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**Original article**

# Combination of a non-ablative 1,927 nm thulium fiber fractional laser and autologous platelet-rich plasma in treatment of male androgenetic alopecia: A pilot study

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***Background:*** Platelet-rich plasma (PRP) is composed of multiple essential growth factors which can stimulate hair growth by promoting cell proliferation, prolonging cell survival and the anagen phase of hair follicles. Fractional laser can create proper wounding which results in subsequent platelet activation and might promote hair growth. Nevertheless, clinical trials related to the efficacy and safety of the combination of fractional laser and PRP have not been established.

***Objectives:*** To investigate the efficacy and safety of the combination of non-ablative fractional laser and platelet-rich plasma for the treatment of male androgenetic alopecia (AGA).

**Methods:** A total of nine men were recruited for a pre- and post- treatment study. Three sessions of fractional 1,927 nm Thulium-doped fiber laser (Lasemd, Lutronic Inc, South Korea) followed by PRP injection on the affected area were performed at 1-month interval. Non-activated PRP was prepared using Ycellbio-kit (Ycellbio Medical Co., Ltd., South Korea). Hair growth was evaluated by using: (i) standardized global photographs; (ii) hair mass index (Hair check system®); (iii) target area hair counts (Trichoscale, Fotofinder); and, (iv) patient self-assessment questionnaires at baseline, then 3 and 6 months after the last treatment.

***Results:*** Nine men with Norwood-Hamilton classification of grade II-IV, mean age 41.3 years old (range 32 - 55) completed the study. At 6 months after completing the three treatment sessions, the terminal hair density significantly increased from baseline by 28.1% (99.1 to 127 = 27.9 hairs/cm$^2$, $P = 0.011$. The increased percentage of total hair density was 9.7% (149.7 to 164.2 = 14.5 hairs/cm$^2$, $P = 0.015$). The hair mass index was increased from baseline by 26.4% (16 to 20.2, $P = 0.024$). The global photography showed improvement in almost all patients: 3 moderate (41 - 70%); 4 slight improvement (1 - 40%) and 2 no change as compared to baseline. The treatment was fair tolerated and the mean visual analog scale (VAS) for pain was 0.8 (0 - 2) and 4.2 (2 - 6) for laser treatment and PRP injection, respectively. Adverse effects were transient erythema and mild burning sensation on the treated areas.

***Conclusion:*** A combination of a 1,927 nm fractional Thulium-doped fiber laser and PRP is considered safe, and effective strategy for the treatment of male AGA. However, to determine the efficacy of this combination therapy, larger sample sizes and longer follow-up durations, randomized, placebo-controlled trials are suggested.

***Keywords:*** Androgenetic alopecia, platelet-rich plasma, fractional laser.

Androgenetic alopecia (AGA) is a common hair disorder in male and female populations causing hair miniaturization by multiple factors, mainly, androgens, and genetic backgrounds.[1] In Thai populations, 40% of men develop hair thinning by the age of 50 years old. [2] Men who suffer from hair thinning problem lose their self-confidence resulted from anxiety, depression and impaired quality of life.

At present, US Food and Drug Administration (FDA) approved in treating AGA includes topical minoxidil, oral finasteride and low-level laser therapy.[3] According to some standard treatment dissatisfaction, new alternative treatment such as fractional laser therapy, autologous platelet-rich plasma

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(PRP) and hair transplantation were used more frequently in clinical practices.

Platelet-rich plasma (PRP) is composed of multiple essential growth factors secreting from platelet granules, namely vascular endothelial growth factor (VEGF), platelet-derived growth factor (PDGF), transforming growth factor-β (TGF-β), insulin-like growth factor 1, 2 (IGF-1, 2), epidermal growth factor (EGF), hepatocyte growth factor (HGF) and fibroblast growth factor (FGF). [4] These growth factors can stimulate hair growth by promoting cell proliferation, prolonging cell survival and the anagen phase of hair follicles. PRP has not only been used in hair disorder but also in other medical purposes, e.g., gingival regeneration[5], bone and cartilage healing, tenosynovitis [6], chronic wounds [7] and aesthetics. [8-10] Previous in vitro studies demonstrated the effect of activated PRP on dermal papilla cells cultured which comprised up regulation of extracellular signal-regulated kinases (ERK), Akt (protein kinase B), bcl-2, beta-catenin activity and FGF-7 expression. All of the aforementioned actions resulted in hair growth stimulation. [11, 12] Fractional non-ablative lasers either Erbium/glass or thulium lasers with optimum settings have been found to stimulate hair growth by Wnt/beta-catenin pathway up regulation and become one of the new effective treatment of androgenetic alopecia. [13, 14] However, certain mechanism of fractional lasers induced hair growth is not well established, some authors postulated the hypothesis of the trauma-induced wound healing effecting hair epithelial proliferation. [14] Currently, autologous PRP has been used as a single or combination therapy with either fractional laser or microneedling in treating AGA. Nevertheless, the clinical trial related to the efficacy and safety of the combination therapy has not been well studied. Our trial aimed to investigate the efficacy and safety of a combination of non-ablative fractional laser and platelet-rich plasma (PRP) for the treatment of mild to moderate severity of male androgenetic alopecia (AGA). We hypothesized that fractional laser could create proper wounding which resulted in subsequent platelet activation and might synergize with PRP in promoting hair proliferation.

## Methods

This is a pilot, open-label, prospective, pre- and post- treatment study approved by institutional review board Chulalongkorn University. Nine Thai men with androgenetic alopecia, Norwood-Hamilton classification II-IV, age between 18 - 60 years old were recruited. Exclusion criteria were as follows: 1) history use of drugs that effected hair growths within the past 6 months prior to the study (finasteride, dutasteride, minoxidil, cyproterone acetate, spironolactone, ketoconazole, anabolic steroids, cyclosporine, diazoxide, phenytoin, psoralens); 2) underlying systemic disease; and, 3) previous hair transplantation.

Fractional 1,927 nm Thulium-doped fiber laser (Lasemd, Lutronic Inc, South Korea) with parameters of 3 - 5 Watts, 5 - 10 mJ/spot, 0.5 - 20 ms, 3 - 5 passes followed by PRP injection were used on hair thinning area. PRP was extracted by using Ycellbio-kit (Ycellbio Medical Co., Ltd., South Korea) with the in-house protocol using centrifuge machine (Eppendorf 5804R, Germany). The whole blood was drawn by venipuncture into syringe containing anticoagulant citrate dextrose solution formula A (ACD-A) with blood: ACD-A solution = 9:1. The small amount of blood samples (0.05 ml) before and after centrifuged from nine male patients were collected and sent to hematology laboratory for complete blood count analysis. The total volume of blood 30 ml was divided into two tubes (15 ml each) which were then centrifuged at 3,000 rpm for 15 minutes single spin, accelerator 7, brake 0, at 21°C to provide buffy coat layer. Buffy coat (containing numerous platelets and white blood cells) was then carefully aspirated 3 ml each tube by using 18G needle under sterile techniques. The total of 6 ml PRP was injected by 30G needle, 0.1 ml/cm$^2$, 3 - 5 mm. in depth over the affected area. Three sessions of this combined treatment were performed at 1-month interval.

Standardized global photographs assessment, hair mass index (Hair check system®), targeted area hair counts (Trichoscale, Fotofinder) and patient self-assessment questionnaires were taken to evaluate hair growth. Photographs of frontal and vertex scalp areas were taken by DSLR camera (Nikon d7200, Japan) using manual mode in the same environment and camera setting at baseline, 3 and 6 months after the last treatment. Three blinded dermatologists performed expert panel global photographic assessment comparing between each visit using a 7-point scale: –3 = greatly decreased (-100% to -71%), –2 = moderately decreased (-70% to -41%), –1 = slightly decreased (-40% to -1%), 0 = no change, 1 = slightly increased (1% to 40%), 2 = moderately increased (41% to 70%), 3 = greatly increased (71% to 100%).

Hair mass index measuring a small change in hair density and hair diameter by cross-sectional trichometry (Haircheck®) were used at baseline and 6 months after the last treatment on the same scalp area. Targeted area hair counts, hair thickness and average hair per unit were evaluated on the same scalp area each visit at baseline 3 and 6 months after the last treatment by using Trichoscale system (FotoFinder®). The selected vertex area was tattooed with temporary black tattoo ink at first visit and a 1 $cm^2$ diameter scalp area with center tattoo marking was shaved during each visit.

All patients completed the written informed consents before the enrollment. The study was conducted at the Division of Dermatology, King Chulalongkorn Memorial Hospital. Participants were asked to assess their pain scores in laser treatment, PRP injection measuring in visual analog scale (VAS) scores (rating 1 - 10) and adverse effects including erythema, burning sensation, folliculitis, erosion and hair shaft breakage after every treatment.

### *Statistical analysis*

Continuous, ordinal and categorical data were reported as mean ± standard deviation, mode and percentage respectively. Wilcoxon signed-rank test were tested by using SPSS statistical software (version 22.0 IBM, Chicago, IL, USA) to evaluate hair changes between baseline, 3 and 6 months after the last treatment. *P* - value considering statistical significant was < 0.05.

## Results

### *Demographic data*

The mean age of the patients was 41 years (range 32 - 55). The Norwood-Hamilton grades of hair loss were stage II, III and IV in 2, 3 and 4 patients, respectively. The mean duration of hair loss was 8.6 years (range 3 – 20 years). Summary of patients' characteristics are shown in Table 1.

### *Complete blood count analysis*

The mean platelets concentration in PRP of all patients was 5.9 (739.4 × $10^3$/$mm^3$) times higher than whole blood (113.4 × $10^3$/$mm^3$). Leukocyte concentrations in PRP increased approximately 3 times higher than whole blood. The proportion of differential leukocyte counts in whole blood was neutrophils: lymphocytes = 66: 25 (%) where as in PRP was neutrophils: lymphocytes = 29: 68 (%). The mean hematocrit in plasma was 5% after centrifugation by our in-house protocol. (Table 2)

**Table 1.** Demographic data (total 9 patients).

| **Age, mean ± SD (range), years** | **41.3 ± 7.9 (32 - 55)** |
|---|---|
| Family history of hair loss, n (%) | 7/9 (78%) |
| NH grades of hair loss, n (%) | |
| II | 2/9 (22%) |
| III | 4/9 (45%) |
| IV | 3/9 (33%) |
| Duration, mean ± SD (range), years | 8.6 ± 4.9 (3 - 20) |
| Previous treatment | |
| Topical minoxidil | 4/9 (44%) |
| Oral finasteride | 1/9 (11%) |

NH: Norwood Hamilton.

**Table 2.** Complete blood count results of whole blood and PRP.

| | **Platelet ($x10^3$/$mm^3$)** | **Leukocyte ($x10^3$ $mm^3$)** | **Neutrophil (%)** | **Lymphocyte (%)** | **Hematocrit (%)** |
|---|---|---|---|---|---|
| Whole blood | 113.4 ± 38.7 | 5.2 ± 1.2 | 66.4 ± 6.2 | 29.4 ± 6.4 | 42.4 ± 4.5 |
| PRP | 739.4 ± 869.0 | 18.1 ± 14.4 | 24.5 ± 28.2 | 67.5 ± 25.4 | 5.3 ± 6.4 |

PRP: Platelet rich plasma.

***Dermoscope evaluation***

Parameters of hair growth that were assessed by trichoscale software, Fotofinder with manual correction at baseline, 3 months after 3rd treatment, and 6 months after 3rd treatment are summarized in Table 3. The significant improvement of total and terminal hair density was observed on trichoscale analysis. The percentage increase of total hair density was 9.7% (149.7 to 164.2 = 14.5 hairs/cm$^2$, $P$ = 0.015). The terminal hair density significantly increased from baseline by 28.1% (99.1 to 127 = 27.9 hairs/cm$^2$, $P$ = 0.011). The improvements of hair density in two participants are shown in Figure 1.

Mean thickness, cumulative thickness and hair per unit at 3 and 6 months after last treatment did not differ from baseline except cumulative thickness at 6 months after last treatment ($P$ = 0.015).

***Hair mass index results***

Hair mass index (HMI) at 6 months after the last treatment demonstrated in Figure 2 revealed a significant increase from baseline by 26.4% (16 to 20.2, $P$ = 0.024). The improvement of hair mass index was observed in all patients.

***Photographic assessments***

The global photographic assessment (GPA) of frontal area at 3 and 6 moths after last treatment showed the improvement of 89% (8/9 patients; 1 moderated, 7 slight improvement and 1 no change) and 67% (6/9 patients; 1 moderated, 5 slight improvement and 3 no change), respectively. The GPA of vertex area at 3 and 6 moths after last treatment showed the improvement of 78% (7/8 patients; 3 moderated, 4 slight improvement and 2 no change) and 78% (7/8 patients; 3 moderated, 4 slight improvement and 2 no change), respectively. The worsening of clinical was not observed in our patients. (Figure 3)

Patient self-assessment at 3 and 6 months after last treatment revealed satisfaction in most of the patients, the results were as follows: at 3 months after last treatment; marked improvement, 11% (1/9); moderate improvement 33% (3/9); slight improvement 34% (3/9); no change 22% (2/9). At 6 months after last treatment showed; marked improvement 11% (1/9); moderate improvement 33% (3/9); slight improvement 22% (2/9); no change 34% (3/9). (Figure 4)

***Safety profiles***

Regarding the safety profile, none of the patients reported of serious adverse effects. Some patients complained about transient erythema and mild pain on the treated area. Both of erythema and pain sensation resolved spontaneously within 1 - 2 days. No dryness, dandruff or folliculitis was reported after any treatment. This combined treatment was fair tolerated and the mean visual analog scale (VAS) for pain was 0.8 (0 - 2) and 4.2 (2 - 6) for laser treatment and PRP injection, respectively.

**Table 3.** Summary hair growth parameters from Trichoscale analysis.

| Parameters | Time | Mean (SD) | *P* - value |
|---|---|---|---|
| Total hair density (hairs/cm$^2$) | Baseline | 149.7 (23.6) | |
| | 3 months after 3rd treatment | 166.4 (23.9) | $P$ = 0.011* |
| | 6 months after 3rd treatment | 164.2 (29.1) | $P$ = 0.015* |
| Terminal hair density (hairs/cm$^2$) | Baseline | 99.1 (33.5) | |
| | 3 months after 3rd treatment | 117.6 (30.2) | $P$ = 0.028* |
| | 6 months after 3rd treatment | 127.0 (25.3) | $P$ = 0.011* |
| Mean thickness (micron) | Baseline | 45.3 (7.2) | |
| | 3 months after 3rd treatment | 45.0 (6.7) | $P$ = 0.888 |
| | 6 months after 3rd treatment | 48.4 (6.8) | $P$ = 0.058 |
| Cumulative hair thickness (mm/cm$^2$) | Baseline | 6.8 (1.8) | |
| | 3 months after 3rd treatment | 7.5 (1.7) | $P$ = 0.074 |
| | 6 months after 3rd treatment | 8.0 (1.9) | $P$ = 0.015* |
| Average hair per unit (hairs/FU) | Baseline | 1.6 (0.2) | |
| | 3 months after 3rd treatment | 1.7 (0.2) | $P$ = 0.286 |
| | 6 months after 3rd treatment | 1.7 (0.2) | $P$ = 0.213 |

*$P$ < 0.05

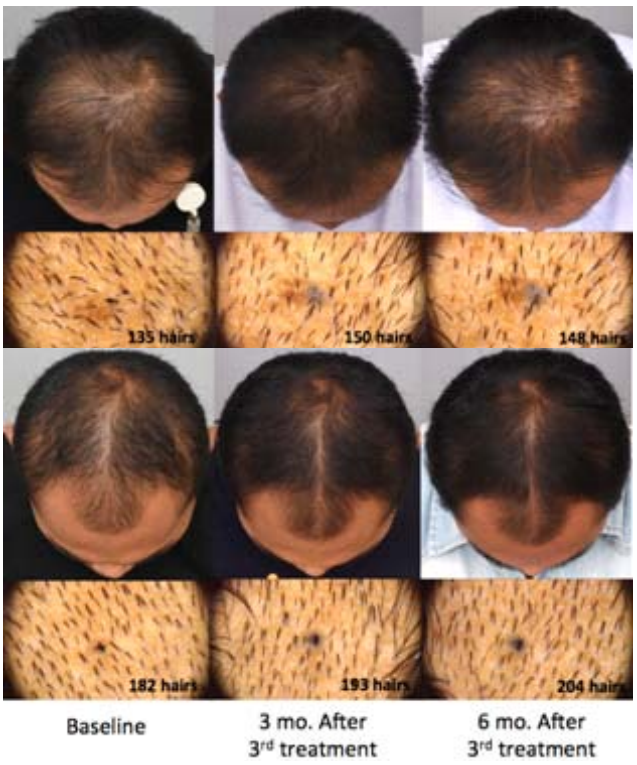


**Figure 1.** Clinical and Dermoscope photos of representative patients.

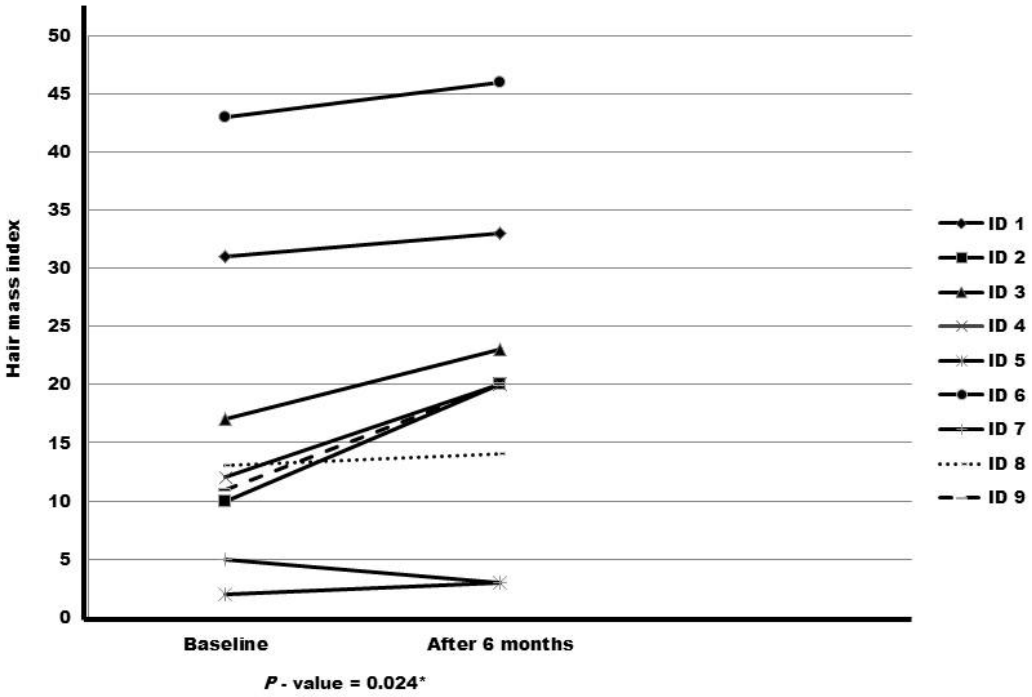


**Figure 2.** Hair mass index at baseline and 6 months after last treatment.

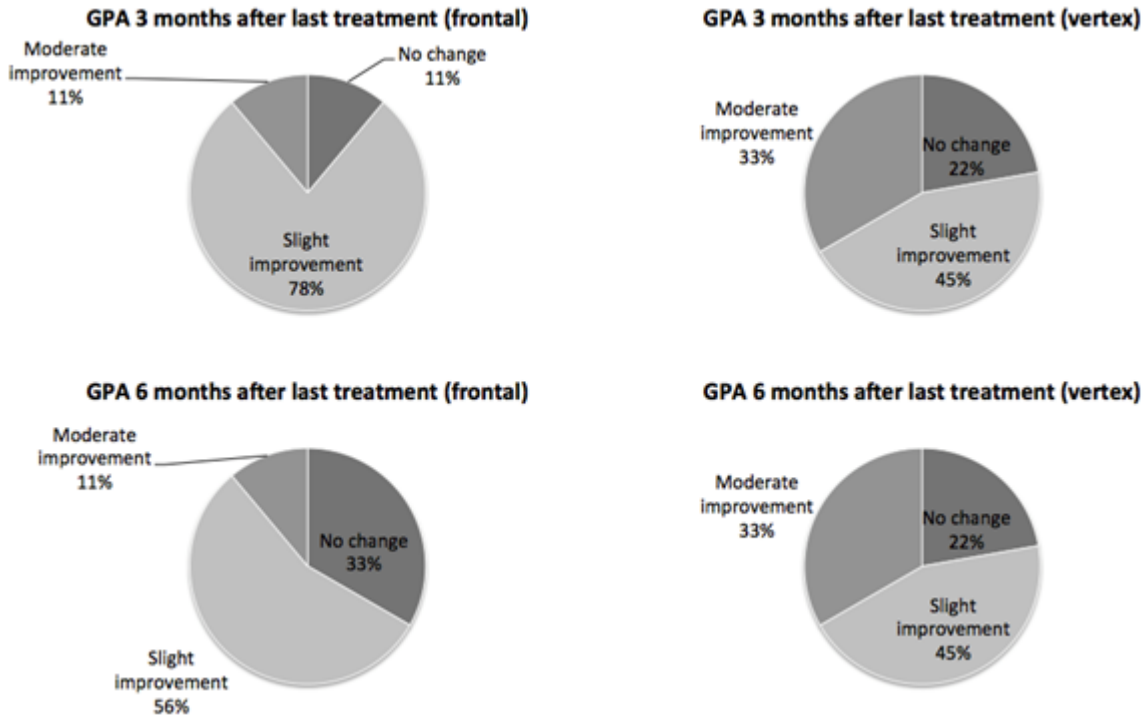


**Figure 3.** Global photographic assessment (GPA) of frontal and vertex area at 3 and 6 months after last treatment.

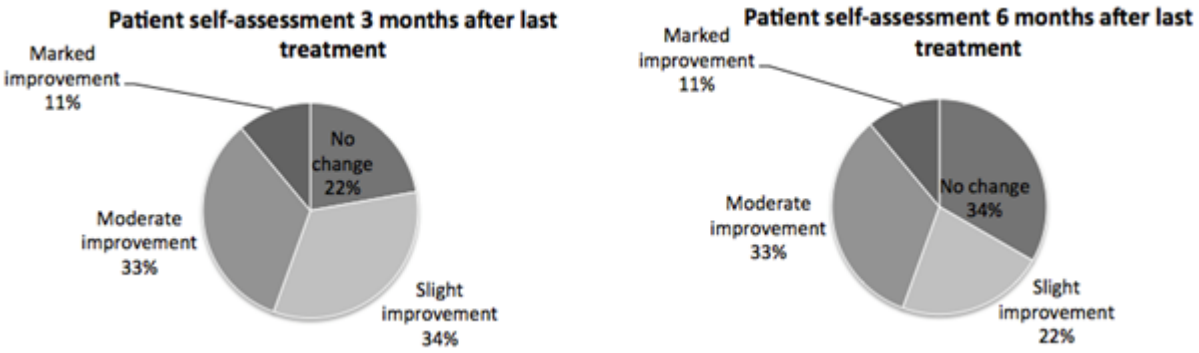


**Figure 4.** Patient self-assessment at 3 and 6 months after last treatment.

## Discussion

Platelet rich plasma is proven by several clinical trials to help increase hair density particularly androgenetic alopecia. [11, 15] Multiple factors may contribute to the efficacy of PRP treatment such as number of platelet, number of leukocyte, used of platelet activators, treatment schedule, and injection technique.

The proper concentration of platelet in PRP ranges between 4 - 7 times higher when compared to baseline. Higher number of platelets results in the increased amount of growth factors that in turn correlated with the better efficacy of PRP treatment. Our study prepared PRP by using Ycellbio-kit (Ycellbio Medical Co., Ltd., South Korea) and the in-house centrifuge protocol to create buffy coat layer. Mean of platelets concentration in our study was 5.9 times higher compared to baseline which is considered a proper concentration. In terms of the process of centrifugation, some authors recommend to avoid high rotation speed, longer centrifuged time and multiple spins to prevent early platelet activation. [16] Plasma rich in platelets that is extracted from buffy coat layer after centrifugation also contains varying amount of leukocytes depending upon the technique of collection. In the present study, we found that the

amount of total leukocytes in PRP was increased 3 folds compared to whole blood and percentage of the differential leukocyte count in PRP also shifted towards the increased proportion of lymphocytes and decreased proportion of neutrophils. Castillo TN, *et al.* [17] compared the differences of growth factor concentrations between leukocyte-rich PRP and leukocyte-poor PRP. The results demonstrated that the concentrations of PDGF and VEGF were higher in leukocyte-rich PRP compared to leukocyte-poor PRP. Moreover, apart from total number of leukocyte, the efficacy of PRP might be effected by particular types of leukocyte as well. Some studies found negative effects of neutrophils on platelets by down regulating platelet activities. [18, 19] According to previous studies, the high amount of leukocytes and the decreased proportion of neutrophils after PRP extraction in our study could result in the increase of total amount of essential growth factors. Orliac S, *et al.* [20] evaluated the effect and local toxicity of repeated subcutaneous PRP injection (weekly for total 5 months) on hair growth in hairless mice model and found that platelet rich plasma that contained some amount of leukocytes improved hair density in hairless mice presumably via growth factor activation without local tissue toxicity. This study abandoned the finding in a previous study regarding inflammatory cytokines toxicity caused by PRP containing leukocytes. [18] Therefore, further studies about the exact effects of different number of leukocytes in PRP on hair growth are suggested.

From several reported trials, in order for PRP to release growth factors, platelets activation using platelet activators such as calcium or thrombin have been suggested. [21] However, Gentile P, *et al.* compared the levels of growth factors between calcium treated PRP and untreated PRP and found that there was no significant different regarding growth factor concentrations between two groups. [4] A previous study suggested that both activated PRP and non-activated PRP could be used effectively for AGA patients. [4] After mixing PRP with platelet activators, the viscosity of PRP increases due to clot formations making scalp injection more difficult compared to non-activated PRP. Therefore, we chose non-activated PRP because of its effectiveness and appropriate texture for scalp injection.

Treatment schedule of PRP protocols comparing among published studies are vary since there is no established guideline. [15] The most widely used treatment duration is 3 sessions every 4 - 6 weeks. Alves R, *et al.* [22] conducted randomized, double-blinded study in twenty-five patients with AGA using 3 sessions of PRP at 1-month intervals. At six months after the first treatment, it showed significant increase in hair counts of 12.8 hairs/cm$^2$ in PRP group compared to decrease hair counts of 2.1 hairs/cm$^2$ in the control. According to the efficacy of this trial, in the present study, we also used same treatment duration as Alves's study and the increasing of hair counts at six months after the last treatment showed similar improvement of 14.5 hairs/cm$^2$. Regarding the same treatment duration between two studies, however, terminal hair density in our study was higher than the previous study. The increasing of terminal hair density at six months after the last treatment was 27.9 hairs/cm$^2$ compared to 5.9 hairs/cm$^2$ in Alves's study. This finding might be explained by the increasing efficacy of a combination therapy, PRP and fractional laser in our study.

The injection technique is also important. Most authors recommended the subdermal or below subdermal injection in order to the better bulb region diffusion of injected PRP. The suggested volume of PRP per area was 0.1 - 0.15 ml/cm$^2$. We used the injection techniques as in the literature reviews to achieve the most effective outcome. [13, 15] Several types of light and laser therapy such as low level laser, He-Ne laser and excimer laser have been currently used to treat hair loss. Fractional lasers also have been reported to increase hair growth, however, the exact mechanism is not yet fully understood. Kim WS, *et al.* [23] conducted C3H/HeN in mice model to evaluate the effects of 1,550-nm fractional erbium-glass laser on hair growth. The increasing in Wnt 5a, beta-catenin signaling pathway which resulted in anagen conversion of hair cycle was found in irradiated mice. The hair growth stimulation effects depend directly on proper laser setting and treatment intervals, too much of laser energy and too frequent treatment intervals might induce fibrosis of dermal tissue and worsening the course of alopecia. A study in animals by Bae JM, *et al.* [24] supported similar findings as in another previous study that ablative fractional laser affects hair cycle changes via Wnt10b and beta-catenin activation. Another proposed mechanism is that new hair follicles formation occur after wound healing following photothermolysis-induced minor trauma. [25, 26] Thulium laser, wavelength 1,927 nm, which is considered one of the

fractional non-ablative laser used in dermatological fields on various purposes. Sung et al. reported the effects of fractional thulium laser on hair growth in mice and androgenic alopecia patients. The results showed increasing hair density and thickness after the laser treatment similar to those observed in erbium glass laser.

Although the effect of PRP on hair regeneration is well established, some studies reported negative effect of PRP monotherapy for AGA patients. Several new trials have used a combination technique of micro-needling or fractional lasers with PRP to enhance efficacy.[27 - 29] Our study was intended to determine the effect of a combination of non-ablative fractional laser and non-activated PRP on patients with mild to moderate severity of male androgenic alopecia. The results of the present study showed significant increase in hair counts and hair density at both 3 months and 6 months after the last treatment. We hypothesized that fractional thulium laser not only help stimulate hair proliferation and prolonging anagen phase by itself but also create proper wounding which resulted in subsequent platelet activation and further release of multiple growth factors. This synergistic effect of fractional lasers and PRP might help promote hair growth.

Regarding the safety, the adverse effects that we found were mild and temporary as transient erythema and mild burning sensation over the treated area. The PRP injection was more painful compared to laser but within acceptable limits. The treatment was considered fairly tolerated by most patients. Small sample sizes were considered our limitations. Moreover, we cannot indicate whether the major effects of hair growth stimulation was resulted mainly from PRP or fractional lasers or needling effects since there was no control group in this study. Another limitation is that we did not evaluate long-term follow up at 12 months after the last treatment.

## Conclusions

Our preliminary study supports that a combination of a 1,927 nm fractional Thulium-doped fiber laser and PRP is a safe and effective adjunctive treatment for male AGA. However, larger and longer, randomized, placebo-controlled trials are needed.

## Conflict of interest

None of the authors has any potential conflict of interest to disclose.

## References

1. Olsen EA, Messenger AG, Shapiro J, Bergfeld WF, Hordinsky MK, Roberts JL, et al. Evaluation and treatment of male and female pattern hair loss. J Am Acad Dermatol 2005;52:301-11.
2. Pathomvanich D, Pongratananukul S, Thienthaworn P, Manoshai S. A random study of Asian male androgenetic alopecia in Bangkok, Thailand. Dermatol Surg 2002;28:804-7.
3. Adil A, Godwin M. The effectiveness of treatments for androgenetic alopecia: A systematic review and meta-analysis. J Am Acad Dermatol 2017;77:136-41.
4. Gentile P, Cole JP, Cole MA, Garcovich S, Bielli A, Scioli MG, et al. Evaluation of not-activated and activated PRP in hair loss treatment: role of growth factor and cytokine concentrations obtained by different collection systems. Int J Mol Sci 2017;18: pii: E408.
5. Martinez-Zapata MJ, Marti-Carvajal A, Solà I, Bolibar I, Angel Expósito J, Rodriguez L, et al. Efficacy and safety of the use of autologous plasma rich in platelets for tissue regeneration: a systematic review. Transfusion 2009;49:44-56.
6. Hamilton BH, Best TM. Platelet-enriched plasma and muscle strain injuries: challenges imposed by the burden of proof. Clin J Sport Med 2011;21:31-6.
7. Cho JW, Kim SA, Lee KS. Platelet-rich plasma induces increased expression of G1 cell cycle regulators, type I collagen, and matrix metalloproteinase-1 in human skin fibroblasts. Int J Mol Med 2012;29:32-6.
8. Cervelli V, Palla L, Pascali M, De Angelis B, Curcio BC, Gentile P. Autologous platelet-rich plasma mixed with purified fat graft in aesthetic plastic surgery. Aesthetic Plast Surg 2009;33:716-21.
9. Sclafani AP. Applications of platelet-rich fibrin matrix in facial plastic surgery. Facial Plast Surg 2009;25: 270-6.
10. Na JI, Choi JW, Choi HR, Jeong JB, Park KC, Youn SW, et al. Rapid healing and reduced erythema after ablative fractional carbon dioxide laser resurfacing combined with the application of autologous platelet-rich plasma. Dermatol Surg 2011;37:463-8.
11. Li ZJ, Choi HI, Choi DK, Sohn KC, Im M, Seo YJ, et al. Autologous platelet-rich plasma: a potential therapeutic tool for promoting hair growth. Dermatol Surg 2012;38:1040-6.
12. Rastegar H, Ahmadi AH, Aghaei M, Ehsani A, Barikbin B. Combination of herbal extracts and platelet-rich plasma induced dermal papilla cell proliferation: involvement of ERK and Akt pathways. J Cosmet

Dermatol 2013;12:116-22.
13. Perper M, Aldahan AS, Fayne RA, Emerson CP, Nouri K. Efficacy of fractional lasers in treating alopecia: a literature review. Lasers Med Sci 2017;32: 1919-25.
14. Cho SB, Goo BL, Zheng Z, Yoo KH, Kang JS, Kim H. Therapeutic efficacy and safety of a 1927-nm fractionated thulium laser on pattern hair loss: an evaluator-blinded, split-scalp study. Lasers Med Sci 2018;33:851-9.
15. Picard F, Hersant B, Niddam J, Meningaud JP. Injections of platelet-rich plasma for androgenic alopecia: A systematic review. J Stomatol Oral Maxillofac Surg 2017;118:291-7.
16. Fukaya M, Ito A. A new economic method for preparing platelet-rich plasma. Plast Reconstr Surg Glob Open 2014;2:e162.
17. Castillo TN, Pouliot MA, Kim HJ, Dragoo JL. Comparison of growth factor and platelet concentration from commercial platelet-rich plasma separation systems. Am J Sports Med 2011;39:266-71.
18. Kobayashi Y, Saita Y, Nishio H, Ikeda H, Takazawa Y, Nagao M, et al. Leukocyte concentration and composition in platelet-rich plasma (PRP) influences the growth factor and protease concentrations. J Orthop Sci 2016;21:683-9.
19. Valles J, Santos MT, Marcus AJ, Safier LB, Broekman MJ, Islam N, et al. Downregulation of human platelet reactivity by neutrophils. Participation of lipoxygenase derivatives and adhesive proteins. J Clin Invest 1993; 92:1357-65.
20. Orliac S, Serfaty JM, Perozziello A, Zurlinden O, Louedec L, Dallaudiere B. Efficacy of subcutaneous injection of platelet-rich plasma in alopecia: A clinical and histological pilot study on a rat model with a six-month long-term follow-up experience. J Cosmet Dermatol 2018;17:214-9.
21. Cervelli V, Gentile P, Scioli MG, Grimaldi M, Casciani CU, Spagnoli LG, et al. Application of platelet-rich plasma in plastic surgery: clinical and in vitro evaluation. Tissue Eng Part C Methods 2009;15: 625-34.
22. Alves R, Grimalt R. Randomized placebo-controlled, double-blind, half-head study to assess the efficacy of platelet-rich plasma on the treatment of androgenetic alopecia. Dermatol Surg 2016;42:491-7.
23. Kim WS, Lee HI, Lee JW, Lim YY, Lee SJ, Kim BJ, et al. Fractional photothermolysis laser treatment of male pattern hair loss. Dermatol Surg 2011;37:41-51.
24. Bae JM, Jung HM, Goo B, Park YM. Hair regrowth through wound healing process after ablative fractional laser treatment in a murine model. Lasers Surg Med 2015;47:433-40.
25. Ansell DM, Kloepper JE, Thomason HA, Paus R, Hardman MJ. Exploring the "hair growth-wound healing connection": anagen phase promotes wound re-epithelialization. J Invest Dermatol 2011;131:518-28.
26. Chuong CM. Regenerative biology: new hair from healing wounds. Nature 2007;447:265-6.
27. Fertig RM, Gamret AC, Cervantes J, Tosti A. Microneedling for the treatment of hair loss? J Eur Acad Dermatol Venereol 2018;32:564-9.
28. Jha AK, Udayan UK, Roy PK, Amar AKJ, Chaudhary RKP. Original article: Platelet-rich plasma with microneedling in androgenetic alopecia along with dermoscopic pre- and post-treatment evaluation. J Cosmet Dermatol 2017 Aug 3. doi: 10.1111/jocd.12394.
29. Strazzulla LC, Avila L, Lo SK, Shapiro J. An overview of the biology of platelet-rich plasma and microneedling as potential treatments for alopecia areata. J Invest Dermatol 2017 Nov 3. pii: S0022-202X(17)32751-3.