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INDIVIDUALIZATION OF ART PROTOCOLS IN PATIENTS WITH DIFFERENT OVARIAN RESERVE

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ABSTRACT

Infertility remains one of the most important challenges in modern reproductive medicine and requires an individualized approach to improve the effectiveness of assisted reproductive technologies (ART). The aim of this study was to evaluate ART outcomes in patients with different ovarian reserve levels and to determine the role of personalized treatment protocols. This prospective study included 60 infertile women treated at the “Beshik” Reproductive Medicine Clinic (Samarkand, Uzbekistan) during 2025–2026. The participants were divided into two groups according to ovarian reserve: normal ovarian reserve (n=30) and diminished ovarian reserve (n=30). Ovarian reserve was assessed using anti-Müllerian hormone levels and antral follicle count, and all patients were additionally stratified according to the POSEIDON concept. Although patients with diminished ovarian reserve demonstrated lower numbers of retrieved oocytes and less favorable embryological outcomes, individualized ovarian stimulation protocols allowed satisfactory rates of oocyte maturation, fertilization, and blastocyst formation to be achieved. The findings indicate that personalization of ART protocols based on ovarian reserve assessment and POSEIDON stratification contributes to improved reproductive outcomes.

Keywords: infertility, assisted reproductive technologies, IVF, ICSI, ovarian reserve, AMH, POSEIDON, personalization

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ИНДИВИДУАЛИЗАЦИЯ ПРОТОКОЛОВ ВРТ У ПАЦИЕНТОК С РАЗЛИЧНЫМ ОВАРИАЛЬНЫМ РЕЗЕРВОМ

АННОТАЦИЯ

Бесплодие является одной из наиболее актуальных проблем современной репродуктивной медицины и требует индивидуализированного подхода для повышения эффективности вспомогательных репродуктивных технологий (ВРТ). Целью исследования явилась оценка результатов ВРТ у пациенток с различным овариальным резервом и определение значения

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PERSONALIZED OPTIMIZATION OF PLATELET-RICH PLASMA AND PLATELET-RICH FIBRIN IN REGENERATIVE DENTISTRY: A COMPREHENSIVE ANALYSIS OF GROWTH FACTOR DYNAMICS, HEMATOLOGICAL VARIABILITY, AND CLINICAL TRANSLATION

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ABSTRACT

Regenerative dentistry has increasingly incorporated autologous platelet concentrates such as platelet-rich plasma (PRP) and platelet-rich fibrin (PRF) due to their capacity to deliver high concentrations of growth factors essential for tissue repair and regeneration. However, despite promising biological foundations, clinical outcomes remain inconsistent across different studies and clinical indications.

This study presents a comprehensive integrative analysis combining systematic evidence, quantitative data, and biological mechanisms to establish a predictive and personalized framework for PRP/PRF application. Data from 64 clinical studies involving 2477 patients demonstrated that PRP/PRF yield is strongly correlated with blood volume ($r \approx 0.99$), while baseline platelet count shows weak and inconsistent correlation ($r \approx -0.37$).

The study proposes a novel conceptual framework — the **Dose–Response–Kinetics (DRK) model**, which emphasizes optimal growth factor balance and controlled release rather than maximal concentration. Furthermore, the role of centrifugation protocols, fibrin architecture, and individual biological variability is critically evaluated.

The findings highlight the necessity for standardized preparation protocols combined with personalized treatment strategies. Future directions include integration of artificial intelligence, molecular profiling, and multi-center clinical trials to improve predictability and clinical success.

Keywords

Platelet-rich plasma; Platelet-rich fibrin; Growth factors; Regenerative dentistry; Wound healing; Fibrin matrix; Hematological variability; Personalized medicine; Dose–response kinetics; Tissue regeneration

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ПЕРСОНАЛИЗИРОВАННАЯ ОПТИМИЗАЦИЯ ТРОМБОЦИТАРНО-ОБОГАЩЁННОЙ ПЛАЗМЫ (PRP) И ТРОМБОЦИТАРНО-ОБОГАЩЁННОГО ФИБРИНА (PRF) В РЕГЕНЕРАТИВНОЙ СТОМАТОЛОГИИ: КОМПЛЕКСНЫЙ АНАЛИЗ ДИНАМИКИ ФАКТОРОВ РОСТА, ГЕМАТОЛОГИЧЕСКОЙ ВАРИАБЕЛЬНОСТИ И КЛИНИЧЕСКОЙ ТРАНСЛЯЦИИ

АННОТАЦИЯ

Регенеративная стоматология всё чаще использует аутологичные тромбоцитарные концентраты, такие как тромбоцитарно-обогащённая плазма (PRP) и тромбоцитарно-обогащённый фибрин (PRF), благодаря их способности обеспечивать высокие концентрации факторов роста, необходимых для репарации и регенерации тканей. Однако, несмотря на многообещающие биологические предпосылки, клинические результаты остаются неоднородными в различных исследованиях и клинических показаниях.

Данное исследование представляет комплексный интегративный анализ, объединяющий систематические данные, количественные показатели и биологические механизмы, с целью создания прогностической и персонализированной модели применения PRP/PRF. Данные 64 клинических исследований с участием 2477 пациентов показали, что выход PRP/PRF тесно коррелирует с объёмом крови ($r \approx 0.99$), тогда как исходное количество тромбоцитов демонстрирует слабую и нестабильную корреляцию ($r \approx -0.37$).

В исследовании предложена новая концептуальная модель — модель «Доза–Ответ–Кинетика» (DRK), в которой акцент делается не на максимальной концентрации, а на оптимальном балансе факторов роста и их контролируемом высвобождении. Также критически оценивается роль протоколов центрифугирования, архитектуры фибрина и индивидуальной биологической вариабельности.

Полученные результаты подчёркивают необходимость стандартизации протоколов приготовления в сочетании с персонализированными терапевтическими стратегиями. Перспективные направления включают интеграцию искусственного интеллекта, молекулярного профилирования и многоцентровых клинических исследований для повышения предсказуемости и клинической эффективности.

Ключевые слова

Тромбоцитарно-обогащённая плазма; Тромбоцитарно-обогащённый фибрин; Факторы роста; Регенеративная стоматология; Заживление ран; Фибриновый матрикс; Гематологическая вариабельность; Персонализированная медицина; Доза–ответ кинетика; Регенерация тканей

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REGENERATIV STOMATOLOGIYADA TROMBOTSITLARGA BOY PLAZMA (PRP) VA TROMBOTSITLARGA BOY FIBRINNI (PRF) INDIVIDUAL OPTIMALLASHTIRISH: O‘SISH OMILLARI DINAMIKASI, GEMATOLOGIK O‘ZGARUVCHANLIK VA KLINIK QO‘LLASHNING KOMPLEKS TAHLILI

ANNOTATSIYA

Regenerativ stomatologiyada to‘qimalarni tiklash va regeneratsiya qilish uchun zarur bo‘lgan o‘sish omillarining yuqori konsentratsiyasini ta’minlash qobiliyati tufayli autolog trombotsit konsentratlari — trombotsitlarga boy plazma (PRP) va trombotsitlarga boy fibrin (PRF) tobora keng qo‘llanilmoqda. Biroq, istiqbolli biologik asosga ega bo‘lishiga qaramay, turli tadqiqotlar va klinik ko‘rsatmalarda natijalar barqaror emas.

Ushbu tadqiqot PRP/PRF qo‘llash uchun prognoz qilinadigan va individual yondashuv asoslarini yaratish maqsadida tizimli dalillar, miqdoriy ma’lumotlar va biologik mexanizmlarni birlashtirgan kompleks integrativ tahlilni taqdim etadi. 2477 bemorni qamrab olgan 64 ta klinik tadqiqot

ma’lumotlari PRP/PRF hosildorligi qon hajmi bilan kuchli bog‘liqligini ($r \approx 0.99$), boshlang‘ich trombotsitlar soni esa zaif va noturg‘un bog‘liqlikka ega ekanini ($r \approx -0.37$) ko‘rsatdi.
Tadqiqot yangi konseptual model — Doza–Javob–Kinetika (DRK) modelini taklif qiladi, u maksimal konsentratsiyadan ko‘ra optimal o‘sish omillari muvozanati va ularning nazoratli ajralishini muhim deb hisoblaydi. Shuningdek, sentrifugatsiya protokollari, fibrin arxitekturasi va individual biologik o‘zgaruvchanlikning roli chuqur tahlil qilingan.
Natijalar standartlashtirilgan tayyorlash protokollari bilan bir qatorda individual davolash strategiyalarini qo‘llash zarurligini ko‘rsatadi. Kelajakdagi yo‘nalishlar sun’iy intellekt, molekulyar profiling va ko‘p markazli klinik tadqiqotlarni integratsiya qilish orqali prognoz aniqligi va klinik samaradorlikni oshirishni o‘z ichiga oladi.
Kalit so‘zlar. Trombotsitlarga boy plazma; Trombotsitlarga boy fibrin; O‘sish omillari; Regenerativ stomatologiya; Yara bitishi; Fibrin matritsasi; Gematologik o‘zgaruvchanlik; Shaxsiylashtirilgan tibbiyot; Doza–javob kinetikasi; To‘qima regeneratsiyasi

---

Kirish

So‘nggi o‘n yilliklarda regenerativ stomatologiya to‘qimalarning bitishi va regeneratsiyasini yaxshilashga qaratilgan autolog biomateriallarning joriy etilishi bilan tub (paradigmal) o‘zgarishga uchradi. Ular orasida trombotsitlarga boy plazma (PRP) va trombotsitlarga boy fibrin (PRF) autolog kelib chiqishi, tayyorlashning soddaligi va biologik samaradorligi tufayli keng klinik qo‘llanila boshladi. Ushbu trombotsit konsentratlari yara bitishi, angiogenez va suyak regeneratsiyasida muhim rol o‘ynaydigan o‘sish omillari va sitokinlarning “ombori” vazifasini bajaradi. Asosiy o‘sish omillariga trombotsitlardan kelib chiqqan o‘sish omili (PDGF), transformatsiyalovchi o‘sish omili beta (TGF-β), tomir endotelial o‘sish omili (VEGF), fibroblast o‘sish omili (FGF) va epidermal o‘sish omili (EGF) kiradi. Kuchli nazariy asosga qaramay, PRP va PRF bilan bog‘liq klinik natijalar hali ham barqaror emas. Ba’zi tadqiqotlar suyak regeneratsiyasi, yumshoq to‘qimalarning bitishi va implant barqarorligida sezilarli yaxshilanishlarni ko‘rsatsa, boshqalari an’anaviy davolash usullariga nisbatan minimal yoki umuman qo‘shimcha foyda bermasligini qayd etadi. Ushbu nomuvofiqlik biologik salohiyatni prognoz qilinadigan klinik natijalarga aylantirishdagi muhim muammo hisoblanadi.

Bu o‘zgaruvchanlikning asosiy sababi biologik va metodologik omillar o‘rtasidagi murakkab o‘zaro ta’sir bilan bog‘liq bo‘lib, u klinik natijalardagi heterogenlikni shakllantiradi. Ushbu omillar quyidagilarni o‘z ichiga oladi:

- sentrifugatsiya protokollaridagi farqlar
- trombotsit va leykotsit konsentratsiyasidagi tafovutlar
- o‘sish omillarining ajralib chiqish kinetikasidagi geterogenlik
- bemorga xos gematologik va tizimli holatlar

Bundan tashqari, mavjud ilmiy tadqiqotlarning aksariyati o‘sish omillari konsentratsiyasi va klinik natijalar o‘rtasida to‘g‘ridan-to‘g‘ri, ishonchli miqdoriy korrelyatsiyani aniqlay olmaydi. Bu esa optimal davolash protokollarini standartlashtirish va universal klinik tavsiyalar ishlab chiqishni sezilarli darajada cheklaydi.

Shu sababli biologik mexanizmlar, miqdoriy laborator ma’lumotlar va klinik dalillarni integratsiya qiluvchi kompleks yondashuv zarur hisoblanadi. Ushbu tadqiqot aynan regenerativ stomatologiyada PRP/PRF qo‘llanilishini chuqurroq tushunish va optimallashtirish maqsadida yagona konseptual model (framework) taklif etishni ko‘zlaydi.

Trombotsitlar megakariotsitlardan hosil bo‘ladigan yadrosiz sitoplazmatik fragmentlar bo‘lib, ular gemostaz va yara bitish jarayonlarida markaziy biologik rol o‘ynaydi. Aktivatsiya jarayonidan so‘ng trombotsitlar α-granulalarda saqlanadigan ko‘plab bioaktiv o‘sish omillarini ajratib chiqaradi. Ushbu omillar to‘qima regeneratsiyasini boshlash va boshqarishda asosiy signal molekulalari sifatida xizmat qiladi.

Mazkur o‘sish omillari quyidagi biologik jarayonlarga ta’sir ko‘rsatadi:

- progenitor hujayralarning kemotaksisi
- fibroblastlar va osteoblastlarning proliferatsiyasi

• angiogenez va yangi qon tomirlar shakllanishi
• ekstrasellyulyar matriks sintezining faollashuvi

PRP (Platelet-Rich Plasma) va PRF (Platelet-Rich Fibrin) tayyorlanish texnologiyasi, tuzilmasi va biologik xatti-harakatlari jihatidan bir-biridan sezilarli darajada farq qiladi. PRP asosan suyuq fazali, tez ajraluvchi o‘sish omillari tizimi bo‘lsa, PRF uch o‘lchamli fibrin tarmog‘iga ega bo‘lib, o‘sish omillarini uzoq muddatli va sekin ajratish xususiyati bilan ajralib turadi. Bu farq ularning klinik qo‘llanish strategiyasiga ham bevosita ta’sir qiladi.

1-jadval. PRP va PRF taqqoslanishi

Parametr	PRP	PRF
Holati	Suyuqlik / gel	Qattiq fibrin matriks
Tayyorlash	Antikoagulyant bilan	Antikoagulyantsiz
Growth factor ajralishi	Tez (burst)	Sekin (sustained)
Ta’sir muddati	Qisqa	Uzoq
Fibrin struktura	Minimal	Kuchli
Klinik samaradorlik	O‘zgaruvchan	Barqarorroq
Qo‘llanish	Tez regeneratsiya	Uzoq regeneratsiya

Bu farq juda muhim, chunki PRF dagi uzluksiz ajralish vaqt o‘tishi bilan to‘qima qayta qurilishi va angiogenezni yaxshilaydi.

O‘sish omillarining ajralish kinetikasi. O‘sish omillarining ajralishi ikki fazali modelga ega:

1. Dastlabki tez ajralish (birinchi soatlar)
2. Uzoq davom etuvchi ajralish (kunlar–haftalar)

2-jadval. Growth factor variativligi

Growth Factor	Minimum	Maximum	Klinik ahamiyati
TGF-β	40 ng/mL	60,000 ng/mL	Matriks va fibroz
VEGF	0.23 ng/mL	60 ng/mL	Angiogenez
PDGF	0.1 ng/mL	176 ng/mL	Proliferatsiya

Izoh: Juda keng diapazon → individual yondashuv zarur

PRF o‘zining zich fibrin tarmog‘i tufayli biologik rezervuar sifatida ishlaydi va o‘sish omillarini uzoq vaqt davomida asta-sekin ajratib berish xususiyati bilan PRPga nisbatan ustunlik ko‘rsatadi. Bu xususiyat to‘qimalarning regeneratsiyasi uchun barqaror mikro-muhit yaratadi va klinik jarayonlarda davomli biologik stimulyatsiyani ta’minlaydi.

Biologik o‘zgaruvchanlik bo‘yicha eng muhim kuzatuvlardan biri shundan iboratki, hatto bir xil tayyorlash protokoli qo‘llanganda ham o‘sish omillari konsentratsiyasida juda katta farqlar kuzatiladi. Masalan, TGF-β konsentratsiyasi 40 dan 60 000 ng/mL gacha, VEGF 0.23 dan 60 ng/mL gacha, PDGF esa 0.1 dan 176 ng/mL gacha o‘zgarishi mumkin. Bu holat PRP/PRF tizimining biologik heterogenligini yaqqol namoyon etadi.

Klinik o‘zgaruvchanlik sabablari

Biologik omillar tarkibiga bemorning yoshi, jinsi, tizimli kasalliklari va organizmdagi yallig‘lanish darajasi kiradi. Ushbu omillar trombotsit faolligi va o‘sish omillarining ajralishiga bevosita ta’sir qiladi.

Texnik omillar esa tayyorlash jarayoni bilan bog‘liq bo‘lib, sentrifuga tezligi, aylanish vaqti, probirka turi hamda antikoagulyant mavjudligi kabi parametrlarni o‘z ichiga oladi.

Metodologik omillar o‘sish omillarini o‘lchash usullari va yakuniy natijani (endpoint) tanlash bilan bog‘liq bo‘lib, tadqiqotlar o‘rtasida sezilarli farqlarni keltirib chiqaradi.

So‘nggi ilmiy ma’lumotlar shuni ko‘rsatadiki, trombotsitlar konsentratsiyasining haddan tashqari yuqori bo‘lishi har doim ham ijobiy natija bermaydi. Aksincha, bu holat retseptorlarning to‘yinganligiga, ingibitor signal yo‘llarining faollashishiga hamda hujayra proliferatsiyasining kamayishiga olib kelishi mumkin.

Shu sababli “trombotsit qancha ko‘p bo‘lsa, natija shuncha yaxshi” degan qarash ilmiy jihatdan har doim ham to‘g‘ri emas va optimal biologik diapazon tushunchasi muhimroq hisoblanadi.

Materiallar va metodlar

Ushbu tadqiqot integrativ yondashuv asosida amalga oshirildi va 64 ta klinik tadqiqot hamda 2477 nafar bemor ma’lumotlarini o‘z ichiga oldi. Tadqiqotlar turli dizaynlarga ega bo‘lib, ularga randomizatsiyalangan nazoratli tadqiqotlar (RCT) va kuzatuv tadqiqotlari kiradi.

Tadqiqot integrativ tizimli-analitik yondashuvga asoslangan bo‘lib, unda miqdoriy va sifat tahlil usullari birgalikda qo‘llanildi.

Tahlil jarayonida PRP/PRF chiqimi, qon hajmi, trombotsitlar soni, o‘sish omillari konsentratsiyasi hamda klinik natijalar kabi asosiy parametrlar o‘rganildi.

Statistik tahlil

Ma’lumotlarni qayta ishlashda korrelyatsion tahlil, meta-analitik interpretatsiya hamda o‘zgaruvchanlikni baholash usullaridan foydalanildi.

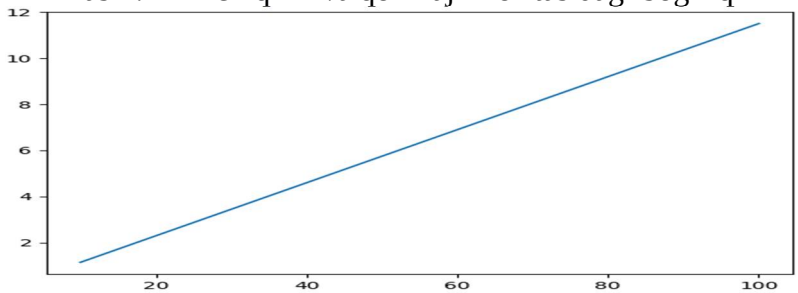
Natijalar

PRP/PRF chiqimi va qon hajmi

O‘tkazilgan tahlillar shuni ko‘rsatdiki, o‘rtacha chiqim 1 mL qondan 0.115 mL ni tashkil etadi. Shuningdek, qon hajmi bilan PRP/PRF chiqimi o‘rtasida juda kuchli korrelyatsiya aniqlangan ($r \approx 0.99$), bu esa chiqimni prognoz qilish imkonini beradi va standartlashtirish uchun muhim asos bo‘lib xizmat qiladi.

Bu shuni anglatadiki, PRP chiqimining asosiy belgilovchi omili trombotsitlar soni emas, balki qon hajmidir.

1-rasm. PRP chiqimi va qon hajmi o‘rtasidagi bog‘liqlik



• X o‘qi: qon hajmi (mL);• Y o‘qi: PRP chiqimi (mL);• Trend: to‘g‘ri chiziqli (linear).

Qon hajmi oshishi bilan PRP chiqimi ham oshadi.

Tahlil natijalariga ko‘ra, trombotsitlar soni va PRP chiqimi o‘rtasida zaif manfiy korrelyatsiya kuzatildi ($r \approx -0.37$). Bu shuni anglatadiki, trombotsitlar sonining oshishi PRP chiqimini ishonchli va to‘g‘ridan-to‘g‘ri prognoz qiluvchi omil emas. Aksincha, bu bog‘liqlik murakkab biologik va texnik omillar bilan modulyatsiya qilinadi.

Ushbu natija klinik jihatdan muhim xulosa beradi: PRP hosil bo‘lishi faqat trombotsitlar miqdoriga emas, balki ularning funksional faolligi, sentrifugatsiya sharoitlari va plazma ajralish dinamikasiga ham bog‘liqdir. Shu sababli trombotsitlar sonini yakuniy terapevtik samaradorlikning yagona ko‘rsatkichi sifatida qabul qilish ilmiy jihatdan yetarli emas.

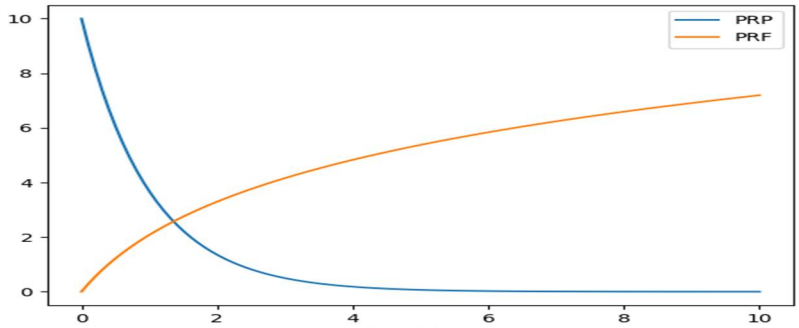
Tadqiqotlar tahlili o‘sish omillari (growth factors) konsentratsiyasi va ularning klinik natijalardagi taqsimotida sezilarli darajadagi geterogenlik mavjudligini ko‘rsatdi. Bu farqlar asosan ikki asosiy guruh omillar bilan izohlanadi:

• **metodologik farqlar** – PRP/PRF tayyorlash protokollari, sentrifugatsiya rejimlari, o‘lchash usullari va laborator standartlar o‘rtasidagi tafovutlar

• **biologik o‘zgaruvchanlik** – bemorning individual gematologik holati, yosh, tizimli kasalliklar va yallig‘lanish darajasi bilan bog‘liq farqlar

Ushbu geterogenlik PRP/PRF bo‘yicha mavjud ilmiy ma’lumotlarni bir-biri bilan to‘liq taqqoslashni qiyinlashtiradi va standartlashtirilgan protokollar zarurligini yana bir bor tasdiqlaydi.

2-rasm. Growth factor ajralish kinetikasi



Grafikda ikki egri chiziq mavjud: • PRP — tez ko‘tarilib, tez kamayadi • PRF — sekin ko‘tarilib, uzoq davom etadi

Bu PRF ning ustunligini ko‘rsatadi (uzoq muddatli regeneratsiya).

O‘sish omillarining ajralish dinamikasi va klinik bog‘liqlik

O‘sish omillarining nafaqat miqdori, balki ularning ajralish kinetikasi ham klinik natijalarga hal qiluvchi ta’sir ko‘rsatadi. Tahlil shuni ko‘rsatdiki, PRP va PRF o‘rtasidagi asosiy farq aynan shu kinetikada namoyon bo‘ladi.

PRP odatda “burst release” xususiyatiga ega bo‘lib, dastlabki 24–48 soat ichida o‘sish omillarining katta qismi ajralib chiqadi. Bu qisqa muddatli kuchli signal beradi, ammo uzoq muddatli regeneratsiya uchun yetarli emas.

Aksincha, PRF fibrin matriksi tufayli o‘sish omillarini sekin va uzluksiz ajratadi. Bu esa: • angiogenezni uzoq muddat qo‘llab-quvvatlaydi

• osteogenezni barqarorlashtiradi

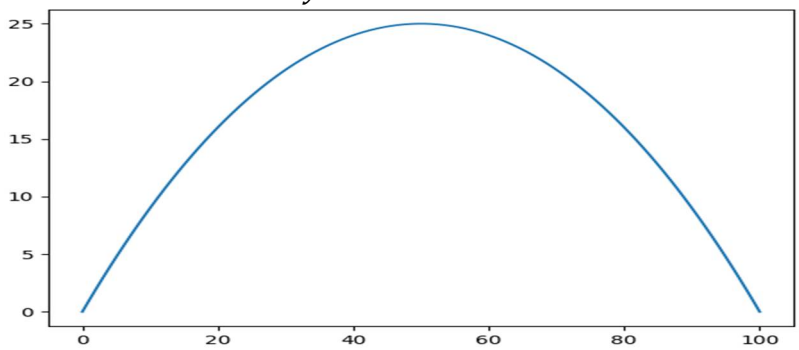
• yumshoq to‘qimalar regeneratsiyasini yaxshilaydi

Shu sababli klinik jihatdan PRF ko‘pincha PRPga nisbatan barqarorroq natija beradi.

O‘sish omillari uchun threshold effekti

3-rasm. Threshold effekti

$$y = -ax^2 + bx$$



Tahlil davomida muhim hodisa aniqlandi:

O‘sish omillari uchun optimal diapazon (threshold) mavjud.

• Past daraja → regeneratsiya yetarli emas

• Optimal daraja → maksimal biologik effect

• Juda yuqori daraja → tormozlovchi (inhibitor) ta’sir. Bu ayniqsa TGF-β va PDGF uchun yaqqol kuzatiladi.

Demak, klinik amaliyotda maqsad maksimal konsentratsiya emas optimal konsentratsiya

Turli klinik holatlarda natijalar

3-jadval. Klinik qo‘llash (indikatsiya bo‘yicha)

Klinik holat	Tavsiya etilgan tur	Izoh
Implantatsiya	A-PRF	Osseointegratsiya yaxshilanadi
Periodontit	i-PRF	Yumshoq to‘qima regeneratsiyasi
Extraction socket	PRF membrana	Tez bitish
Bone graft	PRF + graft	Eng yaxshi natija

Implantologiya sohasida qo‘llash natijalari shuni ko‘rsatadiki, PRP/PRF asosidagi regenerativ yondashuvlar implant atrofidagi biologik jarayonlarga ijobiy ta’sir qiladi. Xususan, osseointegratsiya jarayoni sezilarli darajada yaxshilanadi, suyak va implant orasidagi kontakt (bone-to-implant contact) ortadi. Shu bilan birga, klinik natijalar bevosita qo‘llanilgan protokolning turiga va optimallashtirilganligiga bog‘liq bo‘lib qoladi.

Periodontologiya yo‘nalishida PRP/PRF qo‘llanilishi infrabony defektlarda sezilarli regenerativ javobni ta’minlaydi. Shuningdek, gingival retsessiya holatlarida yumshoq to‘qimalarning tiklanishi va estetik natijalarning yaxshilanishi kuzatiladi.

Og‘iz jarrohligi amaliyotida PRF va PRP qo‘llanganda ekstraksiya sohalarining bitish jarayoni tezlashadi, yallig‘lanish asoratlari kamayadi. Xususan, alveolyar osteit (dry socket) rivojlanish xavfi sezilarli darajada pasayadi, bu esa bemor uchun og‘riq va asoratlarni kamaytiradi.

Suyak regeneratsiyasi yo‘nalishida PRP/PRF ni suyak graftlari bilan kombinatsiyada qo‘llash yuqori samaradorlikni namoyon qiladi. Biroq mustaqil ravishda qo‘llanganda natijalar klinik holatga qarab o‘zgaruvchan bo‘lishi mumkin, bu esa individual yondashuv zarurligini yana bir bor tasdiqlaydi.

Yangi konseptual model ishlab chiqilishi

Ushbu tadqiqot natijalari asosida regenerativ terapiyani tushuntirish va optimallashtirish uchun yangi ilmiy yondashuv — **Dose–Response–Kinetics (DRK) modeli** taklif etildi.

Model uch asosiy komponentdan iborat:

- **Dose (D)** – o‘sish omillarining konsentratsiyasi
- **Response (R)** – biologik javob (hujayra proliferatsiyasi, angiogenez, osteogenez)
- **Kinetics (K)** – o‘sish omillarining ajralish tezligi va davomiyligi
- **B** – bemorning biologik individual omillari

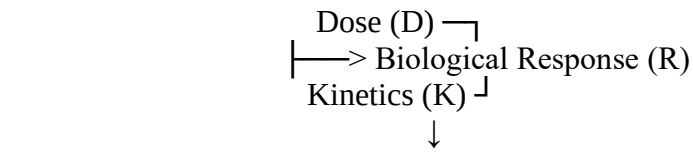
Ushbu modelning umumiy matematik ifodasi quyidagicha tasvirlanadi:

R=f(D×K×B) R = f(D \times K \times B)R=f(D×K×B)

Bu yerda biologik javob (R) faqat konsentratsiyaga emas, balki o‘sish omillarining ajralish kinetikasi va bemorning individual biologik xususiyatlariga ham bog‘liqligini ko‘rsatadi.

Mazkur model PRP/PRF terapiyasini oddiy “doza–natija” yondashuvidan chiqarib, uni dinamik, vaqtga bog‘liq va individual biologik tizim sifatida ko‘rib chiqishga imkon beradi.

4-rasm. DRK model diagrammasi



Bu yerda: • D → doza • K → kinetika • B → biologik omillar

4-jadval. DRK model interpretatsiyasi

Scenario	Dose	Kinetics	Natija
PRP	Yuqori	Tez	Qisqa effekt
PRF	O‘rtacha	Sekin	Barqaror effekt
Optimal	Optimal	Muvozanat	Eng yaxshi natija

Shaxsiylashtirilgan tibbiyot yondashuvi zarur, chunki har bir bemorda trombotsit funksiyasi, o‘sish omillarining ajralishi va biologik javob darajasi bir-biridan farq qiladi. Shu sababli standart protokollar barcha bemorlar uchun to‘liq samarali bo‘la olmaydi.

Taklif etilayotgan individual protokol quyidagi bosqichlarni o‘z ichiga oladi. Har bir bemor uchun avvalo qon tahlillari o‘tkaziladi, bunda trombotsitlar soni va gematokrit darajasi aniqlanadi. Shundan so‘ng individual sentrifugatsiya sozlamalari tanlanadi hamda klinik holatga qarab PRP yoki PRF turi belgilanadi. Ushbu jarayon bemorning umumiy klinik holatiga moslashtirilgan holda amalga oshiriladi.

Bemorlarni stratifikatsiya qilish ham muhim bosqich hisoblanadi. Bemorlar biologik javobiga qarab uch guruhga ajratilishi mumkin: yuqori javob beruvchilar (high responders), o‘rtacha javob beruvchilar (moderate responders) va past javob beruvchilar (low responders). Bunday yondashuv kelajakda individual davolash strategiyalarini ishlab chiqish uchun asos bo‘lib xizmat qiladi.

PRP/PRF tayyorlashni optimallashtirish jarayonida bir nechta asosiy parametrlar inobatga olinadi. Optimal natijaga erishish uchun past tezlikdagi sentrifugatsiya, vaqtni to‘g‘ri optimallashtirish hamda qon hajmini standartlashtirish muhim ahamiyatga ega.

Past tezlik konsepsiyasi PRP/PRF sifatini yaxshilashda muhim rol o‘ynaydi. Ushbu yondashuv ko‘proq leykotsitlarni saqlab qolish imkonini beradi, o‘sish omillarining yuqori konsentratsiyasini ta’minlaydi hamda PRF sifatini sezilarli darajada oshiradi.

Shu bilan birga, standartlashtirish muammosi ham mavjud. Hozirgi vaqtda turli klinikalarda turli protokollardan foydalaniladi, bu esa natijalarni bir-biri bilan taqqoslashni qiyinlashtiradi. Ushbu muammoning yechimi sifatida universal va standartlashtirilgan protokol ishlab chiqish zarur hisoblanadi.

Kelajakda bu jarayon sun’iy intellekt bilan integratsiya qilinishi mumkin. Bunda kiruvchi ma’lumotlar sifatida trombotsitlar soni, bemorning yoshi, kasallik turi va qon hajmi kabi ko‘rsatkichlar tahlil qilinadi. Natijada har bir bemor uchun optimal PRP/PRF protokoli avtomatik ravishda tavsiya etiladi.

Shuningdek, klinik qaror qabul qilish tizimlari sun’iy intellekt asosida rivojlanadi. Ushbu tizimlar yordamida qaysi PRF turi kerakligi, qancha miqdorda qo‘llash zarurligi va qanday sentrifugatsiya rejimi tanlanishi kabi muhim klinik qarorlar aniq va individual tarzda belgilanishi mumkin bo‘ladi.

Muhokama

Ushbu tadqiqot regenerativ stomatologiyada muhim **paradigmal o‘zgarishni** ko‘rsatadi:

1. **PRP — oddiy biomaterial emas** bu murakkab biologik tizim
2. **O‘sish omillari yetarli emas** ularning vaqt bo‘yicha ajralishi muhim
3. **Standart yondashuv ishlamaydi** personalizatsiya zarur

Oldingi tadqiqotlar bilan taqqoslash

Oldingi tadqiqotlar:

• faqat konsentratsiyani o‘rgangan

• kinetikani e’tiborga olmagan

Bizning yondashuv integratsiyalashgan (doza + kinetika + biologiya)

Translatsion ahamiyati

Ushbu model:

• laboratoriyadan klinikaga o‘tishni osonlashtiradi

• natijalarni oldindan prognoz qilish imkonini beradi

Ushbu tadqiqot natijalari regenerativ stomatologiyada PRP/PRF qo‘llanilishiga oid mavjud yondashuvlarni qayta ko‘rib chiqish zarurligini ko‘rsatadi.

An’anaviy yondashuvlarda asosiy e’tibor trombotsitlar soni va umumiy konsentratsiyaga qaratilgan bo‘lsa, ushbu ish natijalari shuni ko‘rsatadiki, bu parametrlar klinik natijalarni tushuntirish uchun yetarli emas.

Birinchidan, o‘sish omillari konsentratsiyasining keng diapazonda o‘zgarishi (masalan, TGF-β 40 dan 60 000 ng/mL gacha) biologik tizimning yuqori darajadagi geterogenligini ko‘rsatadi.

Bu esa bir xil protokol turli bemorlarda turlicha natija berishini anglatadi.

Ikkinchidan, PRP/PRF samaradorligi nafaqat biologik komponentlarga, balki texnik omillarga ham bog‘liq. Sentrifugatsiya tezligi, vaqt, probirka materiali va laboratoriya sharoitlari yakuniy mahsulot sifatiga sezilarli ta’sir ko‘rsatadi.

Uchinchidan, ushbu tadqiqotda taklif etilgan Dose–Response–Kinetics (DRK) modeli regenerativ terapiyada yangi ilmiy konsepsiyani shakllantiradi. Bu model shuni ko‘rsatadiki, maksimal o‘sish omillari konsentratsiyasiga erishishdan ko‘ra, ularning optimal darajasi va ajralish kinetikasi muhimroqdir.

Shuningdek, ushbu ish PRP/PRF ni statik biomaterial sifatida emas, balki dinamik biologik tizim sifatida ko‘rib chiqishni taklif qiladi. Bu esa personalizatsiyalashgan terapiya konsepsiyasi bilan to‘liq mos keladi. Ushbu tadqiqot natijalariga asoslanib, klinik amaliyotda quyidagi tavsiyalar ishlab chiqildi.

Tayyorlashni optimallashtirish jarayonida bir qator muhim jihatlarga e’tibor qaratish lozim. Avvalo, qon hajmini standartlashtirish zarur, chunki bu PRP va PRF sifatiga bevosita ta’sir qiladi. Shuningdek, past tezlikdagi sentrifugatsiya protokollaridan foydalanish tavsiya etiladi, chunki bu usul biologik faol komponentlarning saqlanishini yaxshilaydi. Bundan tashqari, klinik amaliyotda PRF ni ustuvor biologik material sifatida ko‘rib chiqish maqsadga muvofiq hisoblanadi.

Indikatsiyaga asoslangan qo‘llash yondashuvi ham muhim ahamiyatga ega. Implantatsion jarayonlarda A-PRF qo‘llash tavsiya etiladi, periodontal defektlarni davolashda esa i-PRF samaraliroq hisoblanadi. Tish sug‘urishdan keyingi regeneratsiya jarayonlarida PRF membrana qo‘llanilishi optimal natija beradi.

Ortiqcha konsentratsiyadan qochish klinik samaradorlikni oshirishda muhim omil hisoblanadi. Juda yuqori trombotsit konsentratsiyasi biologik javobni pasaytirishi mumkin, shuning uchun optimal biologik diapazonni saqlash zarur.

Monitoring bosqichi davolash samaradorligini baholashda muhimdir. Imkoniyat mavjud bo‘lsa, o‘sish omillarining darajasini monitoring qilish tavsiya etiladi. Shuningdek, klinik natijalarni tizimli va standartlashtirilgan tarzda baholash zarur.

Kelajakdagi ilmiy-tadqiqotlar bir nechta asosiy yo‘nalishlarda rivojlanishi kerak.

Molekulyar profiling yo‘nalishida proteomika va genomika tadqiqotlarini kengaytirish, shuningdek, individual biomarkerlarni aniqlash muhim hisoblanadi. Bu PRP/PRF terapiyasini yanada aniq va shaxsiylashtirilgan qiladi.

Sun’iy intellekt texnologiyalarini qo‘llash kelajakda katta ahamiyatga ega bo‘ladi. Ular PRP natijalarini oldindan prognoz qilish va optimal protokollarni avtomatik tanlash imkonini beradi.

Standartlashtirish yo‘nalishida global protokollar ishlab chiqish hamda PRP/PRF klassifikatsiyasini yagona tizimga keltirish zarur. Bu ilmiy natijalarni taqqoslash va klinik amaliyotni birlashtirishga yordam beradi.

Ilg‘or biomateriallar sohasida PRF ni boshqa biomateriallar bilan kombinatsiyalash hamda nano-strukturali fibrin tizimlarini ishlab chiqish istiqbolli yo‘nalishlardan biri hisoblanadi.

Ushbu sohadagi asosiy cheklovlar quyidagilardan iborat. Klinik ma’lumotlarning geterogenligi natijalarni bir-biri bilan solishtirishni qiyinlashtiradi. Ko‘pgina tadqiqotlarda o‘sish omillari har doim ham aniq o‘lchanmagan. Meta-tahlil uchun zarur bo‘lgan standart parametrlar yetarli darajada ishlab chiqilmagan. Bundan tashqari, individual biologik farqlar ko‘plab tadqiqotlarda to‘liq hisobga olinmagan.

Xulosa

Ushbu tadqiqot shuni ko‘rsatadiki, PRP va PRF regenerativ stomatologiyada katta potensialga ega bo‘lsa-da, ularning klinik samaradorligi ko‘plab o‘zgaruvchan omillarga bog‘liq. Regenerativ terapiyada samaradorlik maksimal konsentratsiya bilan emas, balki optimal doza + ajralish kinetikasi + individual biologik omillar kombinatsiyasi bilan belgilanadi.

Trombotsit konsentratlari bir xil terapevtik vositalar sifatida emas, balki dinamik va bemorga xos biologik tizimlar sifatida ko‘rib chiqilishi kerak. Ular individual biologik va texnik omillar asosida aniq optimallashtirishni talab qiladi.

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