8,17} Furthermore, MMP-3 and MMP-7 were correlated with bone apposition.¹⁸

MMP-7 and MMP-9 have been shown to play an important role in ECM homeostasis and in joint disc remodeling.¹⁵ An MMP-9 increase has been observed in the serum and SF of arthritic patients and it is considered a marker of arthritis and cartilage degradation in animal studies.¹⁰ MMP-9 was highly expressed in patients with anterior disk displacement without reduction (ADDwoR) and advanced osteoarthritis.¹⁹⁻²²

To date, to our best knowledge, no studies have evaluated the MMPs expression in the synovial tissue. It is reasonable to think that the presence of MMPs in the SF derives from the synovial tissue. Therefore, the aim of this study was to assess the expression of MMP-7 and MMP-9 in the synovial tissue of patients with a severe TMJ dysfunction.

Materials and Methods

Patients and tissues

Twenty paraffin blocks of displaced TMJ synovia specimens were retrieved from the archives of the Pontifical Catholic University of Paraná (Brazil).^{11,23,24} Their use had already been approved by the ethics committee of the Pontifical Catholic University of Paraná according to Resolution 196/96 of the National Health Council (registration number 104); similarly, the patients' informed consent had been obtained before tissue collection. The specimens had been removed from eleven females and nine males with ADDwoR diagnosed on the basis of history, clinical examination, and magnetic resonance imaging data. The diagnosis for disc excision was ID with pain and functional impairment.

The inclusion criteria were: i) unsuccessful conservative management; ii) tenderness to TMJ palpation; iii) TMJ pain or interference with jaw movement. The exclusion criteria were: i) other TMJ

diseases; ii) dento-facial deformity; iii) major jaw trauma; iv) previous TMJ surgery; v) prior TMJ treatment with steroid injections. The discs removed from the twenty patients were macroscopically deformed and none had preserved a normal biconcave shape.

Ten TMJ synovia specimens from the collection of Catania Human Anatomy Institute (Italy) were analyzed as controls. They were autopsy specimens from five male donors and five female donors which were selected for their virtually normal shape and condition, since none had macroscopic signs of degenerative or inflammatory joint disease on dissection, nor were they displaced; the donors' clinical histories were negative for generalized joint disease or TMJ arthropathy.

Histology

The TMJ synovia sections were rinsed in phosphate buffered saline (PBS; Sigma, Milan, Italy), fixed in 10% buffered formalin, as previously described.^{25,26} After an overnight wash, specimens were dehydrated in graded ethanol, cleared in xylene and paraffin-embedded, preserving their anatomical orientation. Sections (4-5 µm in thickness) were cut from paraffin blocks using a microtome, mounted on silane-coated slides (Dako, Glostrup, Denmark) and stored at room temperature. The sections were then stained with hematoxylin and eosin and observed using a Zeiss Axioplan light microscope (Carl Zeiss, Oberkochen, Germany) for general morphology. Finally, representative photomicrographs were captured using a Zeiss AxioCam MRc5 digital camera (Carl Zeiss).

Immunohistochemistry

Samples were fixed in 10% buffered formalin for 2 h; after an overnight wash, specimens were dehydrated in graded ethanol and paraffin-embedded. Sections (3-4 µm in thickness) were cut, mounted on silane-coated slides, and air-dried. For immunohistochemical analysis, specimens were processed as previously described.²⁷ Briefly, the slides were dewaxed in xylene, re-hydrated with graded ethanol, incubated for 30 min in 0.3% H₂O₂/methanol solution to quench endogenous peroxidase activity, and then rinsed for 20 min with PBS. Antigen retrieval was performed using a microwave oven (750 W) (5 min x 3) in capped polypropylene slide-holders with citrate buffer (10 mM citric acid, 0.05% Tween 20, pH 6.0; Bio-Optica, Milan, Italy). The sections were incubated overnight at 4°C with anti-MMP-7 or anti-MMP-9 monoclonal antibodies (sc-80205 and sc-13520 respectively, Santa Cruz Biotechnology, Inc., Dallas, TX, USA), both diluted 1:100 in PBS.¹⁵ Immune complexes were then treated with a biotinylated link antibody and then detected with peroxidase labeled streptavidin (LSAB+ System-HRP, K0690; Dako), both incubated for 10 min at room temperature. The immunoreaction was visualized by 3,3'-diaminobenzidine and 0.02% hydrogen peroxide solution (DAB substrate Chromogen System; Dako), as previously described.²⁷ The sections were lightly counterstained with Mayer's hematoxylin (Histolab Products AB, Göteborg, Sweden) mounted in GVA (Zymed Laboratories, San Francisco, CA, USA). The sections were observed and photographed as described above.

Evaluation of immunohistochemistry

The MMP-7 and MMP-9 antibody-staining status were identified as either negative or positive. Immunohistochemical positive staining was defined by the presence of brown chromogen detection on the edge of the hematoxylin-stained cell nucleus, distributed within the cytoplasm or in the membrane *via* evaluation by light microscopy as previously described.²⁸ Positive controls consisted of tissue specimens with known antigenic positivity. Sections treated with PBS without the primary antibodies served as negative controls. Seven fields of about 600.000 µm², randomly selected from each section, were considered for morphometric and

densitometric analysis. The percentage areas (morphometric analysis) stained with MMP-7 and MMP-9 antibodies were expressed as % positive, dark brown pixels of the analyzed fields. While, the levels (high/low) of staining intensity of positive areas (densitometric analysis) were expressed as densitometric count (pixel²) of positive, dark brown pixels of the analyzed fields. These parameters were calculated using software for image acquisition (AxioVision Release 4.8.2 - SP2 Software, Carl Zeiss Microscopy GmbH, Jena, Germany). Data were expressed as mean \pm standard deviation (SD). Digital micrographs were taken and fitted as previously described.

Statistical analysis

Statistical analysis was performed using GraphPad Prism 7.0 (GraphPad Software, Inc., La Jolla, CA, USA). Data were tested for normality with the Kolmogorov-Smirnov test. All variables were normally distributed. Student's *t*-test was used for comparisons between two means. P-values less than 0.05 ($P < 0.05$) and 0.001 ($P < 0.001$) were considered statistically and very statistically significant, respectively.

Results

MMP-7 and MMP-9 expression was confirmed, following immunohistochemistry. Staining was localized in fibroblast-like type B cells expressing MMP-7 and MMP-9. All experimental samples were identified as positively stained.

As shown in Figure 1, densitometric expression of MMP-7 and MMP-9 was significantly increased in ADDwoR when compared to the controls ($P < 0.001$). However, as shown in Figure 2, there was no significant difference between MMP-7 (Figure 2A) and MMP-9 (Figure 2B) immunostainings ($P > 0.05$). ADDwoR fibroblasts staining intensity, localized in the inner layer of the synovial membrane, was statistically significant compared to the control tissue (Figure 2C) ($P < 0.001$).

Discussion

MMPs have been shown to play an important role in ECM homeostasis and in joint disc remodelling. Our results showed a statistically significant difference in MMP-7 and MMP-9 immuno-

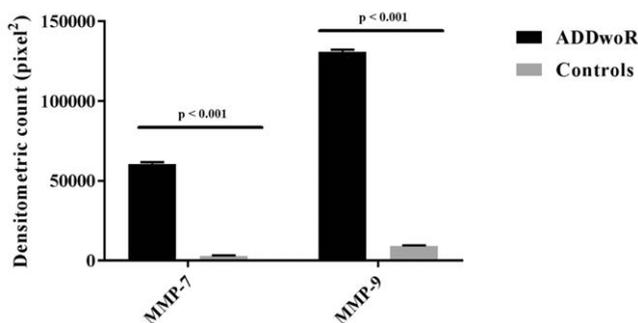


Figure 1. Densitometric analysis. A bar chart representing a comparison of the percentage of MMP-7 and MMP-9 immunostained area in ADDwoR synovial tissues vs. synovial control tissues, expressed by positive percentage, dark brown pixels of the analyzed fields. Data are presented as mean \pm SD. * $P < 0.001$.

expression was detected between the synovial tissues of ADDwoR and control samples. The expression of these MMPs is regulated by several factors including a variety of cytokines, which play an important role in TMJ ID pathogenesis. They have indeed been demonstrated in SF of pathological TMJ, suggesting that their expression could be a potential biochemical marker for articular cartilage degradation.^{8,15,22}

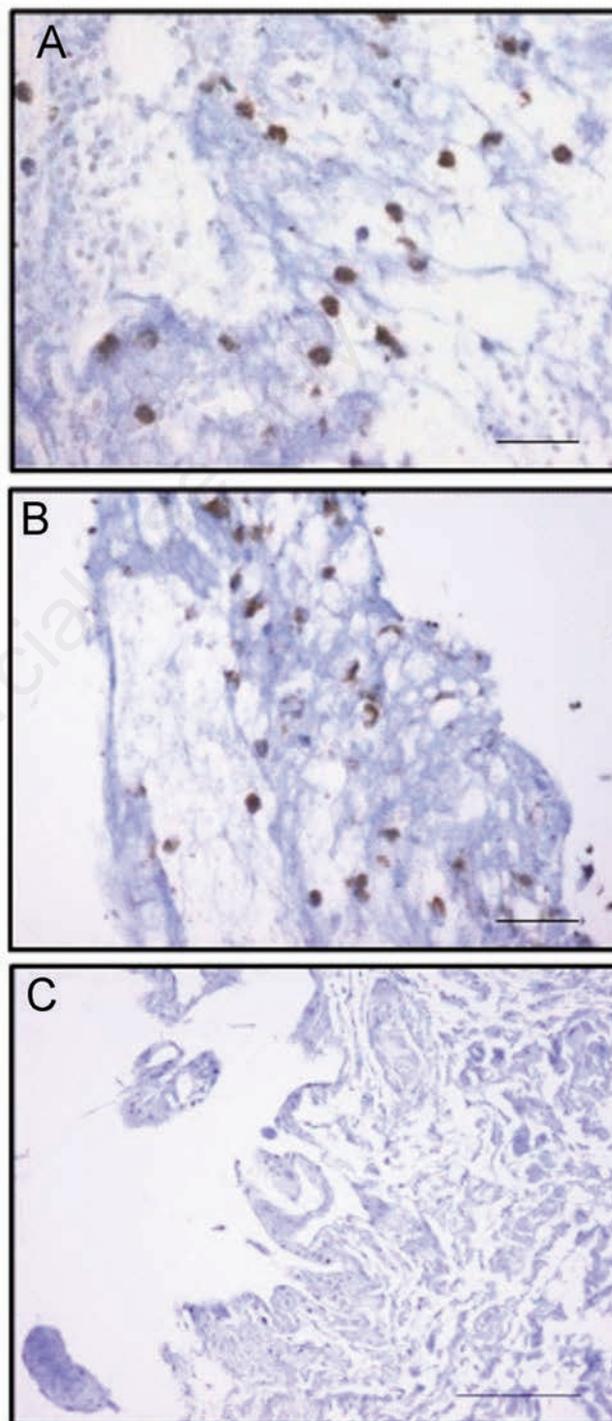


Figure 2. MMP-7 (A) and MMP-9 (B) immunoeexpression of fibroblasts in synovial tissue sample of ADDwoR patient, respectively; magnification 600 x; scale bars: 30 μ m; * $P > 0.05$. C) MMP-7 immunoeexpression in synovial tissue control sample; magnification 400 x; scale bar: 60 μ m.

MMP-7 and MMP-9 are expressed in arthritic joints and can degrade a number of matrix proteins in the joint.²⁹ In osteoarthritis, synovial macrophages, synovial fibroblasts, and chondrocytes may induce the release of MMPs which destroy joint cartilage.^{11,30} In particular, human TMJ synovial cells have been reported to synthesize MMP-1, MMP-3, and MMP-9 *in vitro*.^{31,32}

Transmission electron microscopy analysis showed two types of synovial lining cells, including the macrophages-like type A and fibroblast-like type B cells in the synovial lining layer of TMJ. In particular, a secretory function was attributed to fibroblast-like type B cells.²⁹ These cells secrete type I and II collagens, fibronectin, and glycosaminoglycans into the synovial interstitium and fluids.^{29,33-35} Therefore, it is reasonable to think that the MMPs overexpression in the synovial fluid derives from the secretory activity of fibroblast-like type B cells that showed in our study an overexpression of both MMP-7 and MMP-9.

In conclusion, within the limits of the present study, MMP-7 and MMP-9 were demonstrated to be overexpressed in the synovial tissue of patients with ADDwoR. Further studies about this topic may contribute to better understand the role of the inflammation process on tissue remodeling and destruction in the TMJ.

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