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Research Article

Patient-Centered Evaluation of Visual Function, Pain, and Healing Response in Diabetic Retinopathy Patients Undergoing Panretinal Photocoagulation with Argon and PASCAL Lasers: A Comparative Study

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Abstract

Purpose:This study aimed to evaluate patient-centered outcomes—including visual function, procedural discomfort, and healing response—following panretinal photocoagulation (PRP) with either a 532-nm continuous-wave argon laser or a 577-nm short-pulse PASCAL laser in diabetic retinopathy patients.

Methods:A prospective, interventional study was conducted in a single ophthalmic center involving patients with proliferative diabetic retinopathy. Patients were randomly assigned to receive PRP via single-spot argon laser or short-pulse pattern scanning laser. Outcomes assessed over 12 weeks included best corrected visual acuity (BCVA), contrast sensitivity, color vision, pain perception, treatment duration, and changes in central retinal thickness (CRT) and peripapillary vascular density using OCT and OCT-A.

Results:Both treatment modalities preserved BCVA, chromatic perception, and contrast sensitivity throughout the follow-up period. Patients treated with the short-pulse laser reported significantly lower discomfort and shorter session times. Notably, an increase in CRT and more extensive scar expansion were observed in the continuous-wave laser group. OCT-A imaging showed restoration of peripapillary vascular density at week 12 in both groups.

Conclusion:Although functional outcomes were comparable, PASCAL laser offered a more comfortable experience with minimized retinal thickening and scarring. These findings support the use of short-pulse laser PRP as a patient-friendly alternative for managing diabetic retinopathy.

Keywords: Diabetic retinopathy, panretinal photocoagulation, PASCAL laser, Argon laser, patient pain, OCT-A, central retinal thickness, visual function.

Introduction

Diabetic retinopathy (DR) represents one of the most significant threats to vision among the global working-age population. It manifests due to chronic hyperglycemia-induced damage to retinal vasculature, eventually leading to capillary leakage, ischemia, and neovascularization. In advanced stages, proliferative diabetic retinopathy (PDR) can result in irreversible visual loss unless treated promptly.

Panretinal photocoagulation (PRP) remains the gold standard in the management of high-risk PDR. By inducing controlled thermal burns in the peripheral retina, PRP reduces ischemic drive and the release of vascular endothelial growth factor (VEGF), thereby suppressing neovascular proliferation. However, traditional PRP using continuous-wave (CW) argon lasers often results in considerable collateral damage, including macular edema, choroidal ischemia, and extended retinal scarring.

In response to these limitations, newer modalities like the 577-nm PASCAL laser system have emerged. Unlike single-spot CW lasers, PASCAL delivers short-duration, patterned laser burns, which are hypothesized to minimize heat diffusion, improve procedural comfort, and reduce post-treatment inflammation. While both modalities remain clinically accepted, their comparative performance in preserving visual function, limiting scar expansion, and optimizing patient tolerance warrants closer investigation.

This study explores these parameters using a prospective, interventional approach with a strong focus on functional and experiential outcomes, including pain perception and recovery time.

Objectives

General Objective

To evaluate and compare the functional outcomes and patient experiences of diabetic retinopathy patients treated with panretinal photocoagulation using either a 532-nm continuous-wave argon laser or a 577-nm short-pulse PASCAL laser.

Specific Objectives

- To assess changes in visual acuity, contrast sensitivity, and color vision across both laser treatment

groups over a 12-week follow-up.

- To analyze differences in central retinal thickness (CRT) post-treatment using spectral-domain optical coherence tomography (SD-OCT).
- To monitor peripapillary vascular changes using OCT angiography (OCT-A).
- To compare patient-reported pain scores and total treatment time between the two modalities.
- To quantify scar expansion and assess its progression in both treatment groups.

Methods

This was a prospective, interventional, single-blind case series conducted at a tertiary ophthalmic center. Eligible participants were adults (≥18 years) diagnosed with severe or proliferative diabetic retinopathy based on Early Treatment Diabetic Retinopathy Study (ETDRS) criteria and without evidence of macular edema.

Patient Selection

Inclusion criteria:

- Severe NPDR or PDR without macular edema
- Clear media for retinal imaging
- No prior PRP or recent anti-VEGF treatment

Exclusion criteria:

- Presence of advanced cataract, vitreous hemorrhage, or significant CRT (>300 μm)
- Retinal or choroidal comorbidities
- History of optic neuropathy

Following informed consent, participants were randomized into two groups:

- **Group A**: Treated with 532-nm argon single-spot laser (OcuLight®, IRIDEX)
- **Group B**: Treated with 577-nm PASCAL short-pulse patterned laser (PASCAL Synthesis®, Topcon)

Procedural Protocol

All patients underwent bilateral pupillary dilation with a combination of phenylephrine and tropicamide.

Topical anesthesia (proparacaine) was instilled prior to PRP. A single retina specialist performed all laser treatments. Each eye received PRP in two sessions spaced two weeks apart.

- **Argon Laser Parameters**:
    - Spot size: 200 µm
    - Pulse duration: variable, standard CW
    - Burn pattern: single spots spaced one diameter apart
- **PASCAL Laser Parameters**:
    - Spot size: 200 µm
    - Pulse duration: short (10–20 ms)
    - Burn pattern: 3x3 grid with 1.25 µm spacing

Clinical Assessments

Patients were evaluated at baseline, and post-treatment at week 1, week 4, week 8, and week 12.

Evaluations included:

- **Visual acuity** (ETDRS charts)
- **Contrast sensitivity** (Pelli-Robson chart)
- **Color vision** (Ishihara plates)
- **CRT and scar diameter** (Spectral-domain OCT)
- **Papillary vascular density** (OCT-Angiography)
- **Pain perception** (0–10 numeric pain rating scale)
- **Session duration and number of burns** (recorded immediately post-procedure).

Results

Visual Function

Across the 12-week follow-up, both groups maintained stable visual acuity, contrast sensitivity, and chromatic perception. No significant intergroup differences were observed at any time point ($p > 0.05$), suggesting that both lasers preserve central visual function equally well.

Pain Scores and Treatment Time

Patients treated with the PASCAL laser reported significantly lower pain scores (mean 6.0 ± 1.4) compared to the argon group (mean 8.5 ± 1.5, $p < 0.05$). Session duration was also significantly shorter with the PASCAL laser (mean 4.6 ± 2.6 minutes vs. 7.7 ± 5.3 minutes in the argon group), despite a higher number of laser burns delivered.

Central Retinal Thickness

In the argon group, CRT increased notably by week 8 (287 ± 59 µm), showing a statistically significant rise from baseline ($p < 0.001$). In contrast, the PASCAL group exhibited minimal changes across all time points, indicating better control over retinal inflammation and edema.

Scar Expansion

Laser scars in the argon group expanded progressively, reaching a mean diameter of 354 ± 46 µm by week 12. The PASCAL group showed smaller, more contained scarring (214 ± 31 µm at week 12), demonstrating reduced collateral damage.

Vascular Density Recovery

Both groups experienced a transient dip in peripapillary vascular density post-PRP, but levels returned to baseline by week 12, confirming successful vascular autoregulation and perfusion recovery.

Table 1: Central Retinal Thickness (CRT) Comparison

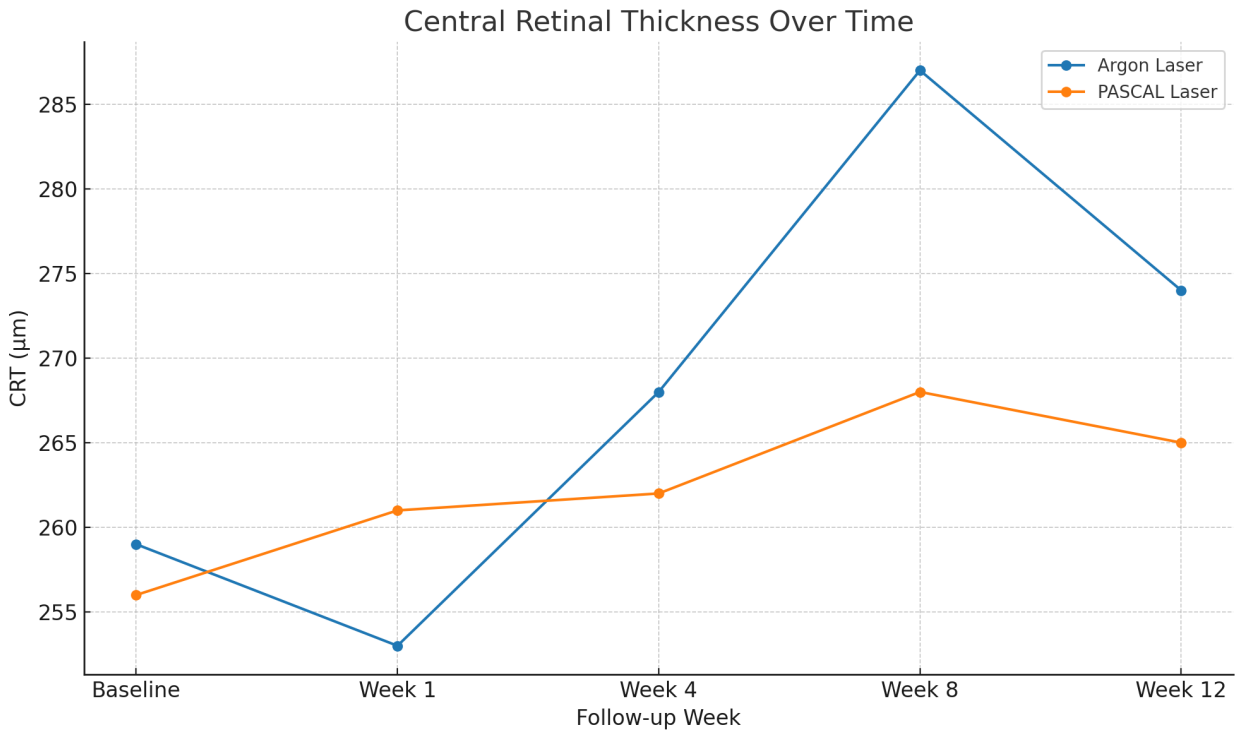
Follow-up Week	CRT (µm) - Argon Laser	CRT (µm) - PASCAL Laser
Baseline	259	256
Week 1	253	261
Week 4	268	262
Week 8	287	268
Week 12	274	265

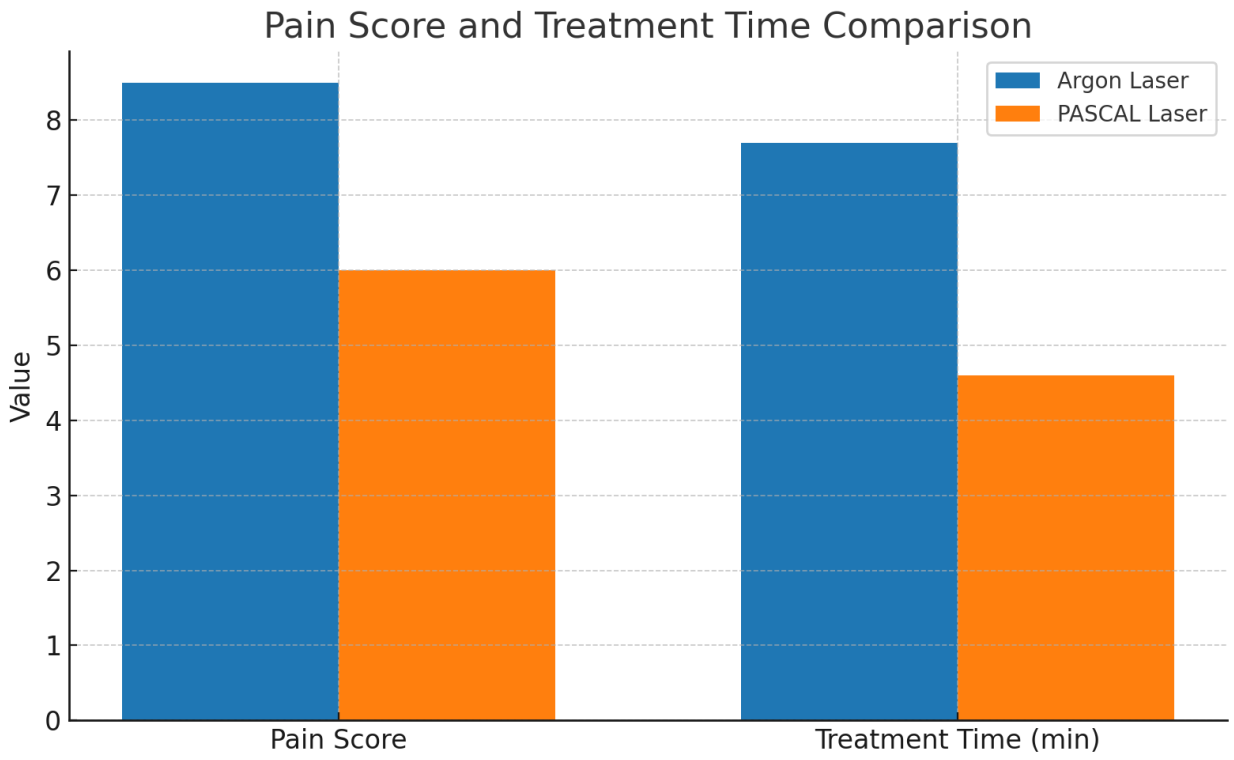
Table 2: Pain Score and Treatment Duration

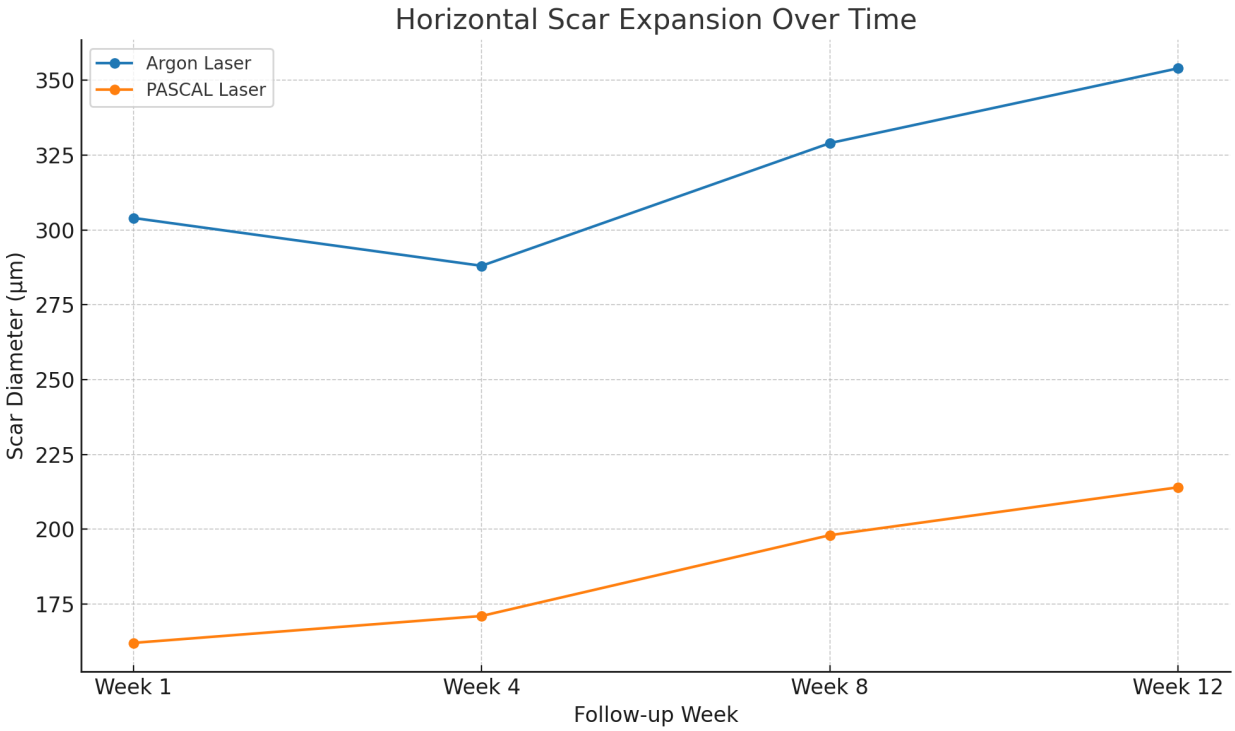
Parameter	Argon Laser	PASCAL Laser
Pain Score (0–10)	8.5	6.0
Treatment Duration (minutes)	7.7	4.6

Table 3: Horizontal Scar Expansion Over Time

Follow-up Week	Scar Diameter (µm) - Argon	Scar Diameter (µm) - PASCAL
Week 1	304	162
Week 4	288	171
Week 8	329	198
Week 12	354	214




Pain Score and Treatment Time Comparison
Argon Laser
PASCAL Laser
Value
0
1
2
3
4
5
6
7
8
Pain Score
Treatment Time (min)


Horizontal Scar Expansion Over Time
Argon Laser
PASCAL Laser
Scar Diameter (µm)
175
200
225
250
275
300
325
350
Week 1
Week 4
Week 8
Week 12
Follow-up Week

Discussion

This study provides valuable insights into the distinct clinical and procedural differences between traditional continuous-wave (CW) single-spot panretinal photocoagulation (PRP) and advanced short-pulse pattern scanning laser systems, particularly the PASCAL laser. Although both treatment modalities were found to be equally effective in halting disease progression and preserving central visual acuity, significant disparities emerged in terms of patient comfort, tissue response, and overall treatment experience.

One of the most compelling findings was the **marked improvement in patient tolerance** associated with the PASCAL laser. Patients undergoing treatment with the short-pulse laser consistently reported **lower pain scores** and **shorter treatment durations**, factors which are particularly relevant in real-world clinical practice where patient anxiety, fatigue, and compliance can significantly impact therapeutic success. For many elderly or chronically ill patients, lengthy or painful procedures can lead to incomplete treatment courses or reluctance to undergo follow-up sessions. The PASCAL system's efficient energy delivery and shorter exposure times reduce both psychological and physical treatment burdens, potentially leading to better adherence and treatment outcomes.

From a physiological standpoint, the study reinforces existing literature that **shorter pulse durations result in reduced thermal diffusion** into surrounding retinal tissues. This targeted delivery minimizes injury to adjacent photoreceptors, retinal pigment epithelium (RPE), and other neurosensory layers. As a consequence, inflammatory cytokine cascades triggered by tissue damage—such as the upregulation of IL-6, MCP-1, and VEGF—are subdued, resulting in **lower central retinal thickness (CRT)** and **more contained laser scars** over time. These observations not only reflect improved structural preservation but also suggest a decreased risk of secondary complications like macular edema or chorioretinal scarring.

Furthermore, the **differences in scar expansion** highlight another critical advantage of the PASCAL system. The argon laser group exhibited significantly greater horizontal scar growth by week 12, which may correlate with broader photoreceptor apoptosis and secondary gliotic reactions. In contrast, PASCAL-treated eyes demonstrated **minimal scar progression**, indicating a more controlled and localized photocoagulative response—an important factor for long-term retinal stability and functional preservation.

In summary, while the primary endpoint of visual acuity preservation was achieved with both laser modalities, the PASCAL system demonstrated **superior outcomes** in secondary parameters including **pain**

reduction, tissue preservation, and recovery dynamics. These findings advocate for a paradigm shift toward patient-centered laser therapies that not only control disease but also prioritize treatment tolerability and safety.

Conclusion

Panretinal photocoagulation with short-pulse 577-nm PASCAL laser offers a compelling advantage in terms of patient comfort, procedural efficiency, and retinal tissue preservation, without compromising therapeutic efficacy. For clinicians managing diabetic retinopathy, this modality represents a modern, patient-centered alternative to traditional argon laser therapy.

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