Advances in the Application of Autologous Platelet Concentrate in the Postprint

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Abstract

Autologous platelet concentrate (APC) is a platelet concentrate obtained by centrifugation of human or animal blood, which mainly includes first-generation platelet-rich plasma (PRP) and second-generation platelet-rich fibrin (PRF). It is widely applied in various fields such as dental implants, bone defect repair, and burn plastic surgery because of its role in wound healing and tissue repair. In recent years, autologous platelet concentrate has been applied to improve ovarian function, promote the repair of endometrial hyperplasia, treat cervical and vulvo-related lesions, and has achieved significant efficacy. However, there is a lack of effective integration of PRP and PRF research results in the field of gynecology. This paper systematically and comprehensively reviews the preparation, biological properties, and applications in various gynecological diseases, in order to provide clinicians with new treatment strategies for gynecological diseases and reference for the further application of APC.

Full Text

Advances in the Application of Autologous Platelet Concentrate in the Field of Gynecology

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Abstract

Autologous platelet concentrate (APC) is a platelet-rich product obtained through centrifugation of human or animal blood, primarily comprising first-generation platelet-rich plasma (PRP) and second-generation platelet-rich fibrin (PRF). Due to its role in wound healing and tissue repair, APC has been widely applied in various fields including dental implants, bone defect repair, and burn plastic surgery. In recent years, APC has demonstrated significant efficacy in improving ovarian function, promoting endometrial hyperplasia repair, and treating cervical and vulvar lesions. However, research findings on PRP and PRF in gynecology lack effective integration. This paper systematically and comprehensively reviews the preparation methods, biological properties, and applications in various gynecological diseases to provide clinicians with novel treatment approaches and references for further APC application.

Keywords: Gynecologic diseases; Platelet-rich plasma; Platelet-rich fibrin; Autologous platelet concentrates; Endometrial hyperplasia; Ovarian diseases; Review

Platelets originate from mature megakaryocytes in bone marrow and aggregate to initiate hemostasis upon tissue trauma. Platelet cytoplasm contains numerous granules that, upon activation and degranulation, release abundant growth factors involved in wound healing and tissue regeneration, thereby promoting cell proliferation and migration [1-3]. Autologous platelet-rich concentrate is a high-concentration platelet product obtained by centrifuging whole blood, with platelet content 4-5 times higher than that of whole blood [4], playing a crucial role in wound healing, tissue repair, and regeneration.

Autologous platelet-rich concentrates mainly include first-generation platelet-rich plasma (PRP) and second-generation platelet-rich fibrin (PRF), which have been widely used in oral implantology [5-6], bone defect repair [7], burn and cosmetic surgery [8], and other fields. In recent years, autologous platelet-rich fibrin concentrate has been applied in gynecological conditions such as endometrial, cervical, and vulvar lesions with remarkable efficacy. However, gynecologists have limited knowledge of these applications. This article reviews the progress of autologous platelet-rich concentrate applications in gynecological diseases to provide clinicians with new diagnostic and treatment approaches and to support further research and application development.

1. Literature Search Strategy

A computerized search of PubMed, Web of Science, Embase, and China Knowledge Network (CNKI) databases was conducted from inception to February

2023. English search terms included "platelet-rich plasma," "platelet-rich fibrin," "PRP," "PRF," and "gynecological," while Chinese search terms included "autologous platelet-rich plasma concentrate,""platelet-rich fibrin,""PRP,""PRF," and "gynecological diseases."Inclusion criteria comprised clinical or basic studies, reviews, meta-analyses, and case reports on preparation, biological characterization, and treatment applications of autologous platelet-rich plasma concentrates, PRP, or PRF. Exclusion criteria included conference abstracts, commentaries, letters to the editor, and literature with unavailable full text or poor quality.

2. PRP-Related Studies

2.1 Preparation Methods of PRP

Platelet-related products first emerged in the 1870s, with platelet concentrates gaining widespread attention following the development of PRP extraction technology in the 1990s [9]. PRP is a highly concentrated platelet plasma obtained through centrifugation of autologous whole blood, containing growth factors at concentrations 5-10 times higher than whole blood. PRP is primarily prepared via gradient-density centrifugation, including one-step, two-step, and three-step methods. Two-step centrifugation is widely used clinically due to its high platelet concentration and growth factor yield [10]. The main procedures are as follows [11]: (1) Venous blood is drawn and injected into test tubes containing anticoagulant; (2) To prevent platelet activation during centrifugation, the recommended temperature is 21-24°C. After centrifugation at a specific force, the blood separates into three layers: the bottom red blood cell layer (approximately 1/2 of total blood volume), a thin middle white layer rich in leukocytes, and a yellow top platelet layer containing few leukocytes; (3) The plasma above the red blood cell layer is aspirated with a pipette and transferred to another sterile tube without anticoagulant; (4) After centrifugation, the plasma separates into two layers: the upper 2/3 is platelet-poor plasma, while the lower 1/3 is platelet-rich plasma. Thirty milliliters of venous blood typically yields 3-5 mL of PRP; (5) The upper platelet-poor plasma layer is removed with a pipette, leaving sufficient plasma to suspend the platelet-enriched fraction. Bovine thrombin and calcium chloride are added to activate platelets before clinical application. With the advancement and clinical adoption of PRP technology, commercial PRP preparation systems have become available.

2.2 Structural and Biological Characteristics of PRP

To the naked eye, PRP appears as a red viscous liquid. Under scanning electron microscopy, platelets are observed aggregating into clusters stacked upon each other with numerous pseudopodia protruding, while some leukocytes are dispersed among the platelets [12]. PRP platelets are enriched with numerous cytokines and growth factors, including insulin-like growth factor, vascular endothelial growth factor, platelet-derived angiogenic factor, transforming growth factor-β, fibroblast growth factor, epidermal growth factor, connective tissue growth factor, and interleukin-8, which are released upon platelet activation

[13]. In addition to growth factors, platelets secrete fibronectin, hyaluronan, and sphingosine 1-phosphate, which promote wound repair and tissue regeneration by enhancing cell chemotaxis, adhesion, proliferation, migration, and angiogenesis [14]. With a pH of 6.5-6.7, PRP provides a weakly acidic medium that inhibits microorganisms. Additionally, platelets secrete bactericidal proteins and release antimicrobial peptides upon activation [15], enabling PRP to exert antimicrobial effects through multiple mechanisms.

2.3 Basic Research on PRP in Gynecological Diseases

2.3.1 Promotion of Endometrial Cell Proliferation and Repair SUGINAMI et al. [16-17] analyzed platelet distribution patterns during the human menstrual cycle using immunohistochemistry, finding that platelets were more abundant in the endometrial stroma near the luminal epithelium during the menstrual phase and less numerous during the proliferative and secretory phases. When platelets were co-cultured with EM-E6/E7/hTERT immortalized endometrial epithelial cells, they promoted cell adhesion to stromal gel and increased cell-cell contact by enhancing E-cadherin expression, suggesting platelet involvement in human endometrial re-epithelialization. AGHAJANOVA et al. [18] demonstrated that activated 5% PRP promoted migration of human endometrial mesenchymal fibroblasts, endometrial mesenchymal stem cells, and bone marrow-derived mesenchymal stem cells, as well as proliferation of human endometrial mesenchymal fibroblasts and endometrial mesenchymal stem cells. These studies provide in vitro evidence that platelet concentrates promote endometrial regeneration and repair. In animal studies, intrauterine PRP injection promoted regeneration of ethanol-induced endometrial injury in rats, reduced endometrial fibrosis, and increased endometrial receptivity [19]. ZHANG et al. [20] investigated the synergistic therapeutic effect of PRP combined with menstrual blood-derived stromal cells on mechanical uterine adhesion injury, finding that PRP enhanced the reparative effects of menstrual blood-derived stromal cells on the endometrium. These studies provide evidence supporting clinical PRP application for improving endometrial function.

2.3.2 Protection of Ovarian Function from Injury To investigate the protective effect of PRP on ovarian ischemia/reperfusion injury, BAKACAK et al. [21] conducted a uterine adnexal torsion experiment in 60 female rats. The experimental group received intraperitoneal PRP injection 30 minutes before torsion induction. After torsion release, the experimental group showed superior outcomes compared to the control group in terms of oxidative stress levels, histopathological changes, and reduction of ovarian ischemia/reperfusion injury, suggesting that PRP can protect ovarian function from ischemia/reperfusion damage.

2.4 Clinical Application of PRP in Gynecological Diseases

2.4.1 Promotion of Postoperative Wound Healing and Complication Reduction Upon activation, PRP platelets release multiple high-concentration growth factors that far exceed the threshold required for wound repair, rapidly initiating healing processes, promoting proliferation and migration of local repair cells, extracellular matrix deposition, and local vascular regeneration. PRP has demonstrated significant efficacy in healing diabetic chronic wounds, pressure ulcers, and other refractory wounds. TEHRANIAN et al. [24] studied the effect of autologous PRP on wound healing in high-risk cesarean section patients, randomly dividing 140 patients into two groups: an intervention group receiving PRP treatment postoperatively and a control group receiving routine care. Results showed that redness, ecchymosis, and pain decreased significantly more in the PRP group than in the control group ($P<0.001$), suggesting that PRP can accelerate healing of refractory wounds after cesarean delivery. Another Phase I/II prospective study evaluated PRP safety and efficacy in gynecological surgery, enrolling 55 consecutive patients who received 20 mL of PRP directly at the surgical site postoperatively. Compared with the control group, the PRP group had lower pain scores (2.7 vs. 6.7, $P<0.001$), reduced morphine dosage (17 mg vs. 26 mg, $P<0.05$), and no adverse effects [25]. MEDEL et al. [26] found that using platelet gel before vulvar reconstruction effectively prevented postoperative wound rupture in locally advanced vulvar cancer surgery. The study divided patients undergoing radical vulvovaginal surgery into Group A (n=10) and Group B (n=15), with Group A receiving platelet gel placement in the vaginal fissure during reconstructive surgery while Group B underwent surgery alone. Group A showed significantly lower rates of wound infection, vaginal wound necrosis, and wound dehiscence compared to Group B ($P<0.05$), as well as significantly reduced postoperative fever incidence, shorter hospitalization time, and faster wound healing ($P<0.05$).

2.4.2 Treatment of Vulvar and Cervical Lesions BEHNIA-WILLISON et al. [27] studied PRP therapeutic effects on glucocorticoid-resistant vulvar lichen sclerosus, with patients receiving three vulvar PRP injections at 4-6 week intervals, followed by additional PRP after 12 months. Twenty-eight patients showed clinical improvement in lesion size, with 28.6% experiencing complete lesion disappearance after PRP treatment. HUA et al. [28] conducted a randomized clinical study comparing PRP and laser treatment for benign cervical lesions, demonstrating that the PRP group had significantly shorter re-epithelialization time and lower adverse reaction incidence than the laser group.

2.4.3 Improvement of Ovarian Function and Ovarian Responsiveness in IVF Ovarian reserve function is a crucial indicator for evaluating female fertility, yet poor ovarian response and low fertilization rates due to age-related factors during ovulation induction remain challenging problems in fertility preservation. White et al. [29] showed that intraovarian injection of platelet-derived

growth factors may promote oocyte recovery. CAKIROGLU et al. [30] performed intraovarian PRP injections in 311 women aged 24-40 years with primary ovarian insufficiency, finding that PRP increased serum anti-Müllerian hormone values and improved female fertility. Seven point four percent of women conceived naturally after PRP injection, and 64.8% developed dominant follicles and attempted in vitro fertilization, with 82 (26.4%) achieving successful fertilization. Subsequently, CAKIROGLU et al. [31] performed intraovarian PRP injections in 474 women aged 30-45 years with a history of poor ovarian response (POR), with 65.8% achieving successful IVF and embryo transfer. Abundant blood supply and platelet-derived cytokines are essential for normal ovarian function, and the high cytokine content in PRP may promote ovarian neovascularization and cellular activation, thereby improving ovarian responsiveness and female fertility.

2.4.4 Promotion of Endometrial Regeneration and Repair to Improve Pregnancy Outcomes The endometrium is crucial for embryo implantation and pregnancy maintenance. Endometrial repair disorders resulting from damage to the endometrial basal layer represent an important cause of uterine infertility and pregnancy complications. Current therapeutic approaches to promote endometrial regeneration, including estrogen [32] and stem cells [33], have limitations. CHANG et al. [34] and COLOMBO et al. [35] studied five IVF cases with poor endometrial response where endometrial thickness remained <7 mm after standard hormone replacement therapy. However, after injecting 0.5-1.0 mL of PRP into the uterine cavity on the 10th day of menstruation in conjunction with conventional hormone therapy, PRP promoted endometrial growth and all five patients achieved successful pregnancy. COLOMBO et al. [35] applied PRP in patients whose endometrial thickness remained <6 mm after three classical drug regimens, leading to cycle cancellation, and found that 87% of patients showed significant endometrial thickness increase before progesterone injection and embryo transfer. In studies by CHANG et al. [36] and DOGRA et al. [37], the PRP group showed superior endometrial thickness, clinical pregnancy rate, and cycle cancellation rate compared to the control group. NAZARI et al. [38] reported that in 18 patients with previous recurrent implantation failure, intrauterine injection of 0.5 mL PRP 48 hours before embryo transfer resulted in successful pregnancies in 16 out of 18 patients (with two early miscarriages) that continued to term. In a subsequent randomized controlled study of 138 patients who failed to conceive after three or more high-quality embryo transfers, intrauterine injection of 0.5 mL PRP 48 hours before blastocyst transfer yielded a clinical pregnancy rate of 44.89% in the PRP group versus 16.66% in the control group ($P<0.05$) [3]. These findings demonstrate that PRP has significant efficacy in patients with thin endometrium, repeated implantation failure due to uterine factors, and uterine adhesions, not only increasing endometrial thickness but also improving endometrial function, providing a novel therapeutic approach in reproductive medicine.

3. PRF-Related Studies

3.1 Characteristics of PRF

PRF is a platelet concentrate obtained by centrifuging venous blood, representing the second generation of autologous platelet concentrates discovered by DOHAN et al. [2] in 2006. PRF offers several advantages over PRP: (1) It is easy to prepare, requiring only one centrifugation step without anticoagulant addition or prothrombin activation; (2) It forms a loose three-dimensional mesh structure that entraps platelets and growth factors together; (3) PRF is rich in fibronectin, which can cover wounds and promote healing. Studies report that the PRF matrix contains glycosaminoglycans (heparin, hyaluronic acid) with strong affinity for circulating small polypeptides, and the fibronectin matrix stimulates integrin αv$ $3 expression, giving PRF robust capacity to support cell migration and healing [39].

3.2 Clinical Application of PRF in Gynecological Diseases

Currently, PRF has demonstrated significant efficacy in promoting alveolar bone regeneration, cranial bone repair, and corneal repair [40-41], but gynecological studies remain relatively rare. In pelvic reconstructive surgery, vaginal grafts (whether absorbable or non-absorbable) have serious adverse effects. GORLERO et al. [42] conducted a prospective observational study evaluating PRF effects on vaginal prolapse surgery repair. Ten patients requiring surgical repair with high recurrence risk factors (grade II or higher) received PRF at the surgical site, showing 80% anatomical structure restoration, 100% prolapse symptom improvement, 20% increase in sexual activity, no pain during intercourse, and no intraoperative or postoperative complications. SHIRVAN et al. [43] found that autologous PRP combined with PRF represents a novel minimally invasive treatment for genital fistulas, achieving clinical cure in 11 patients with normal transvaginal physical examination and cystography. WANG et al. [44] found that pregnancy rates were significantly higher in the PRF group compared to the non-treated group, with significantly lower uterine adhesion scores, indicating that PRF effectively promotes endometrial repair and reduces re-formation of uterine adhesions. YANG Mukun et al. [45] analyzed endometrial tissues from uterine adhesion patients treated with PRF, finding increased numbers of endometrial glands and expression of Ki67, cytokeratin 18, and vimentin, along with significantly reduced fibrotic area compared to preoperative measurements. This suggests that PRF may promote wound repair by stimulating endometrial gland proliferation and inhibiting fibrosis.

4. Summary and Outlook

Autologous platelet-rich concentrates (PRP) are derived from the patient' s own body, avoiding allergic reactions, cross-infections, and immune rejection during use. Their high concentration of growth factors offers broad application prospects for promoting wound healing and tissue regeneration. PRP and

PRF have demonstrated prominent utility in gynecological diseases, including promoting endometrial regeneration and repair in uterine adhesions, improving pregnancy outcomes, and enhancing ovarian function and responsiveness during IVF. Both PRP and PRF play important roles in addressing two of the most challenging issues affecting female fertility, demonstrating strong potential for fertility preservation.

However, research on autologous platelet-rich plasma concentrates in gynecology faces several challenges: (1) More in-depth basic research is needed to elucidate the mechanisms by which PRP and PRF promote wound healing and tissue regeneration; (2) The use of PRP and PRF in gynecology remains in its infancy, with current research primarily based on case reports and retrospective studies with low evidence levels. Large-scale, multicenter, high-quality randomized controlled trials are needed to further validate the short-term and long-term safety and efficacy of PRP and PRF; (3) There is an urgent need to establish standardized protocols for PRP and PRF application, including preparation methods, application procedures, quality control, dosage, and usage guidelines.

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Conflict of Interest: The authors declare no conflict of interest.

References

[1] NARAYANASWAMY R, PATRO B P, JEYARAMAN N, et al. Evolution and clinical advances of platelet-rich fibrin in musculoskeletal regeneration [J]. Bioengineering (Basel), 2023, 10(1): 58. DOI: 10.3390/bioengineering10010058.

[2] DOHAN D M, CHOUKROUN J, DISS A, et al. Platelet-rich fibrin (PRF): a second-generation platelet concentrate. Part II: platelet-related biologic features [J]. Oral Surg Oral Med Oral Pathol Oral Radiol Endod, 2006, 101(3): e45-50. DOI: 10.1016/j.tripleo.2005.07.009.

[3] NAZARI L, SALEHPOUR S, HOSSEINI M S, et al. The effects of autologous platelet-rich plasma in repeated implantation failure: a randomized controlled trial [J]. Hum Fertil (Camb), 2020, 23(3): 209-213. DOI: 10.1080/14647273.2019.1569268.

[4] KOBAYASHI E, FLÜCKIGER L, FUJIOKA-KOBAYASHI M, et al. Comparative release of growth factors from PRP, PRF, and advanced-PRF [J]. Clin Oral Investig, 2016, 20(9): 2353-2360. DOI: 10.1007/s00784-016-1893-5.

[5] PANDA S, MISHRA L, ARBILDO-VEGA H I, et al. Effectiveness of autologous platelet concentrates in management of young immature necrotic permanent teeth-a systematic review and meta-analysis [J]. Cells, 2020, 9(10): 2241.

DOI: 10.3390/cells9102241.

[6] YU H Y, CHANG Y C. A bibliometric analysis of platelet-rich fibrin in dentistry [J]. Int J Environ Res Public Health, 2022, 19(19): 12545. DOI: 10.3390/ijerph191912545.

[7] LIU X Y, YIN M J, LI Y, et al. Genipin modified lyophilized platelet-rich fibrin scaffold for sustained release of growth factors to promote bone regeneration [J]. Front Physiol, 2022, 13: 1007692. DOI: 10.3389/fphys.2022.1007692.

[8] EVANS A G, IVANIC M G, BOTROS M A, et al. Rejuvenating the periorbital area using platelet-rich plasma: a systematic review and meta-analysis [J]. Arch Dermatol Res, 2021, 313(9): 711-727. DOI: 10.1007/s00403-020-02173-z.

[9] GRAIET H, LOKCHINE A, FRANCOIS P, et al. Use of platelet-rich plasma in regenerative medicine: technical tools for correct quality control [J]. BMJ Open Sport Exerc Med, 2018, 4(1): e000442. DOI: 10.1136/bmjsem-2018-000442.

[10] AMABLE P R, CARIAS R B, TEIXEIRA M V, et al. Platelet-rich plasma preparation for regenerative medicine: optimization and quantification of cytokines and growth factors [J]. Stem Cell Res Ther, 2013, 4(3): 67. DOI: 10.1186/scrt218.

[11] DHURAT R, SUKESH M. Principles and methods of preparation of platelet-rich plasma: a review and author' s perspective [J]. J Cutan Aesthet Surg, 2014, 7(4): 189-197. DOI: 10.4103/0974-2077.150734.

[12] COPELLITI F, CATTANI C, DIMARTINO V, et al. Platelet derivatives and the immunomodulation of wound healing [J]. Int J Mol Sci, 2022, 23(15): 8370. DOI: 10.3390/ijms23158370.

[13] LOURENÇO E S, MOURÃO C F A B, LEITE P E C, et al. The in vitro release of cytokines and growth factors from fibrin membranes produced through horizontal centrifugation [J]. J Biomed Mater Res A, 2018, 106(5): 1373-1380. DOI: 10.1002/jbm.a.36346.

[14] VAN DER BIJL I, VLIG M, MIDDELKOOP E, et al. Allogeneic platelet-rich plasma (PRP) is superior to platelets or plasma alone in stimulating fibroblast proliferation and migration, angiogenesis, and chemotaxis as relevant processes for wound healing [J]. Transfusion, 2019, 59(11): 3492-3500. DOI: 10.1111/trf.15535.

[15] SHARARA F I, LELEA L L, RAHMAN S, et al. A narrative review of platelet-rich plasma (PRP) in reproductive medicine [J]. J Assist Reprod Genet, 2021, 38(5): 1003-1012. DOI: 10.1007/s10815-021-02146-8.

[16] SUGINAMI K, SATO Y, HORIE A, et al. Platelets are a possible regulator of human endometrial re-epithelialization during menstruation [J]. American Journal of Reproductive Immunology, 2016: 1-8. DOI: 10.1111/aji.12609.

[17] SUGINAMI K, SATO Y, HORIE A, et al. Platelet-derived microparticles and soluble factors differentially regulate human endometrial epithelial cell movement [J]. Am J Reprod Immunol, 2017, 77(4): e12641. DOI: 10.1111/aji.12641.

[18] AGHAJANOVA L, HOUSHDARAN S, BALAYAN S, et al. In vitro evidence that platelet-rich plasma stimulates cellular processes involved in endometrial regeneration [J]. J Assist Reprod Genet, 2018, 35(5): 757-770. DOI: 10.1007/s10815-018-1130-8.

[19] JANG H Y, MYOUNG S M, CHOE J M, et al. Effects of autologous platelet-rich plasma on regeneration of damaged endometrium in female rats [J]. Yonsei Med J, 2017, 58(6): 1195-1203. DOI: 10.3349/ymj.2017.58.6.1195.

[20] ZHANG S W, LI P P, YUAN Z W, et al. Platelet-rich plasma improves therapeutic effects of menstrual blood-derived stromal cells in rat model of intrauterine adhesion [J]. Stem Cell Res Ther, 2019, 10(1): 61. DOI: 10.1186/s13287-019-1155-7.

[21] BAKACAK M, BOSTANCI M S, İ • NANC F, et al. Protective effect of platelet rich plasma on experimental ischemia/reperfusion injury in rat ovary [J]. Gynecol Obstet Invest, 2016, 81(3): 225-231. DOI: 10.1159/000440617.

[22] STREIT-CIEC' KIEWICZ D, KOLODYN' SKA A, FUTYMA-GABKA K, et al. Platelet rich plasma in gynecology-discovering undiscovered-review [J]. Int J Environ Res Public Health, 2022, 19(9): 5284. DOI: 10.3390/ijerph19095284.

[23] EVERTS P A, VAN ERP A, DESIMONE A, et al. Platelet rich plasma in orthopedic surgical medicine [J]. Platelets, 2021, 32(2): 163-174. DOI: 10.1080/09537104.2020.1869717.

[24] TEHRANIAN A, ESFEHANI-MEHR B, PIRJANI R, et al. Application of autologous platelet-rich plasma (PRP) on wound healing after Caesarean section in high-risk patients [J]. Iran Red Crescent Med J, 2016, 18(7): e34449. DOI: 10.5812/ircmj.34449.

[25] FANNING J, MURRAIN L, FLORA R, et al. Phase I/II prospective trial of autologous platelet tissue graft in gynecologic surgery [J]. J Minim Invasive Gynecol, 2007, 14(5): 633-637. DOI: 10.1016/j.jmig.2007.05.014.

[26] MEDEL S, ALARAB M, KUFAISHI H, et al. Attachment of primary vaginal fibroblasts to absorbable and nonabsorbable implant materials coated with platelet-rich plasma: potential application in pelvic organ prolapse surgery [J]. Female Pelvic Med Reconstr Surg, 2015, 21(4): 190-197. DOI: 10.1097/SPV.0000000000000178.

[27] BEHNIA-WILLISON F, POUR N R, MOHAMADI B, et al. Use of platelet-rich plasma for vulvovaginal autoimmune conditions like lichen sclerosus [J]. Plast Reconstr Surg Glob Open, 2016, 4(11): e1124. DOI: 10.1097/GOX.0000000000001124.

[28] HUA X L, ZENG Y, ZHANG R R, et al. Using platelet-rich plasma for the treatment of symptomatic cervical ectopy [J]. Int J Gynaecol Obstet, 2012, 119(1): 26-29. DOI: 10.1016/j.ijgo.2012.05.029.

[29] WHITE Y A R, WOODS D C, TAKAI Y, et al. Oocyte formation by mitotically active germ cells purified from ovaries of reproductive-age women [J]. Nat Med, 2012, 18(3): 413-421. DOI: 10.1038/nm.2669.

[30] CAKIROGLU Y, SALTIK A, YUCETURK A, et al. Effects of intraovarian injection of autologous platelet rich plasma on ovarian reserve and IVF outcome parameters in women with primary ovarian insufficiency [J]. Aging (Albany NY), 2020, 12(11): 10211-10222. DOI: 10.18632/aging.103403.

[31] CAKIROGLU Y, YUCETURK A, KARAOSMANOGLU O, et al. Ovarian reserve parameters and IVF outcomes in 510 women with poor ovarian response (POR) treated with intraovarian injection of autologous platelet rich plasma (PRP) [J]. Aging (Albany NY), 2022, 14(6): 2513-2523. DOI: 10.18632/aging.203972.

[32] CHANG Y N, DUAN H, SHEN X, et al. Controversy in the management of oestrogen therapy before hysteroscopic adhesiolysis: a systematic review and meta-analysis [J]. Reprod Biomed Online, 2020, 41(4): 715-723. DOI: 10.1016/j.rbmo.2020.06.012.

[33] ZHANG Y L, SHI L B, LIN X N, et al. Unresponsive thin endometrium caused by Asherman syndrome treated with umbilical cord mesenchymal stem cells on collagen scaffolds: a pilot study [J]. Stem Cell Res Ther, 2021, 12(1): 420. DOI: 10.1186/s13287-021-02499-z.

[34] CHANG Y J, LI J J, CHEN Y Q, et al. Autologous platelet-rich plasma promotes endometrial growth and improves pregnancy outcome during in vitro fertilization [J]. Int J Clin Exp Med, 2015, 8(1): 1286-1290.

[35] COLOMBO G V L, FANTON V, SOSA D, et al. Use of platelet rich plasma in human infertility [J]. J Biol Regul Homeost Agents, 2017, 31(2 Suppl. 2): 179-182.

[36] CHANG Y J, LI J J, WEI L N, et al. Autologous platelet-rich plasma infusion improves clinical pregnancy rate in frozen embryo transfer cycles for women with thin endometrium [J]. Medicine (Baltimore), 2019, 98(3): e14062. DOI: 10.1097/MD.0000000000014062.

[37] DOGRA Y, SINGH N, VANAMAIL P. Autologous platelet-rich plasma optimizes endometrial thickness and pregnancy outcomes in women with refractory thin endometrium of varied aetiology during fresh and frozen-thawed embryo transfer cycles [J]. JBRA Assist Reprod, 2022, 26(1): 13-21. DOI: 10.5935/1518-0557.20210037.

[38] NAZARI L, SALEHPOUR S, HOSEINI S, et al. Effects of autologous platelet-rich plasma on implantation and pregnancy in repeated implantation failure: a pilot study [J]. Int J Reprod Biomed, 2016, 14(10): 625-628.

[39] CHOUKROUN J, DISS A, SIMONPIERI A, et al. Platelet-rich fibrin (PRF): a second-generation platelet concentrate. Part V: histologic evaluations of PRF effects on bone allograft maturation in sinus lift [J]. Oral Surg Oral Med Oral Pathol Oral Radiol Endod, 2006, 101(3): 299-303. DOI: 10.1016/j.tripleo.2005.07.012.

[40] MICKO L, SALMA I, SKADINS I, et al. Can our blood help ensure antimicrobial and anti-inflammatory properties in oral and maxillofacial surgery? [J]. Int J Mol Sci, 2023, 24(2): 1073. DOI: 10.3390/ijms24021073.

[41] FARSHIDFAR N, AMIRI M A, JAFARPOUR D, et al. The feasibility of injectable PRF (I-PRF) for bone tissue engineering and its application in oral and maxillofacial reconstruction: from bench to chairside [J]. Biomater Adv, 2022, 134: 112557. DOI: 10.1016/j.msec.2021.112557.

[42] GORLERO F, GLORIO M, LORENZI P, et al. New approach in vaginal prolapse repair: mini-invasive surgery associated with application of platelet-rich fibrin [J]. Int Urogynecol J, 2012, 23(6): 715-722. DOI: 10.1007/s00192-011-1631-8.

[43] SHIRVAN M K, ALAMDARI D H, GHOREIFI A. A novel method for iatrogenic vesicovaginal fistula treatment: autologous platelet rich plasma injection and platelet rich fibrin glue interposition [J]. J Urol, 2013, 189(6): 2125-2129. DOI: 10.1016/j.juro.2012.12.064.

[44] WANG Z J, YANG M K, MAO L L, et al. Efficacy and safety of autologous platelet-rich fibrin for the treatment of infertility with intrauterine adhesions [J]. J Obstet Gynaecol Res, 2021, 47(11): 3883-3894. DOI: 10.1111/jog.14964.

[45] YANG M K, WANG Z J, CUI G X, et al. Effect of platelet-rich fibrin on wound repair of intrauterine adhesions [J]. Journal of Clinical Transfusion and Laboratory Medicine, 2022, 24(3): 363-368.

Note: Figure translations are in progress. See original paper for figures.