

A phase III randomized study of apremilast, an oral phosphodiesterase 4 inhibitor, for active ankylosing spondylitis

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Conflicts of interest

P.C. Taylor has received grant/research support from Celgene. D. van der Heijde has served as a consultant for AbbVie, Amgen, Astellas, AstraZeneca, Bristol-Myers Squibb, Boehringer Ingelheim, Celgene, Cyxone, Daiichi, Eli Lilly, Galapagos, Gilead, GSK, Janssen, Merck, Novartis, Pfizer, Regeneron, Roche, Sanofi, Takeda and UCB Pharma, and is a director of Imaging Rheumatology BV. R. Landewé has served as a consultant for AbbVie, Eli Lilly, Galapagos, Gilead, Merck, Novartis, Pfizer and UCB Pharma and received an honorarium from Celgene for reading films for this study. S. McCue is a former employee of Celgene. S. Cheng is an employee of Amgen Inc. and a former employee of Celgene. A. Boonen has received grant/research support from Celgene.

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ABSTRACT

Objective. To evaluate the efficacy and safety of apremilast, an oral phosphodiesterase 4 inhibitor, in patients with active ankylosing spondylitis (AS).

Methods. This phase III, multicenter, double-blind, placebo-controlled study (NCT01583374) randomized patients with active AS (1:1:1) to placebo, apremilast 20 mg twice daily, or apremilast 30 mg twice daily for 24 weeks, followed by a long-term extension phase (up to 5 years). The primary endpoint was assessment of the SpondyloArthritis International Society 20 (ASAS 20) response at Week 16. The impact of treatment on radiographic outcomes after 104 weeks was assessed using the modified Stoke Ankylosing Spondylitis Spine Score (mSASSS).

Results. In total, 490 patients with active AS were randomized in the study (placebo: n = 164; apremilast 20 mg twice daily: n = 163; apremilast 30 mg twice daily: n = 163). The primary endpoint of ASAS 20 response at Week 16 was not met (placebo: 37%; apremilast 20 mg twice daily: 35%; apremilast 30 mg twice daily: 33%; $p = 0.44$ vs placebo). At Week 104, mean (SD) changes from baseline in mSASSS were 0.83 (3.6), 0.98 (2.2), and 0.57 (1.9) in patients initially randomized to placebo, apremilast 20 mg twice daily, and apremilast 30 mg twice daily, respectively. The most frequently reported adverse events through Week 104 were diarrhea, nasopharyngitis, upper respiratory infection, and nausea.

Conclusion. No clinical benefit was observed with apremilast treatment in patients with active AS. The safety and tolerability of apremilast were consistent with its known profile.

INTRODUCTION

Ankylosing spondylitis (AS), which is characterized by back pain and sacroiliitis, can result in bone formation and spinal vertebrae fusion(1, 2). Non-steroidal anti-inflammatory drugs (NSAIDs) are recommended as first-line treatment for AS. Conventional disease-modifying anti-rheumatic drugs (DMARDs) have not been effective in axial disease(3). Biologic DMARDs are recommended when disease activity is persistently high despite adequate NSAID or conventional DMARD trials. Current practice starts with a tumor necrosis factor (TNF) blocker(4, 5).

Apremilast is an oral phosphodiesterase 4 (PDE4) inhibitor available for treating adult patients with plaque psoriasis, active psoriatic arthritis or active Behçet's syndrome(6). Phosphodiesterase 4 inhibition elevates intracellular cAMP levels, which in turn downregulate inflammatory responses by modulating expression of TNF- α , IL-23, IL-17, and other pro-inflammatory cytokines(7, 8). Apremilast has been associated with increases in anti-inflammatory mediators, including IL-10 and IL-1 receptor antagonists(8, 9).

In a phase II study of 36 patients, apremilast 30 mg twice daily was associated with improvements in AS symptoms over 12 weeks, although patients did not appear to reach maximum clinical response at Week 12(10). This phase III, randomized, double-blind study evaluated apremilast efficacy and safety in patients with documented AS. It included a 24-week, placebo-controlled period with long-term extension up to 5 years. These are the first results reported through 2 years.

MATERIALS AND METHODS

Study design. AS-001 (ClinicalTrials.gov, NCT01583374) included a 6-week screening period and 24-week, randomized, double-blind, placebo-controlled period with long-term extension up to 5 years. The study was conducted between May 2012 and October 2018 at 88 sites in North America, Europe, Australia, South Africa, and Russia. Patients were randomized (1:1:1) to placebo, apremilast 20 mg twice daily or apremilast 30 mg twice daily for 24 weeks, stratified by C-reactive protein (CRP) concentration at screening (normal: ≤ 1.5 mg/dl; elevated: > 1.5 mg/dl) and baseline Bath Ankylosing Spondylitis Disease Activity Index (BASDAI)(11) score (< 6.0 and ≥ 6.0). A 7-day stepwise treatment titration schedule was implemented to decrease dose-related gastrointestinal effects associated with this drug class. At Week 16, patients receiving placebo or apremilast 20 mg without $\geq 20\%$ or ≥ 1 unit improvement from baseline in at least 2 of the 4 domains of the Assessment of SpondyloArthritis International Society 20 (ASAS 20)(12) response criteria were switched to apremilast 30 mg in a blinded manner.

At Week 24, patients could enter a long-term extension phase up to an additional 4.5 years (236 weeks). All remaining placebo patients were switched to apremilast 30 mg. Patients initially receiving apremilast 20 mg without $\geq 20\%$ and ≥ 1 unit improvement from baseline in at least 2 of the 4 ASAS 20 domains were switched to apremilast 30 mg; patients initially receiving apremilast 30 mg continued on that treatment.

This study was conducted in accordance with International Conference on Harmonisation guidelines and Declaration of Helsinki's general ethical principles and received approval from institutional review boards (IRBs)/independent ethics

committees at each study site (main IRB approval number, 12/WM/0215) . Informed written consent was obtained from patients before any study-related procedure.

Patients. Eligible patients were aged ≥ 18 years with AS fulfilling modified New York criteria (radiographic criterion by a central reader; at least 1 clinical criterion)(13).

Patients had active axial disease symptoms at screening and baseline (randomization), determined by BASDAI numerical rating scale (NRS) scores ≥ 4 and total back pain NRS scores ≥ 4 .

Co-medications were allowed if the corticosteroid (≤ 10 mg/day or prednisone equivalent at stable dose for ≥ 28 days) or conventional DMARD (methotrexate ≤ 25 mg/week, sulfasalazine ≤ 3 g/day, hydroxychloroquine ≤ 400 mg/day or chloroquine ≤ 250 mg/day for ≥ 16 weeks) dose was stable at randomization and maintained through the 24-week placebo-controlled period. NSAIDs and/or cyclooxygenase-2 inhibitors, acetaminophen/paracetamol (≤ 2600 mg/day), and opioid analgesics (≤ 30 mg oral morphine or equivalent/day) were allowed.

Key exclusion criteria were prior treatment with biologic DMARD for AS, any alkylating agents or total lymphoid irradiation; intra-articular or parenteral corticosteroid 6 weeks before randomization; autoimmune disease or inflammatory joint disease diagnosis other than AS; uncontrolled, severe psoriasis (body surface area involvement $> 10\%$); and active inflammatory bowel disease, uncontrolled uveitis or any poorly controlled disease. Patients with history of suicide attempt before randomization or major psychiatric illness requiring hospitalization within 3 years were excluded.

The study protocol, amendments, and informed consent form (ICF) were approved by the IRB at each investigational site or by a central review board, which included public and patient representation. The ICF provided patients with information about the study and expected visits; patients signed the ICF at screening and were expected to have a randomization visit, scheduled on-study visits and post-study follow-up visit. Patients were randomized if the investigator confirmed they had active AS and met inclusion/exclusion criteria after the 6-week screening phase. Patients were asked about any adverse events (AEs) and completed health assessment questionnaires throughout the study. Safety and efficacy monitoring were performed by an independent, external data monitoring committee.

Clinical outcomes measures. The primary endpoint was the proportion of patients achieving an ASAS 20 response at Week 16, defined as improvement from baseline of $\geq 20\%$ and ≥ 1 unit in at least 3 of the 4 ASAS 20 domains on a scale of 0–10 units and no worsening from baseline of $\geq 20\%$ and ≥ 1 unit in the remaining ASAS 20 domain.

Secondary endpoints included ASAS 20 response at Week 24 and changes from baseline scores at Week 24 in total BASDAI, Bath Ankylosing Spondylitis Functional Index(14) (BASFI; 0–10 range; higher score indicates reduced function), Ankylosing Spondylitis Quality of Life Questionnaire (ASQoL; 0–18 range; higher scores indicate worse QoL), 36-item Short-Form Health Survey version 2 (SF-36v2) physical component summary (0–100 range for individual domain scores, with normative physical composite summary score of 50 and standard deviation [SD] of 10; higher scores indicate better health), and total Bath Ankylosing Spondylitis Metrology Index

(BASMI)-Linear (0–10 range; higher scores indicate more severe spinal mobility limitation). Exploratory endpoints included proportion of patients achieving an ASAS 40, ASAS 5/6 ($\geq 20\%$ improvement in 5 of the 6 domains), ASAS partial remission (≤ 2 on 0–10 unit NRS in 4 domains of ASAS response criteria), Ankylosing Spondylitis Disease Activity Score(15) (ASDAS; higher scores indicate greater disease activity), Maastricht Ankylosing Spondylitis Enthesitis Score(16) (MASES; $\geq 20\%$ improvement in scores), and mean change in CRP levels among all patients and in those with baseline CRP >1.5 mg/dl.

Imaging outcomes. Radiographic analyses were based on changes from baseline in modified Stoke Ankylosing Spondylitis Spine Score (mSASSS)(17) at Week 104 for all patients with radiographic data at this time point. Lateral-view radiographs of cervical and lumbar spines were obtained at baseline and after 2 years in all patients. Radiographs were mixed and scored by 2 trained, independent readers blinded to time points, study, and treatment using mSASSS; average scores from 2 readers were reported. Magnetic resonance imaging (MRI) of the entire spine and sacroiliac joints was conducted at Weeks 16, 52, and 104 in a subset of patients (those participating in the MRI substudy who had a baseline MRI) using the Berlin Method of Ankylosing Spondylitis for the spine(18) (Berlin-modified ASspiMRI-a) and Spondyloarthritis Research Consortium of Canada(19) (SPARCC) criteria for the sacroiliac joint (data only shown for Week 104). For the MRI substudy, assessments were conducted at selected sites with adequate MRI capabilities; patients signed a separate informed consent form. At least 2 trained independent central reviewers evaluated each case

(double review) in a blinded fashion. If adjudication was required, a third reviewer completed an independent assessment. Total SPARCC scores (total possible score: 72) and total Berlin-modified ASspiMRI-a scores (total possible score: 69) were calculated for each time point.

Comparison to OASIS. Given the lack of control for radiographic assessments over 2 years, a post-hoc analysis utilized the Outcome in Ankylosing Spondylitis International Study (OASIS) database to further assess radiographic progression with a historical control group. OASIS is a large prevalence cohort with AS from rheumatology centers in Belgium, France, and The Netherlands who received best standard of care initiated in 1996, before biologic DMARDs were available(20). Baseline and 2-year radiographs from OASIS (N = 186) have been used as comparators to assess radiographic progression with TNF inhibitors(20-22). Radiographic results from patients in this study with baseline and Week 104 spinal radiographic images (n = 286) were compared with data from the full OASIS cohort and from a matched subset of patients meeting key active AS eligibility criteria (baseline BASDAI ≥ 4 , total back pain ≥ 4). In a second reading, all radiographs were mixed with films from OASIS as a control cohort and read in a similar manner as described.

Safety assessments. Safety endpoints included AEs, discontinuations due to AEs and clinically significant changes in physical examination, vital sign or laboratory findings.

Statistical analyses. A sample size of 456 patients (152 patients/treatment group) was calculated to have 90% power to detect an absolute treatment difference of 17.5% between placebo (25.0%) and apremilast (combined; 42.5%) for the proportion of patients achieving ASAS 20 responses. The safety population (safety analyses) and modified intent-to-treat (mITT) population (efficacy analyses) included all patients who were randomized and received at least 1 dose of study drug.

Proportions of patients achieving an ASAS 20 response at Week 16 (primary endpoint) between the apremilast 30 mg and placebo groups were compared using the Cochran-Mantel-Haenszel test, adjusting for the strata of high-sensitivity CRP concentration from screening ($\leq 1.5 / > 1.5$ mg/dl) and baseline BASDAI score ($< 6.0 / \geq 6.0$). Patients prematurely discontinuing study drug due to lack of efficacy before the Week 16 evaluation were considered ASAS 20 non-responders. For any missing data in one or more ASAS domains, ASAS 20 response was derived using the last-observed value(s) for the missing domain(s) at Week 16. For secondary Week 24 response endpoints, the same approach of defining non-responders applied in the primary endpoint was used for patients meeting early escape criteria at Week 16. For continuous endpoints with missing values, last-observation-carried-forward methodology was used for missing values; for patients who escaped early at Week 16, baseline values were used for imputing missing values at Week 16 or 24. Statistical tests were conducted between groups for pre-defined primary and secondary endpoints in a hierarchical manner. A gatekeeping procedure using serial testing was applied to adjust for multiplicity. Efficacy endpoints beyond Week 24 were summarized using descriptive statistics. Based on data as observed, categorical data were summarized

using frequency counts; continuous data were summarized by change from baseline. Two-sided 95% CIs were provided as appropriate.

Change from baseline in mSASSS at Week 104 was calculated for the placebo, apremilast 20 mg, and apremilast 30 mg groups (per randomization). Comparisons to the complete OASIS dataset (full cohort) and OASIS-matched cohort were conducted at the $\alpha = 0.050$ (2-sided) level. An analysis of covariance model was used, including van der Waerden normal scores of change from baseline in mSASSS as the response variable with group/cohort as a factor and van der Waerden normal scores of the baseline value as a covariate. Change from baseline in mSASSS to Week 104 was summarized for the apremilast and OASIS populations. Radiographic progression was defined as change in mSASSS >0 in the AS-001 Week 104 analysis and change in mSASSS ≥ 1 in the OASIS analysis.

RESULTS

Patients. In total, 490 patients were randomized initially to placebo ($n = 164$), apremilast 20 mg ($n = 163$), or apremilast 30 mg ($n = 163$), of whom 58%, 66%, and 66% completed Week 104, respectively. Patient disposition at Weeks 16, 24, 52, and 104 and reasons for discontinuation are shown in **Figure 1**. At Week 16, a total of 149 patients met early escape criteria (apremilast 20 mg/30 mg: $n = 49$ [30%]; apremilast 30 mg/30 mg: $n = 49$ [30%]; placebo/apremilast 30 mg: $n = 51$ [31%]). Baseline patient demographics and disease characteristics represented a typical AS population with active disease and were generally comparable across treatment groups (**Table 1**). Mean (median) duration of AS (since diagnosis) was 10.6 (7.2) years, with 38.4% of

patients having a >10-year duration of AS before study entry. Mean BASDAI score was 6.4, indicating active disease, and mean BASMI-Linear score was 4.47, indicating moderate to severe limitation. Overall, 71% of patients had prior treatment with at least 1 conventional AS therapy, such as corticosteroids, NSAIDs or DMARDs (**Table 1**); 28% were taking at least 1 DMARD at baseline, with most receiving sulfasalazine.

Efficacy. The primary endpoint of ASAS 20 at Week 16 was not met. At Week 16, similar ASAS 20 responses were achieved: 37% (60/164) of patients receiving placebo, 35% (57/163) receiving apremilast 20 mg, and 33% (53/163) receiving apremilast 30 mg (mITT population, $p = 0.4383$; **Table 2**).

ASAS 20 response rates were generally similar at Week 24: 32% (52/164) with placebo, 36% (59/163) with apremilast 20 mg, and 34% (55/163) with apremilast 30 mg. ASAS 40 response rates (exploratory endpoint) were achieved by 18% of patients receiving placebo, 20% receiving apremilast 20 mg, and 15% receiving apremilast 30 mg. Additional secondary endpoints for disease activity and self-reported health-related outcomes at Week 24 are summarized (**Table 2**). Compared with placebo, no significant differences were observed with apremilast 30 mg in change from baseline in BASDAI, BASFI, ASQoL, SF-36v2 physical component summary, BASMI-Linear scores, or ASDAS. Proportions of patients achieving an ASAS 5/6 response, ASAS partial remission, and $\geq 20\%$ improvement in enthesitis by MASES were similar among placebo and apremilast treatment groups. No significant change in CRP was observed with apremilast versus placebo in all patients or in patients with baseline CRP >1.5 mg/dL.

Week 104 ASAS 20 response rates for patients remaining in the study were generally comparable across groups: 69.5% (66/95), 57.8% (63/109), and 53.3% (57/107) for those initially randomized to placebo, apremilast 20 mg, and apremilast 30 mg, respectively.

Imaging assessment. The radiographic subset included 92 patients initially receiving placebo, 104 receiving apremilast 20 mg, and 101 receiving apremilast 30 mg. Baseline demographics and disease characteristics of patients with radiographic data were similar to the overall study population. Mean baseline mSASSS was slightly higher in the apremilast 30 mg group versus the group initially randomized to placebo (baseline mSASSS: 12.8, 15.7, and 15.2 for placebo, 20 mg, and 30 mg, respectively). At Week 104, mean (SD) changes from baseline in mSASSS were 0.83 (3.6), 0.98 (2.2), and 0.57 (1.9) in patients initially randomized to placebo, apremilast 20 mg, and apremilast 30 mg, respectively (**Table 3**). Cumulative probability of changes in mSASSS from baseline to Week 104 showed 71% of patients receiving placebo, 67% receiving apremilast 20 mg, and 75% receiving apremilast 30 mg did not have radiographic progression (**Table 3**; **Figure S1**).

Mean (SD) MRI Berlin-modified ASspiMRI-a scores at baseline were 4.6 (7.0), 4.0 (5.7), and 4.1 (4.5) in the placebo (n = 22), apremilast 20 mg (n = 14), and apremilast 30 mg (n = 18) groups, respectively. At Week 104, mean (SD) change from baseline in MRI Berlin-modified ASspiMRI-a scores were -0.6 (3.7), -2.0 (3.2), and -1.2 (1.7), respectively. Mean (SD) MRI SPARCC scores at baseline were 4.4 (9.7), 6.0 (10.3), and 5.7 (9.4) in the placebo (n = 30), apremilast 20 mg (n = 24), and apremilast

30 mg (n = 23) groups, respectively. At Week 104, mean (SD) change from baseline in MRI SPARCC scores were -1.7 (5.7), -1.9 (5.5), and -2.1 (6.4), respectively.

Comparison to OASIS. Compared with the OASIS-matched group, apremilast cohorts had higher body weight, shorter AS disease duration, and higher DMARD usage. Baseline disease activity measures were slightly greater in the apremilast cohorts than the OASIS-matched cohort. Mean [SD] baseline mSASSS for the OASIS-matched and AS-001 cohorts were not similar (7.4 [10.8] and 12.3 [17.9], respectively). Baseline characteristics of the OASIS-matched and AS-001 cohorts are shown in **Table S1**. The OASIS-matched cohort had milder disease at baseline than AS-001 patients. Patients in AS-001 had a greater change in mSASSS from baseline and a higher proportion of patients with radiographic progression over 2 years (29.6% vs 17.9% [OASIS matched] and 23.6% [OASIS overall]; second reading of films; **Table 4**).

Safety. At Week 24, at least 1 AE was observed in half of patients receiving placebo (82/164; 50%), apremilast 20 mg (89/163; 55%), and apremilast 30 mg (85/163; 52%). Rates of serious AEs (SAEs) were 0.6% with placebo (n = 1), 1.8% with apremilast 20 mg (n = 3), and 3.7% with apremilast 30 mg (n = 6). SAEs included malignant melanoma (placebo); uveitis, alcoholic liver disease, urinary calculus, and renal colic (apremilast 20 mg); and AS exacerbation, chest pain, depression, vertigo, sick sinus syndrome, abdominal hernia, upper abdominal pain, and postoperative cardiac function disturbance (apremilast 30 mg). Rates of AEs leading to discontinuation were <10% in all treatment groups (placebo: 4%; apremilast 20 mg: 6%; apremilast 30 mg: 7%). At

Week 24, the most common AEs observed in any treatment group (placebo, apremilast 20 mg, and apremilast 30 mg) were diarrhea (3%, 12%, and 9%, respectively), headache (5%, 6%, and 10%, respectively), and nausea (4%, 6%, and 9%, respectively) (**Table 5**).

At Week 104, at least 1 AE was observed in 104 (64%) patients receiving apremilast 20 mg, 42 (58%) receiving apremilast 20 mg/30 mg, and in 219 (72%) receiving apremilast 30 mg. Rates of SAEs were 6% in the apremilast 20 mg group (n = 10), 6% in the apremilast 20/30 mg group (n = 4) and 9% in the apremilast 30 mg group (n = 28). Rates of AEs leading to discontinuation were ≤10% in all treatment groups (apremilast 20 mg: 10%; apremilast 20/30 mg: 1%; apremilast 30 mg: 10%). Two deaths occurred during the study, including thrombotic cerebral infarction (n = 1; apremilast 20/30 mg) and cardiopulmonary arrest (n = 1; apremilast 30 mg). At Week 104, the most common AEs observed in any treatment group (apremilast 20 mg, apremilast 20/30 mg, and apremilast 30 mg) were diarrhea (15%, 4%, and 11%, respectively), nasopharyngitis (13%, 11%, and 15%, respectively), upper respiratory infection (8%, 7%, and 7%, respectively) and nausea (7%, 7%, and 8%, respectively) (**Table 5**). Thirty-four patients (6.9%) had a medical history of uveitis. Among all patients, 17 (3.6%) reported uveitis during the apremilast-exposure period. Two patients (1 each in the apremilast 20 mg and 30 mg groups) had an SAE of uveitis; both had a history of uveitis.

DISCUSSION

This phase III study of patients with AS could not establish a treatment benefit for apremilast. The proportions of patients who achieved an ASAS 20 response at Weeks 16 (primary endpoint) and 24 with apremilast and placebo were similar, indicating no improvement in signs and symptoms of AS. There were also no significant differences at Week 24 in other measures of disease activity, including changes from baseline in BASDAI, BASFI, BASMI-Linear scores, ASDAS and CRP levels. In addition, no improvement was observed in health-related quality-of-life measures (ASQoL and SF-36v2 physical component summary). No differences were observed among treatment groups in MRI Berlin-modified ASspiMRI-a or MRI SPARCC scores at Week 104 versus baseline scores.

During the study, clinical safety and efficacy results were presented and provided at investigators' meetings to allow investigators to determine whether patients were obtaining sufficient clinical benefit to continue in the study during the long-term extension phase. On initial radiological assessment at the first reading, apremilast showed a modest improvement on radiograph progression over 2 years. Given that an initial signal of potential radiographic improvement was observed and the analysis had no comparator, a post-hoc analysis was undertaken utilizing the OASIS database as a historical comparison group to further understand the possible modest radiographic effect observed with apremilast. After matching for disease activity, a second reading of apremilast radiographs was not consistent with the first reading and did not show a halt in radiographic progression versus standard of care. However, limitations should be noted with this comparison, as there were differences in the demographic, disease

activity and radiographic data between patients in the OASIS and AS-001 studies. Furthermore, there were differences in the mSASSS scores between the radiographic re-reading and initial reading for the apremilast and OASIS cohorts. Therefore, effects on radiographic progression could not be accurately determined due to these discrepancies but are unlikely due to lack of effect on clinical disease activity, and if present, suggest a modest effect between the original readings and re-readings. Although efficacy in treatment of AS was not observed in this study, safety findings were consistent with previous clinical studies of apremilast and confirmed the acceptable safety and tolerability profile, with no new safety issues identified(23-28).

It is known that PDE4 inhibition raises intracytoplasmic AMP, which has a number of subsequent effects(9). These effects include enhanced production of anti-inflammatory IL-10, as well as activation of protein kinase A, which in turn inhibits NFkB-mediated production of pro-inflammatory cytokines, including TNF, IL-17, IL-23, interferon- γ . Overall, this pattern of cytokine modulation might be expected to be beneficial in the amelioration of symptoms and signs of AS. However, it is difficult to extrapolate from preclinical studies whether some of these mediators may be more dominantly affected than others and whether the effects may vary in different immune cell subtypes. A hypothetical speculation might be that the failure of apremilast to demonstrate efficacy in this study suggests a dominant effect of PDE4 inhibition on IL-23 in keeping with the failure of biologic DMARDs targeting p19 to show efficacy in such a disease phenotype.

In this phase III study, apremilast did not demonstrate a treatment benefit in patients with active AS. Safety and tolerability assessments were consistent with the

known safety profile of apremilast in other patient populations, including psoriasis and psoriatic arthritis.

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Data availability statement: Qualified researchers may request data from Amgen clinical studies. Complete details are available at <http://www.amgen.com/datasharing>.

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Figure Legend

Figure 1. Patient disposition through Week 104. BID: twice daily.

Table 1. Baseline demographics and clinical characteristics (mITT population*).

Characteristic	Apremilast		
	Placebo, n = 164	20 mg twice daily, n = 163	30 mg twice daily, n = 163
Age, yrs, mean (SD)	44.0 (12.9)	45.2 (11.9)	44.8 (11.8)
Female, n (%)	40 (24.4)	42 (25.8)	56 (34.4)
Race, n (%)			
White	158 (96.3)	154 (94.5)	158 (96.9)
Asian	2 (1.2)	2 (1.2)	0 (0.0)
Black	1 (0.6)	2 (1.2)	2 (1.2)
Pacific Islander	1 (0.6)	0 (0.0)	0 (0.0)
Other	1 (0.6)	2 (1.2)	3 (1.8)
Missing	1 (0.6)	3 (1.8)	0 (0.0)
Region, n (%)			
North America	26 (15.9)	26 (16.0)	24 (14.7)
Europe	114 (69.5)	115 (70.6)	125 (76.7)
Rest of world	24 (14.6)	22 (13.5)	14 (8.6)
Weight, kg, mean (SD)	80.3 (17.7)	79.4 (15.3)	79.8 (17.2)
BMI, kg/m ² , mean (SD)	26.9 (5.4)	27.0 (4.5)	27.0 (4.8)

AS diagnosis duration [†] , yrs, mean (SD)	10.4 (10.4)	11.1 (11.3)	10.3 (9.9)
CRP category at screening, n (%)			
Normal (≤ 1.5 mg/dl)	118 (72.0)	117 (71.8)	118 (72.4)
Elevated (> 1.5 mg/dl)	46 (28.0)	46 (28.2)	45 (27.6)
Positive HLA-B27, n (%)	140 (85.4)	136 (83.4)	131 (80.4)
Prior conventional therapy use [‡] , n (%)	114 (69.5)	118 (72.4)	118 (72.4)
Prior DMARD use, n (%)	49 (29.9)	47 (28.8)	61 (37.4)
Methotrexate (mean dose: 14.6 mg/week)	15 (9.1)	17 (10.4)	13 (8.0)
Sulfasalazine (mean dose: 1.9 g/day)	39 (23.8)	32 (19.6)	46 (28.2)
Hydroxychloroquine (mean dose: 200 mg/day)	0 (0.0)	1 (0.6)	1 (0.6)
Other (not specified)	0 (0.0)	0 (0.0)	3 (1.8)
Glucocorticoid (mean dose: 5.5 mg/day), n (%)			
With baseline DMARD use	8 (4.9)	4 (2.5)	6 (3.7)
Without baseline DMARD use	1 (0.6)	1 (0.6)	5 (3.1)
NSAID use, n (%)	145 (88.4)	128 (78.5)	133 (81.6)
Narcotic and/or analgesic use [§] , n (%)	11 (6.7)	20 (12.3)	18 (11.0)

Patient Global Assessment of Disease Activity (0–10, NRS), mean (SD)	7.2 (1.7)	7.0 (1.8)	6.9 (1.7)
Total back pain (0–10, NRS), mean (SD)	7.2 (1.5)	7.1 (1.5)	6.9 (1.7)
ASDAS, mean (SD)	3.7 (0.8)	3.6 (0.9)	3.6 (0.8)
BASFI score (0–10, NRS), mean (SD)	5.8 (2.2)	5.8 (2.1)	5.7 (2.1)
BASDAI score (0–10, NRS), mean (SD)	6.5 (1.3)	6.5 (1.4)	6.4 (1.4)
BASMI score (0–10, NRS), mean (SD)	4.4 (1.6)	4.6 (1.7)	4.4 (1.7)
ASQoL score (0–18), mean (SD)	9.1 (4.6)	8.4 (4.5)	8.6 (4.9)
SF-36v2 PCS, mean (SD)	32.6 (7.8)	31.9 (8.6)	32.2 (8.8)
SF-36v2 MCS, mean (SD)	46.9 (10.4)	49.5 (8.9)	47.5 (9.5)

*The n reflects the number of modified intent-to-treat patients; actual number of patients available for each parameter may vary.

†Low back pain and stiffness duration.

‡Includes corticosteroids, DMARDs and NSAIDs.

§Baseline medications used ≤28 days on/before the first dose of investigational drug; use of permitted medications must have continued concomitantly per protocol.

AS: ankylosing spondylitis; ASDAS: Ankylosing Spondylitis Disease Activity Score;

ASQoL: Ankylosing Spondylitis Quality of Life Questionnaire; BASDAI: Bath Ankylosing

Spondylitis Disease Activity Index; BASMI: Bath Ankylosing Spondylitis Metrology

Index; BASFI: Bath Ankylosing Spondylitis Functional Index; CRP: C-reactive protein;

DMARD: disease-modifying anti-rheumatic drug; MCS: mental component summary;

mITT: modified intention to treat; NRS: numerical rating scale; NSAID: non-steroidal

anti-inflammatory drug; PCS: physical component summary; SF-36v2: 36-item Short-Form Health Survey version 2.

Table 2. Summary of primary, secondary, and exploratory efficacy endpoints (mITT population*).

Endpoint	Apremilast (mg)			Difference for apremilast 30 mg vs placebo (95% CI)	<i>P</i> value for apremilast 30 mg vs placebo
	Placebo, n = 164	20 mg twice daily, n = 163	30 mg twice daily, n = 163		
Primary endpoint (Week 16)					
ASAS 20 response, n (%)	60 (37)	57 (35)	53 (33)	−4.1 (−14.3, 6.2)	0.43
Secondary endpoints (Week 24)					
ASAS 20 response, n (%)	52 (32)	59 (36)	55 (34)	2.0 (−8.1, 12.2)	0.70
Change from baseline in BASFI (0–10), LSM (SE)	−0.94 (0.14) (n = 164)	−1.11 (0.14) (n = 162)	−0.99 (0.14) (n = 160)	−0.05 (−0.41, 0.32)	0.80
Change from baseline in BASDAI (0–10), LSM (SE)	−1.21 (0.14) (n = 164)	−1.30 (0.14) (n = 162)	−1.18 (0.14) (n = 160)	+0.03 (−0.33, 0.40)	0.86
Change from baseline in ASQoL (0–18), LSM (SE)	−1.77 (0.28) (n = 160)	−1.50 (0.28) (n = 161)	−1.52 (0.28) (n = 156)	+0.25 (−0.49, 0.99)	0.51
Change from baseline in SF-36v2 PCS, LSM (SE)	3.50 (0.55) (n = 160)	3.46 (0.55) (n = 161)	3.79 (0.56) (n = 155)	0.29 (−1.18, 1.76)	0.70

Change from baseline in SF-36v2 MCS, LSM (SE)	1.93 (0.55) (n=160)	1.09 (0.55) (n=161)	1.07 (0.55) (n=155)	-0.87 (-2.33, 0.59)	0.24
Change from baseline in BASMI-Linear, LSM (SE)	-0.19 (0.04) (n = 163)	-0.16 (0.04) (n = 162)	-0.13 (0.04) (n = 158)	0.06 (-0.06, 0.17)	0.33
Exploratory endpoints (Week 24)					
Proportion of patients achieving ASAS 40 response, n (%) [†]	30 (18.3)	32 (19.6)	24 (14.7)	-3.6 (-11.5, 4.3)	0.39
ASAS 5/6 response, n (%)	27 (17)	25 (15)	26 (16)	-0.5 (-8.4, 7.3)	0.90
ASAS partial response, n (%)	7 (4)	10 (6)	7 (4)	0 (-4.3, 4.4)	0.99
Change from baseline in ASDAS, LSM (SE)	-0.39 (0.06)	-0.47 (0.06)	-0.42 (0.06)	-0.03 (-0.19, -0.12)	0.71
≥20% Improvement in enthesitis by MASES, n/N (%)	52/117 (44)	46/113 (41)	42/101 (42)	-3.0 (-16.1, 10.1)	0.66
Mean (SE) change from baseline in CRP (mg/dl) in all patients	0.06 (0.09) (n = 164)	0.00 (0.09) (n = 163)	0.00 (0.09) (n = 163)	-0.07 (-0.31, 0.18)	0.60
Mean (SE) change from baseline in CRP in patients with baseline CRP >1.5 mg/dl	0.08 (0.23) (n = 46)	-0.48 (0.23) (n = 46)	-0.01 (0.23) (n = 45)	-0.09 (-0.74, 0.56)	0.79

*Baseline observation carried forward for early escape or discontinuation due to lack of efficacy; last observation carried forward for other early discontinuation.

†ASAS 40 response criteria: in Patient Global Assessment of Disease (0–10 unit), Total Back Pain, Function (BASFI score), and Inflammation (mean of BASDAI Questions #5 and #6 for morning stiffness), 3 of 4 domains improved by $\geq 40\%$ and ≥ 2 units on scale of 0–10 and no worsening in remaining domain.

ASAS: Assessment of the SpondyloArthritis International Society; ASDAS: Ankylosing Spondylitis Disease Activity Score; ASQoL: Ankylosing Spondylitis Quality of Life Questionnaire; BASDAI: Bath Ankylosing Spondylitis Disease Activity Index; BASFI: Bath Ankylosing Spondylitis Functional Index; BASMI-Linear: Bath Ankylosing Spondylitis Metrology Index-Linear; CRP: C-reactive protein; LSM: least-squares mean; MASES: Maastricht Ankylosing Spondylitis Enthesitis Score; SF-36v2 PCS: 36-item Short-Form Health Survey version 2 physical component summary score.

Table 3. Change from baseline in radiographic mSASSS and proportion of patients with no radiographic progression at Week 104 (original reading of films).

	Placebo/apremilast 30 mg twice daily, n = 92	Apremilast 20/20 mg and 20/30 mg twice daily, n = 104	Apremilast 30 mg/ 30 mg twice daily, n = 101	All N = 297
Baseline mSASSS, mean (SD)	12.83 (18.63)	15.69 (19.65)	15.16 (20.75)	14.62 (19.70)
Change from baseline at Week 104, mean (SD)*	0.83 (3.57)	0.98 (2.18)	0.57 (1.86)	0.79 (2.60)
Proportion of patients with no radiographic progression [†] , n (%)	65 (70.7)	70 (67.3)	76 (75.2)	211 (71.0)

*As observed.

[†] Radiographic progression was defined as a change in mSASSS >0.

CRP: C reactive protein; mSASSS: modified Stoke Ankylosing Spondylitis Spine Score.

Table 4. Comparison of change from baseline in radiographic mSASSS at Week 104: AS-001 vs OASIS data (second reading of films).

	AS-001 apremilast 30 mg twice daily population, n = 98	OASIS-matched population, n = 56	OASIS overall population, n = 178
Baseline mSASSS, mean (SD)	12.3 (18.0)	7.4 (10.8)	7.9 (12.6)
mSASSS to Week 104, mean change from baseline (SD)	0.87 (2.5)	0.55 (3.2)	0.63 (2.5)
Patients without radiographic progression*, %	70.4	82.1	76.4

*Radiographic progression was defined as a change in mSASSS ≥ 1 for this analysis.

mSASSS: modified Stoke Ankylosing Spondylitis Spine Score; OASIS: Outcome in Ankylosing Spondylitis International Study.

Table 5. Overview of adverse events at Weeks 24 and 104 (safety population).

	Apremilast					
	Placebo, n = 164	20 mg twice daily, n = 163		30 mg twice daily, n = 163		EAIR/100 Patient- Years
		EAIR/100 Patient- Years	n (%)	EAIR/100 Patient- Years	n (%)	
Week 24 (safety population)		63.3		63.1		67.5
Any TEAE	82 (50)	184.5	89 (55)	223.2	85 (52)	193.6
Any serious TEAE	1 (1)	1.6	3 (2)	4.8	6 (4)	9.0
Any TEAE leading to discontinuation	6 (4)	9.5	9 (6)	14.4	12 (7)	17.9
Week 24 AEs in ≥5% in any group						
Headache	8 (5)	13.1	9 (6)	14.9	16 (10)	25.4
Nausea	6 (4)	9.6	10 (6)	16.8	14 (9)	22.4
Nasopharyngitis	6 (4)	9.8	9 (6)	14.7	7 (4)	10.6
Diarrhea	5 (3)	8.0	20 (12)	35.1	15 (9)	23.8
Upper abdominal pain	3 (2)	4.8	3 (2)	4.8	9 (6)	13.7

Week 104	Apremilast 20 mg twice daily*, n = 163		Apremilast 20/30 mg twice daily†, n = 72		Apremilast 30 mg twice daily‡, n = 305	
Patient years	181.2		113.7		492.8	
	n (%)	EAIR/100 Patient Years	n (%)	EAIR/100 Patient Years	n (%)	EAIR/100 Patient Years
Any TEAE	104 (64)	131.6	42 (58)	76.0	219 (72)	97.1
Any serious TEAE	10 (6)	5.7	4 (6)	3.7	28 (9)	6.0
Any TEAE leading to discontinuation	16 (10)	8.9	1 (1)	0.9	31 (10)	6.4
Week 104: AEs in ≥5% in any group						
Diarrhea	25 (15)	16.5	3 (4)	2.7	34 (11)	7.6
Nasopharyngitis	21 (13)	13.3	8 (11)	7.6	46 (15)	10.4
Upper respiratory infection	13 (8)	7.7	5 (7)	4.6	22 (7)	4.8
Nausea	12 (7)	7.2	5 (7)	4.7	24 (8)	5.2
Headache	10 (6)	5.9	3 (4)	2.7	22 (7)	4.7
Bronchitis	6 (4)	3.4	5 (7)	4.6	8 (3)	1.7
Muscle spasm	5 (3)	2.8	4 (6)	3.7	2 (1)	0.4
Frequent bowel movements	2 (1)	1.1	4 (6)	3.7	3 (1)	0.6

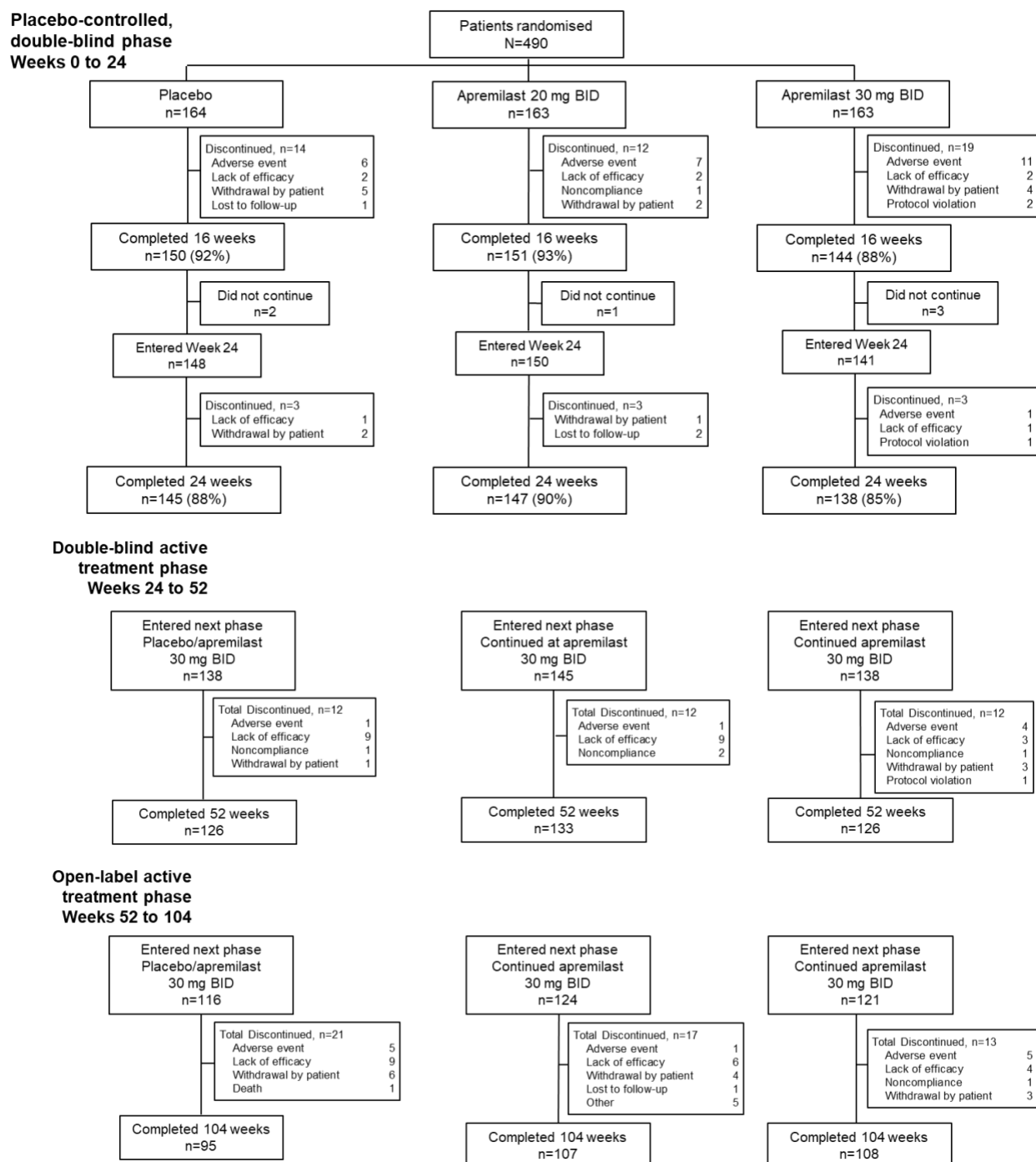
*Includes patients randomized to apremilast 20 mg at baseline who continued on apremilast 20 mg.

†Includes patients treated with apremilast 20 mg from Week 0 who escaped to apremilast 30 mg.

‡Includes patients who were treated with apremilast 30 mg from Week 0 and patients treated with placebo from Week 0 who transitioned to apremilast 30 mg; these patients' TEAEs that occurred under 30 mg treatment are counted.

AE: adverse event; EAIR: exposure-adjusted incidence rate; TEAE: treatment-emergent adverse event.

Figure 1. Patient disposition through Week 104. BID: twice daily.



Supplementary Materials

Table S1. Baseline demographics and disease characteristics in OASIS matched cohort and AS-001 population.

Characteristic	OASIS matched cohort, n = 56	AS-001 Population		
		Placebo/ apremilast 30 mg twice daily, n = 87	Apremilast 20 mg twice daily, n = 101	Apremilast 30 mg twice daily, n = 98
Age, yrs, mean (SD)	44.3 (13.1)	42.5 (11.9)	44.7 (11.7)	44.6 (11.1)
Female, n (%)	21 (37.5)	18 (20.7)	23 (22.8)	36 (36.7)
Region, n (%)				
North America	0 (0.0)	10 (11.5)	17 (16.8)	14 (14.3)
Europe	56 (100)	63 (72.4)	71 (70.3)	75 (76.5)
Rest of world	0 (0.0)	14 (16.1)	13 (12.9)	9 (9.2)
Weight, kg, mean (SD)	71.9 (15.3)	81.5 (15.9)	78.5 (13.3)	80.0 (18.1)
BMI, kg/m ² , mean (SD)	25.1 (5.1)	26.7 (4.9)	26.8 (4.0)	27.1 (5.0)
AS duration, yrs, mean (SD)	22.4 (12.6)	10.0 (10.1)	11.1 (11.4)	9.7 (9.1)
Baseline DMARD use, n (%)	2 (3.6)	28 (32.2)	33 (32.7)	38 (38.8)
Baseline NSAID use, n (%)	38 (67.9)	77 (88.5)	81 (80.2)	80 (81.6)
Total back pain (0–10, NRS), mean (SD)	6.2 (1.4)	7.1 (1.6)	7.1 (1.5)	6.8 (1.7)
Baseline BASFI score (0–10, NRS), mean (SD)	5.1 (2.2)	5.6 (2.1)	5.7 (2.0)	5.5 (2.1)
Baseline BASDAI score (0–10, NRS), mean (SD)	5.6 (1.3)	6.3 (1.3)	6.5 (1.3)	6.3 (1.3)
Baseline BASMI-Linear score (0–10, NRS), mean (SD)	4.1 (1.6)	4.2 (1.4)	4.6 (1.7)	4.3 (1.6)

AS: ankylosing spondylitis; BASDAI: Bath Ankylosing Spondylitis Disease Activity Index; BASFI: Bath Ankylosing Spondylitis Functional Index; BASMI-Linear: Bath Ankylosing Spondylitis Metrology Index-Linear; BMI: body mass index; DMARD: disease-modifying anti-rheumatic drug; OASIS: Outcome in Ankylosing Spondylitis International Study; NRS: numerical rating scale; NSAID: non-steroidal anti-inflammatory drug.

Figure S1. Cumulative probability of change from baseline in the modified Stoke Ankylosing Spondylitis Spine Score at Week 104 (data shown represent the total AS-001 study population). The smallest detectable change was 3.37.

