Clinical and synovial tissue studies in psoriatic arthritis
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A prospective, randomized, placebo-controlled study to identify biomarkers associated with active treatment in psoriatic arthritis: Effects of adalimumab treatment on synovial tissue

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Abstract

Objective
To determine which of the changes in synovial tissue correlates best with clinical response associated with effective therapy (adalimumab) to facilitate the planning of future studies with therapeutic agents for psoriatic arthritis (PsA).

Methods
Twenty-four active PsA patients were randomized to receive adalimumab (n=12) or placebo (n=12) for 4 weeks. Synovial biopsies were obtained before and after 4 weeks of treatment. Immunohistochemical analysis was performed to characterize the cell infiltrate, expression of cytokines and matrix metalloproteinases (MMPs), and vascularity. Sections were analyzed by digital image analysis. Statistical analysis was performed using covariance analysis.

Results
The mean DAS28 after 4 weeks was 1.92 units lower (95% confidence interval (CI) 1.07 - 2.77) after adalimumab therapy compared with placebo. Paired pre- and post-treatment synovial samples were available from 19 patients. Many cell types were reduced after adalimumab treatment compared to placebo. After applying a ranked ANCOVA model to correct for baseline imbalances, a significant effect of treatment was observed on CD3 positive cells: there was a median reduction of 248 cells/mm² after adalimumab versus placebo treatment (P = 0.035). In addition, the expression of MMP-13 was significantly reduced after active treatment: the integrated optical density (IOD)/mm² was 18,190 lower after adalimumab treatment as compared to placebo (P = 0.033).

Conclusion
Adalimumab therapy in PsA is associated with a marked reduction in T cell infiltration and MMP-13 expression in synovial tissue, suggesting that these parameters could be used as biomarkers that are sensitive to change after active treatment in small proof of concept studies in PsA.
A prospective, randomized, placebo-controlled study to identify synovial biomarkers

Because the synovium is a primary site of inflammation, there is increasing interest in studying the synovial tissue (ST) of patients with rheumatoid arthritis (RA) and psoriatic arthritis (PsA). In addition to the use of synovial biopsies for diagnostic purposes (1;2) and pathogenetic studies (3;4), serial synovial biopsies have been used to evaluate the effects of novel treatments (5;6). This approach has been proposed to screen for therapeutic effects of novel antirheumatic interventions (7).

The increase in the development of a variety of new, targeted therapies clearly raises the need for sensitive biomarkers, which could be used for selection purposes during the development process. In RA a decrease in synovial macrophages has been shown to correlate with clinical improvement (8-10). No synovial changes were detectable with analysis of serial synovial samples from RA patients who received either placebo or ineffective treatment (9;11-13). This suggests that analysis of serial biopsies could be used as a screening method to test new compounds requiring relatively small numbers of subjects. The absence of changes in the ST after treatment would suggest that the therapy is probably not effective.

To date, only a few studies have been conducted in PsA evaluating synovial changes after therapy. These studies were not placebo-controlled, with biopsies taken at different time points, and in part with variable results (6;14-18). Based on the limited data available it was hypothesized that an early decrease in macrophages (or macrophage subsets), combined with decrease in vascular markers and/or adhesion molecules, which were observed in some of these studies, would best predict clinical response in PsA.

The primary objective of this study was, therefore, to investigate the early changes in the ST alongside clinical response, by using a known clinically effective therapy (i.e. adalimumab 40 mg subcutaneously every other week) (19), to identify sensitive biomarkers that may facilitate the planning of future studies with novel agents to treat PsA.
Patients and Methods

Patients
Patients with PsA fulfilling the CASPAR classification criteria for PsA (20;21), aged 18-80 years, were included into the study after written informed consent was obtained. Patients had to have active disease at time of enrollment, defined by the presence of at least 2 tender and 2 swollen joints out of the 68 joints for tenderness and 66 joints for swelling assessed. One of the swollen joints had to be a knee, ankle or wrist joint that was accessible for arthroscopy. Patients were allowed to use concomitant methotrexate, which had to be stable for at least 28 days. They were not allowed to use any other disease-modifying antirheumatic drug (DMARD) one month prior to baseline. For leflunomide a 2 months washout period was required. Use of non-steroidal anti-inflammatory drugs was allowed, provided that the dose had been stable for at least 28 days. Parenteral, intra-articular or oral use of corticosteroids within 28 days before enrolment into the study was not allowed. Topical treatments for psoriasis were not allowed 14 days prior to baseline, with the exception of low potency (class I) topical steroids to be used on scalp, palms, groin and/or soles of feet only. Other exclusion criteria were the use of any biological agent or investigational drug within the previous 6 months, and having a history of tuberculosis or a malignancy in the past 10 years. Infection with HIV, hepatitis B or C virus was excluded via serologic testing. Patients with another serious infection within 4 weeks before baseline, or a significant history of cardiac, renal, neurological or metabolic disease were excluded from the study. Female patients who were pregnant or breastfeeding were not allowed to enter the study.

Study protocol
This was a randomized, double-blind, placebo-controlled, single center study performed at the Academic Medical Center of the University of Amsterdam. The study protocol was approved by the Medical Ethics Committee of the institute and all patients signed informed consent before start of the study. They had a complete medical history taken and underwent a full physical examination, including joint assessment by a rheumatologist and skin assessment by a dermatologist. Routine clinical chemistry, hematology and urinalysis assessments were performed, as well as a chest X-ray and PPD skin test prior to baseline to exclude patients with (latent) tuberculosis. Eligible patients were included into the study within 2 weeks after screening, and were seen at baseline, week 4 and week 12. Clinical assessment included a 68 joint count for tenderness and 66 joint count for swelling, a psoriasis area and severity index (PASI), a subject’s visual analog score (VAS) for pain, ranging from 0 mm (no pain) to 100 mm (the worst possible pain), a subject’s and investigator’s global disease assessment, and a Health Assessment Questionnaire.
A prospective, randomized, placebo-controlled study to identify synovial biomarkers (HAQ) for functional (dis)ability. Furthermore, CRP levels and ESR were determined. A blinded, independent assessor performed the clinical evaluation. The disease activity score evaluated in 28 joints (DAS28), which has been shown to discriminate between active drug and placebo in clinical trials in PsA, was chosen to monitor changes in clinical disease activity after therapy (22;23). In addition, the ACR criteria for improvement were assessed (24).

**Treatment**

Patients were randomized to receive subcutaneous injections with either adalimumab 40 mg or matching placebo at baseline (day 1) and day 15 in a 1:1 ratio. After the second arthroscopy all patients received adalimumab 40 mg every other week.

**Arthroscopy**

A needle arthroscopy of an actively inflamed joint (knee, ankle, or wrist) was performed under local anesthesia in all patients before treatment and 28 days after initiation of study medication from the same joint. The procedures for needle arthroscopy and tissue processing were performed as described previously in detail (25). In summary, to minimize sampling error biopsies were taken from 6 or more sites of the joint during each procedure (26;27). ST biopsy specimens were immediately embedded in TissueTek OCT (Miles Diagnostics, Elkhart, IN), snap-frozen by immersion in methylbutane (-80°C), and stored in liquid nitrogen until further processing. Before staining, coded ST samples were cut with a cryostat (5 μm), fixed with acetone, and endogenous protease activity was blocked with 0.3% hydrogen peroxide.

**Immunohistochemical analysis**

Serial sections were stained with the following antibodies: anti-CD3 (SK7, BD Biosciences, San Jose, CA), anti-CD4 (SK3, BD Biosciences), anti-CD8 (C8/114B, Dako, Glostrup, Denmark), anti-CD15 (C3D-1, Dako), anti-CD22 (CLB-B-ly/1,6B11, Sanquin, Amsterdam, The Netherlands), anti-CD38 (HB-7, BD Biosciences), anti-CD55 (clone 67, Serotech, Oxford, UK), anti-CD68 (EMB11; Dako), and anti-CD163 (5C6 FAT, Bachem Peninsula Laboratories, San Carlos, CA) to analyze the cell infiltrate. Antibodies against myeloid-related protein (MRP)8 (8-5C2, BMA Biomedicals, Augst, Switzerland) and MRP14 (S36.48, BMA Biomedicals) were used to detect infiltrating monocytes/macrophages in an early stage of differentiation.

For immunohistochemical analysis of cytokine expression, IL-1β (2D8; Immunokontact, Stockholm, Sweden), and IL-6 (B-E8, Invitrogen, Breda, The Netherlands) were stained. Furthermore, von Willebrand’s factor (vWF; F8/86; Dako) was used as a marker to detect blood vessels. Additionally, the expression of metalloproteinase (MMP)-3 (MAB1339,
Bio-Connect, Huissen, the Netherlands) and MMP-13 (VIIIa2, Oncogene, Cambridge, MA) was determined.

Sections with non-assessable tissue, defined by the absence of an intimal lining layer, were excluded from analysis. Staining for cellular markers was performed using a 3-step immunoperoxidase method as previously described (28). For the determination of cytokine expression, biotinylated tyramine (BT) was used for amplification after incubation with the secondary antibody, and incubation with streptavidin-horse radish peroxidase (HRP) was followed by detection with amino-ethylcarbazole (AEC), as previously described (29;30). For control sections, the primary antibodies were omitted or irrelevant antibodies were applied.

**Digital image analysis**

After immunohistochemical staining, all sections were coded and randomly analyzed by computer-assisted digital image analysis (DIA). For all markers, 18 high-power fields were analyzed. CD68 and CD163 expression (macrophage markers) were analyzed separately in the intimal lining layer and the synovial sublining. The images of the high-power fields were analyzed using the Qwin analysis system (Leica, Cambridge, UK), as described previously in detail (31;32).

**Statistical analysis**

SPSS for Windows (12.0.2) was used for statistical analysis. Baseline characteristics between the 2 groups were compared using a Student’s t-test for normal distributed data and a Mann Whitney U test for variables with a very skewed distribution. Correlations of changes in clinical parameters and immunohistochemical markers were analyzed with Spearman’s rank correlation. Additionally, each of the endpoints was analyzed using an analysis of covariance model (ANCOVA) after rank transformation to correct for baseline differences (33). The model included terms for treatment as a fixed effect and the baseline measurement as a covariate. The aim was to assess the treatment difference.

**Results**

**Demographic features**

Twenty-four patients (15 males, 9 females) were included in the trial, 12 patients were randomized to receive adalimumab and 12 placebo treatment. The mean age was 42.8 (range 21-61) years for the patients in the adalimumab group and 47.2 (25-78) years in the placebo group (Table 1). The mean PsA disease duration was comparable in both groups. Concomitant methotrexate was used by 7 patients in the adalimumab group
and 5 patients in the placebo group in a comparable dose (mean 18.2 mg/week and 19.0 mg/week, respectively). None of the patients had used TNF inhibitors in the past. Most patients (n=16) had polyarticular involvement according to the Moll and Wright classification (34), a minority had an oligoarticular phenotype (n=7) or predominantly distal interphalangeal involvement (n=1). Two of the patients with polyarticular disease also had axial involvement. The PsA phenotypes were not equally distributed among the two groups, with the placebo group harboring more polyarticular patients than the adalimumab group (10 versus 6). Despite this difference, the patient groups were comparable with regard to disease activity markers, such as CRP and DAS28. All patients received the 2 injections with study medication according to the protocol. Overall study medication was well tolerated. No infections other than common cold were reported in the 4 weeks study period. One patient in the placebo group complained of more pain in her ankle after the first arthroscopy, but could undergo the second arthroscopy.

**Clinical response**

As anticipated, a markedly positive effect of adalimumab treatment was seen on the DAS28 (23), which was 1.92 units lower compared with placebo after 4 weeks of treatment (95% confidence interval -2.73 to -1.11, p<0.001). The clinical response was also evident in the other disease activity measures, with significant improvements in CRP, ESR, DAS28, patient’s global assessment of disease activity, patient’s assessment of pain, and PASI. The differences in these measures between the two groups were statistically significant (all p<0.05).

**Table 1. Demographic and clinical features of the 24 PsA patients enrolled in the study.**

<table>
<thead>
<tr>
<th></th>
<th>Adalimumab (n=12)</th>
<th>Placebo (n=12)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>age, yrs</strong></td>
<td>42.8 (21-61)</td>
<td>47.2 (25-78)</td>
</tr>
<tr>
<td><strong>no. men/women</strong></td>
<td>9/3</td>
<td>6/6</td>
</tr>
<tr>
<td><strong>no. (%) currently receiving MTX</strong></td>
<td>7 (58)</td>
<td>5 (42)</td>
</tr>
<tr>
<td><strong>dose MTX, mg/week</strong></td>
<td>18.2 (10-25)</td>
<td>19.0 (15-25)</td>
</tr>
<tr>
<td><strong>PsA disease duration, yrs</strong></td>
<td>5.5 (0.4-14.1)</td>
<td>8.4 (1.9-18.2)</td>
</tr>
<tr>
<td><strong>no. (%) RF positive</strong></td>
<td>2 (17)</td>
<td>1 (8)</td>
</tr>
<tr>
<td><strong>no. (%) anti-CCP positive</strong></td>
<td>1 (8)</td>
<td>0</td>
</tr>
<tr>
<td><strong>no. (%) erosive</strong></td>
<td>7 (58)</td>
<td>5 (42)</td>
</tr>
<tr>
<td><strong>ESR, mm/hour</strong></td>
<td>24.2 (4-66)</td>
<td>22.4 (3-66)</td>
</tr>
<tr>
<td><strong>CRP, mg/liter</strong></td>
<td>19.9 (2.3-81.6)</td>
<td>9.9 (1.3-26.7)</td>
</tr>
<tr>
<td><strong>DAS28 score</strong></td>
<td>4.67 (3.0-5.78)</td>
<td>5.07 (2.21-6.83)</td>
</tr>
<tr>
<td><strong>patient’s global assessment of disease activity (VAS 0-100 mm)</strong></td>
<td>73 (45-94)</td>
<td>62.8 (18-92)</td>
</tr>
<tr>
<td><strong>patient’s assessment of pain (VAS 0-100 mm)</strong></td>
<td>72.8 (55-91)</td>
<td>67.4 (11-89)</td>
</tr>
<tr>
<td><strong>PASI</strong></td>
<td>5.89 (0-14.0)</td>
<td>4.72 (0-7.0)</td>
</tr>
</tbody>
</table>

All values are mean (range) except where indicated otherwise. PsA = psoriatic arthritis; MTX = methotrexate; RF = rheumatoid factor; ESR = erythrocyte sedimentation rate; CRP = C-reactive protein; DAS28 = disease activity score in 28 joints; VAS = visual analog scale; PASI = psoriasis area and severity index.
confidence interval (CI) 1.07 - 2.77, P < 0.001) (Figure 1). The mean (± SD) DAS28 decreased from 4.67 ± 0.98 to 2.87 ± 1.27 one month after initiation of adalimumab therapy. This improvement was not seen in the placebo group, where the mean DAS28 was 5.07 ± 1.29 before versus 5.20 ± 1.31 after treatment. After 4 weeks of treatment, 11 of the adalimumab patients fulfilled the EULAR criteria for clinical response (23;35) (6 patients were good and 5 were moderate responders), versus 0 in the placebo group. Clinical improvement was sustained at week 12, when all 12 adalimumab treated patients fulfilled the EULAR criteria for clinical response (7 good and 5 moderate responders). Based on the 68 tender joint count and 66 swollen joint count an ACR20 response for improvement (24) was observed in 5 patients after 4 weeks of adalimumab treatment (of which 4 also fulfilled the ACR50 response criteria), but in none of the placebo treated patients. After 12 weeks of adalimumab treatment 10 patients fulfilled ACR20 criteria, of which 7 also met the ACR50 response criteria.

The mean PASI score after 4 weeks of adalimumab treatment was 2.61 points lower compared to placebo (95% CI -0.08 - 5.30, P = 0.056). The mean PASI decreased from 5.89 ± 4.25 to 4.01 ± 2.49 in the adalimumab group, whereas there was a slight increase in the placebo group from 4.72 ± 2.55 to 5.45 ± 4.05.

At 4 weeks the ESR and CRP levels were respectively 58% (95% CI 30% - 86%, P = 0.001) and 57% (95% CI 29% - 84%, P < 0.001) lower after adalimumab treatment than after placebo treatment. The mean ESR was reduced from 24.2 ± 21.7 mm/h to 8.1 ± 7.5

![Figure 1](image.png)

*Figure 1. Effect of treatment with either adalimumab or placebo on the individual DAS28. A marked reduction is seen after adalimumab treatment for 4 weeks.*
mm/h after adalimumab treatment, and the mean CRP from 19.9 ± 25.7 mg/L to 2.1 ± 1.4 mg/L, whereas after placebo treatment there was no clear-cut change: ESR from 22.4 ± 18.7 to 19.6 ± 11.9 mm/h and CRP from 9.9 ± 9.1 to 9.2 ± 10.0 mg/L, respectively.

**Immunohistochemical analysis**

Despite randomization, there were clear differences at baseline for several synovial markers between adalimumab and placebo groups, as shown in Table 2 (adalimumab and placebo before). Most of these baseline differences were not statistically significant except for the number of CD8 positive cells, CD163 positive cells, and MMP-3 expression, which were significantly higher in the adalimumab group. A marked reduction was observed in most cell types after active treatment. The effect after adalimumab was significant for CD3 positive T cells: there was a median decrease of 248 cells/mm² after adalimumab compared to placebo treatment. There was clear interindividual variability, which is a well known phenomenon in patients with various arthritides including PsA (4;36). However, on the group level there was a marked decrease in CD3 positive T cells (median ± standard error (SE) of the median: 212 ± 230 cells/mm²) in the adalimumab group (Figure 2), whereas in the placebo group there was an increase (36 ± 33 cells/mm²). A similar effect was observed for the two T cell subpopulations: there was a trend towards a reduction of CD4 positive cells (386 ± 278 cells/mm²) after adalimumab compared to an increase (148 ± 589 cells/mm²) after placebo treatment; and a reduction of CD8 positive cells (103 ± 72 cells/mm²) after adalimumab versus a small increase (4 ± 7 cells/mm²) after placebo treatment.

Following adalimumab treatment there also was a decrease in the number of CD163 positive cells (resident macrophages), and CD68 positive macrophages, especially in the synovial sublining, but these changes did not reach statistical significance, possibly due to the relatively small number of patients. Similar changes were observed for MRP-8 and MRP-14 positive macrophages (infiltrating monocytes/macrophages in an early stage of differentiation). There were also trends towards decreased infiltration by CD22 positive B cells, CD38 positive plasma cells, and CD15 positive neutrophils after active treatment.

There was a trend towards reduction in the expression of the vascular marker vWF, and the pro-inflammatory cytokines IL-1 and IL-6 after treatment with adalimumab as compared to placebo, but the differences were not statistically significant. There was considerable reduction of expression of MMP-3 and MMP-13 in the adalimumab group as compared to placebo. The expression of MMP-13 was decreased with 9,188 ± 8,653 IOD/mm² (median ± SE of the median) after adalimumab treatment as compared to an increase of 9,002 ± 5,469 IOD/mm² after placebo. When ANCOVA was applied to correct for the imbalances at baseline, it turned out that the baseline
Table 2.

<table>
<thead>
<tr>
<th></th>
<th>Adalimumab before</th>
<th>Adalimumab reduction</th>
<th>Placebo before</th>
<th>Placebo reduction</th>
<th>ANCOVA P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD68total</td>
<td>1,927 ± 133</td>
<td>435 ± 197</td>
<td>835 ± 516</td>
<td>-534 ± 567</td>
<td>0.31</td>
</tr>
<tr>
<td>CD68L</td>
<td>378 ± 28</td>
<td>236 ± 61</td>
<td>177 ± 140</td>
<td>-419 ± 249</td>
<td>0.35</td>
</tr>
<tr>
<td>CD68SL</td>
<td>1,423 ± 262</td>
<td>147 ± 59</td>
<td>753 ± 628</td>
<td>-184 ± 99</td>
<td>0.23</td>
</tr>
<tr>
<td>CD163total</td>
<td>1,243 ± 208</td>
<td>765 ± 309</td>
<td>480 ± 178</td>
<td>286 ± 409</td>
<td>0.67</td>
</tr>
<tr>
<td>CD163L</td>
<td>426 ± 203</td>
<td>167 ± 72</td>
<td>68 ± 8</td>
<td>39 ± 46</td>
<td>0.15</td>
</tr>
<tr>
<td>CD163SL</td>
<td>1,081 ± 155</td>
<td>674 ± 265</td>
<td>468 ± 206</td>
<td>256 ± 389</td>
<td>0.85</td>
</tr>
<tr>
<td>CD3</td>
<td>533 ± 36</td>
<td>212 ± 230</td>
<td>144 ± 66</td>
<td>-36 ± 33</td>
<td>0.035*</td>
</tr>
<tr>
<td>CD4</td>
<td>1130 ± 265</td>
<td>386 ± 278</td>
<td>184 ± 21</td>
<td>-148 ± 589</td>
<td>0.084</td>
</tr>
<tr>
<td>CD8</td>
<td>177 ± 103</td>
<td>103 ± 72</td>
<td>27 ± 7</td>
<td>-4 ± 7</td>
<td>0.12</td>
</tr>
<tr>
<td>CD15</td>
<td>35 ± 13</td>
<td>22 ± 8</td>
<td>13 ± 1</td>
<td>12 ± 28</td>
<td>0.42</td>
</tr>
<tr>
<td>CD22</td>
<td>306 ± 167</td>
<td>210 ± 145</td>
<td>44 ± 7</td>
<td>20 ± 27</td>
<td>0.89</td>
</tr>
<tr>
<td>CD38</td>
<td>15 ± 11</td>
<td>4 ± 1</td>
<td>4 ± 1</td>
<td>1 ± 1</td>
<td>0.83</td>
</tr>
<tr>
<td>CD55</td>
<td>660 ± 218</td>
<td>85 ± 145</td>
<td>681 ± 30</td>
<td>230 ± 288</td>
<td>0.60</td>
</tr>
<tr>
<td>VWF</td>
<td>137,853 ± 42,944</td>
<td>47,107 ± 25,755</td>
<td>87,300 ± 8,092</td>
<td>-38,191 ± 76,306</td>
<td>0.37</td>
</tr>
<tr>
<td>IL-1b</td>
<td>515,740 ± 200,575</td>
<td>272,189 ± 74,412</td>
<td>620,179 ± 485,911</td>
<td>31,219 ± 134,893</td>
<td>0.31</td>
</tr>
<tr>
<td>IL-6</td>
<td>169,164 ± 181,653</td>
<td>39,063 ± 49,052</td>
<td>38,671 ± 12,175</td>
<td>-66,403 ± 125,364</td>
<td>0.18</td>
</tr>
<tr>
<td>MRP8</td>
<td>1,483 ± 1,550</td>
<td>1,313 ± 1,644</td>
<td>396 ± 139</td>
<td>-23 ± 233</td>
<td>0.11</td>
</tr>
<tr>
<td>MRP14</td>
<td>3,976 ± 1,380</td>
<td>2,814 ± 2,339</td>
<td>1,837 ± 1,360</td>
<td>489 ± 247</td>
<td>0.82</td>
</tr>
<tr>
<td>MMP-3</td>
<td>247,021 ± 101,010</td>
<td>138,679 ± 99,428</td>
<td>17,680 ± 1,913</td>
<td>138 ± 529</td>
<td>0.64</td>
</tr>
<tr>
<td>MMP-13</td>
<td>25,822 ± 15,822</td>
<td>9,188 ± 8,653</td>
<td>14,673 ± 10,350</td>
<td>-9,002 ± 5,469</td>
<td>0.033*</td>
</tr>
</tbody>
</table>

Median values (± standard error (SE) of the median) for the synovial biomarkers before treatment and median reduction (± SE of the median) after 4 weeks of treatment in each group, and P-value of the ranked ANCOVA applied: CD68+ macrophages (total), CD68+ macrophages in the intimal lining layer (L) and in the synovial sublining (SL), CD163+ cells (subset of macrophages) (total), CD163+ cells in L and SL, CD3+ T cells, CD4+ and CD8+ T cells, CD15+ neutrophils, CD22 + B cells, CD38+ plasma cells, and CD55+ fibroblast-like synoviocytes are provided as cells/mm². Expression of von Willebrand Factor (vWF), IL-1β, IL-6, myeloid related protein (MRP)-8, MRP-14, matrix metalloproteinase (MMP)-3, MMP13, are provided as median (± SE of the median) integrated optical density (IOD)/mm². Differences before treatment between the groups were statistically significant for CD163+ cells (total, L and SL), CD8+ cells, and MMP-3 expression, which were higher in the adalimumab group. After ANCOVA was applied to correct for baseline imbalances, the effect of treatment after 4 weeks was significant only for the reduction in the number of CD3 positive cells (P=0.035) and MMP-13 expression (P=0.033)*.
measurement had the strongest effect on change in any parameter tested, but for reduction in the number of CD3 positive cells and MMP-13 expression the effect of treatment remained significant (P = 0.035 for CD3 positive cells, and P = 0.033 for expression of MMP-13).

**Correlation between clinical improvement and changes in synovial biomarkers**

For the cellular markers clinical improvement was strongly correlated with a decrease in CD3 positive T cells (Spearman’s rho = 0.644, P = 0.003), CD4 positive cells (rho = 0.649, P = 0.003), and MRP8 positive macrophages (rho = 0.561, P = 0.012) (Figure 3), but there was no statistically significant correlation with changes in other cell types. There was also a strong correlation between clinical improvement and the reduction of MMP-13 (rho = 0.619, P = 0.005) (Figure 3) and MMP-3 (rho = 0.560, P = 0.013).

**Discussion**

This placebo-controlled study with adalimumab was conducted to address the question which features in PsA ST samples could be used as a biomarker for clinical efficacy on the group level in relatively small studies of short duration. The results presented here show that clinically effective adalimumab therapy is particularly associated with a

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**Figure 2.** Representative photograph showing CD3+ T cells (red-brown) in psoriatic arthritis synovial tissue before and after treatment with adalimumab (upper panel left and right) or placebo (lower panel left and right). Magnification x 200. A marked reduction of the number of CD3+ T cells was observed after 4 weeks of adalimumab treatment.
marked reduction in CD3 positive T cell infiltration and expression of MMP-13 in the ST of PsA patients 4 weeks after initiation of treatment. Previous work on synovial biomarkers in PsA patients has been mainly limited to open studies, mostly of longer duration. Open label treatment of 10 PsA patients with methotrexate resulted in a decrease in T cells and macrophages as well as reduced expression of IL-8, E-selectin, intercellular adhesion molecule-1 (ICAM-1), and MMP-3 after 6 to 12 months of treatment (14). In another study 52 patients with peripheral

Figure 3.
Scatter plots showing individual data points for the correlation between change in DAS28 (delta DAS28, a positive value represents clinical improvement) on the Y-axis and change in biomarker (a positive value represents a reduction of the expression) on the X-axis after 4 weeks for: CD3 positive cells (rho = 0.644, P = 0.003), CD4 positive cells (rho = 0.649, P = 0.003), expression of MRP8 (rho = 0.561, P = 0.012) and MMP-13 (rho = 0.619, P = 0.005)
A prospective, randomized, placebo-controlled study to identify synovial biomarkers

arthritides due to spondyloarthritis were included; 16 of these had PsA (15). The patients underwent synovial biopsy at baseline and 12 weeks following different treatment regimens (infliximab, etanercept, sulfasalazine or no DMARD). Clinical improvement correlated with a decrease in CD163 positive macrophages, polymorphonuclear cells (PMNs), and MMP-3 expression. A study on the effects of TNF blockade showed in 11 PsA patients, who were treated with infliximab (3 mg/kg) combined with stable methotrexate treatment, a significant reduction of ICAM-1, vWF and αvβ3 expression (17). There was also a trend towards a reduction of both T cells and macrophages. Similarly, another study demonstrated a decrease in macrophage numbers and vascular markers in the synovium of 9 PsA patients 8 weeks after initiation of infliximab (5 mg/kg) treatment (18). A study on the effects of alefacept revealed a significant decrease in T cell numbers after 4 weeks of treatment, and a significant reduction of both T cells and macrophages after 12 weeks of treatment in 11 PsA patients (6). Finally, experimental treatment with IL-10 subcutaneously for 4 weeks resulted in decreased T cell and macrophage infiltration in the synovium (37).

The present study was designed to determine which synovial biomarkers are associated on the group level with active treatment, identical to the approach that we have previously described in RA patients (8). In RA macrophage numbers were previously identified as synovial biomarkers associated with active treatment. These results have been confirmed and validated in various studies (9;10;38). Of interest, although we did observe clear trends towards decreased numbers of macrophages and macrophage subsets after active treatment, analysis of covariance indicates that in PsA especially the number of CD3 positive T cells and the expression of MMP-13 could be used to screen for potentially active drugs in small proof of concept studies of short duration. The results presented here underscore the important role of T cells in the pathogenesis of PsA (39), consistent with the observation that specific targeting of T cells may result in clinical benefit in this disease (6;40).

A potential drawback of this study, although randomized, is the fact that there were baseline differences – in both clinical and synovial variables – between the adalimumab and placebo group despite randomisation, which is probably related to the relatively small number of patients. The ANCOVA model, however, includes the baseline value for each marker as a covariate, thereby correcting for these baseline imbalances (41). Using this model to describe the relationship between clinical improvement and changes in ST, the effect of treatment was sustained for a reduction of T cells and MMP-13 expression. Another potential limitation of this exploratory study is related to the high number of synovial parameters tested, and the chance of erroneously reporting statistical significance in the context of multiple comparisons. The limited power of our study did not allow a conservative Bonferroni correction. Of importance, very recently other investigators
have independently confirmed the specific decrease in CD3+ T cells in the synovium after initiation of TNF blockade in patients with PsA (42). Thus, it appears unlikely that the identification of CD3+ T cells as a key synovial biomarker associated with active treatment can merely be explained by chance.

The reduction of synovial inflammation associated with clinical improvement of the joint and skin after adalimumab treatment is also consistent with previous reports showing a decrease in leukocyte numbers (including T cells and macrophages), as well as reduced vascularity and expression of pro-inflammatory cytokines and MMPs in the synovium of PsA patients after infliximab treatment (15-18). The cellular changes might be explained in part by changes in cell migration due to reduced neoangiogenesis and reduced expression of adhesion molecules and chemokines, as suggested previously (14;16;17;43).

Analysis of molecular markers in synovial tissue is increasingly used in clinical trials on targeted therapies. With this approach, tissue specificity is not a problem and examination of serial biopsy samples can be used to monitor the response in individual patients and screen for interesting biological effects at the site of inflammation. This study clearly shows that changes in T cell numbers and the expression of MMP-13 in the synovium of PsA patients may be used as biomarkers to screen for effective therapies during early drug development. It can be anticipated that future developments will include the use of more extensive markers of synovial inflammation and joint degradation as well as the use of panels of biomarkers in serum and synovial tissue samples.

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Reference List


