

Sovremennyye Cojnye Meniteli I Kananeinjenernyye Construction And Reconstruction Of Cojnyx Defects In The Maxillofacial Area

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Abstract

Restoration of the jaw defect in the maxillofacial region remains one of the most common types of reconstructive surgery due to the combination of high functional and aesthetic requirements. Traditional methods (autodermoplasty, loskutnyye operatsii) have a limited volume of donor tissue, risk of donor morbidity and expressed rubtsevaniem. Development of kojnyx zameniteley and tissue engineering construction (TIK) has opened up new possibilities for the regeneration of kojnyx cover skins, including the use of biopolymer matrices, cellular transplants, mesenchymal stem cells, and also technological 3D-bioprinting.

In the review, data from Russian and foreign researches (USA, Europe, China, Colombia, South Korea), post-processing applications and bioengineering equivalents, dermal matrix, stem cells and bioprinting constructions in the treatment of defects, and the total number and jaw-line area. Obsujdayutsya klassifikatsiya kojnyx zameniteley, ix biomaterialnyye osnovy, kletochnyye komponenty, klinicheskiye rezultaty i ogranicheniya s akcentom na rekonstruktsionnyy litsa.

Key words: skin replacement, tissue engineering, dermal equivalent, maxillofacial region, stem cells, 3D bioprinting, dermal matrix, regenerative medicine.

Introduction

Povrejdeniya myagkix tkaney chelyustno-lytsevoy oblasti voznikayut pri vysokoenerticheskikh traumax, obshirnyx jogax, oncological resections, vrojdyonnyx porakax development and infectious-necrotic processes. Dlya etoy anatomicheskoy zony character no sechetanie:

- slojnoy triokhmernoy architectural tissue (coat, podkojnaya kletchatka, mimicheskiye muscles);
- vysokoy vascularizatsii and innervatsii;
- kriticheskikh funktsionalnyx zadach (mimicry, articulation, feeding, zashchita organov zreniya i dyxatelnyx putey);
- krayne vysokikh esteticheskikh trebovaniy.

Klassicheskiye metody vosstanovleniya — local and free skin-muscular flaps, autodermoplasty rasshcheplyonnymi ili polnosloynymi transplantatami — pozvolyayut closed defects, no soprovoddayutsya donor trauma, limited volume of tissue and rarely neudovletvoritelnyimi kosmeticheskimi rezultaty.

Na etom fone razvivaetsya napravlenie bioinjenernyx kojnyx zameniteley i tkaneinjenernyx konstruktsiy koji, vklyuchayushchix:

- biological (natural) dermal matrices;
- synthetic and biosynthetic polymer frameworks;
- vivye equivalenty koji with fibroblasts, keratinocytes, stem cells;
- slozhnyye 3D-bioprinting cochnyye analogue.

Rossiyskiye obzory Meleshinoy i saavt. I work on the problem of inflammation of the skin and kojnyx zameniteley describe in detail the biological wound process, the role of fibroblasts, tuchnyx cells, the matrix and the development of bioengineering equivalents of kojnyx zameniteley, ix biological and mechanical properties, as well as new approaches - 3D-bioprinting, prevascularized constructions and stem-cells technology.

Tsel dannogo obzora — systematizirovat dannye o kojnyx zamenitelyax i tkaneinjenernyx konstruktsiyax, primenyaemyx dlya vosstanovleniya kojnyx defektov, s osobym aksentom na vozmozhnosti ix ispolzovaniya v chelyustno-lytsevoy oblasti.

Materialy i metody literaturnogo poiska.

Provedyon tselenapravlenyy poisk publikatsii na angliyskom i russkom yazykax v bazax PubMed , Scopus , Web of Science , eLibrary , CyberLeninka for the period 2005–2025.

В обзор включены:

- fundamental and clinical observations of kojnym zamenitelyam and equivalent koji;
- work on tkaneengineernyx constructions and stem cell cells and patients with traumatic defects.

Separately analyzed works from China, Europe, USA, South Korea and Colombia, postvyashchyonnye innovative technology (3D-bioprinting, prevascularized construction, regional trial application of dermal matrix).

Results review and obsujdenie.

Classification kojnyx zameniteley.

According to the modern classification, kojnye meniteli is a heterogeneous group of biological, synthetic or combined materials, temporarily or permanently replacing the structure and function.

Basic groups:

Biological (native and decellularized tissues):

- allo- and xenodermal transplants;
- decellularized dermal matrices (including glycerine, cryoconservation).

1. Synthetic and biosynthetic polymer matrices.

- polyurethane, poly(lactide / glycolide), copolymer e- caprolactone ;
- Hydrogels and hydrocolloids (chitosan, alginate, gelatin, collagen gel).

2. Liver dermal and epidermal-dermal equivalents.

- constructs with keratinocytes , fibroblasts, stem cells;
- commercial products such as Epicel ®, Apligraf ®, Dermagraft ® and dr.
- Analogue of 3D bioprinting skin: mnogocelolasty , keratinotsity , endotheliotsity).

Dlya chylyustno-litsevoy oblasti osobenno vajny:

thin, elastic, good vascular construction ;

*minimalnaya contractura and defoogicheskie cojnye zameniteli vklyuchayut decellyulyarizovannye dermal matrices (human and xenogenic), placental membranes and others. They preserve the structure of the extracellular matrix (collagen I, III, laminin , fibronectin), ensuring good cellular adhesion and angiogenesis.

Kolombiyskie issledovaniya sravnivali rasshcheplyonnye kojnye autotransplantaty s i bez dobavleniya glycerinovoy acellulyarizovannoy dermal matrix (GADM). Pozano uluchshenie kachestva rubtsa i bolee blagopriyatnyy relief poverkhnosti pri ispolzovanii GADM.

In this context, Integra ® (double-layered and interlayered dermal regeneration template) is used in the reconstruction of the face of the jaw, demonstrating increased mobility and aesthetics compared to traditional autodermoplasty .

Preimushchestva biological matrices for ChLO:

- Horoshaya integration and vascularization ;
- Relatively low immunogenicity (after decellularization);
- uluchshenie kachestva rubtsa i elasticnosti.

Limitations:

- stoimost and availability of commercial products;
- zavisimost ot kachestva obrabotki donorskogo materiala;
- inogda — neokhodimost vtorigo etapa (nanesenie autoloskutov).

3. Liver equivalents and stem cells.

Otechestvennye and zarubezhnye obzory otmechayut, chto jivye equivalenty koji (Living Skin Equivalents , LSE) include cellular components (keratinocytes , fibroblasts, stem cells) and biomatrix . Such constructions are possible:

- active synthesis component matrix;
- the secretory factor is correct;
- modulirovat vospalitelnyi otvet i reparatsiyu.

Fibroblasty, kak pokazano v rossiyskikh rabotakh, sokhranyayut diploidnyy karyotype, nizkuyu immunogenost i dlitelno produtsiruyut collagen, glycosaminoglycany, fibronectin, chto delaet ix klyuchevym komponentom dermalnyx equivalents.

The use of mesenchymal stem cells (MSC) and epidermal stem cells has potential: luchshey vascularizatsii za schyot paracrine stimulation of angiogenesis; nyx dermatozax.

Dlya chylyustno-litsovoy oblasti live kojnye equivalent interesny tem, chto pozvolyayut dobitsya maksimaly "soft", plastichnogo pokrytiya, blizkogo po tsvetu i texture k okrujayushchey koje, chto kritichno dlya litsa.

4. Polymers, hydrogels and hybrid matrices.

Rossiyskie issledovaniya po polymeram v lechenii ran podchyorkivayut znachenie biopolimerov i hydrogel kak nositeley dlya kletok i faktorov rosta. Natural polymers (collagen, gelatin, fibrin, chitosan, gel) have high mechanical stability and time degradation.

Synthetic polyethers (PLA, PGA, PLGA, PCL) and polyurethane provide:

- controlled degradation;
- nastraivaemye mekhanicheskie svoystva;
- vozmojnost 3D-formovaniya slojnyx geometriy.

Hybrid constructions (collagen + synthetic polymer, chitosan + alginate, etc.) are used as basic perevazochnyx means, foam, film, and matrix for skin equivalents.

Dlya ChLO eto vajno, tak kak neokhodima kombinatsiya prochnost, vek, krylev nosa.

5. 3D bioprinting and personalized skin equivalents.

Special treatment — 3D-bioprinting, especially relevant for layer relief. Yuzhnokoreyskaya goszdannogo na osnove CT-dannyx pacienta i napechatannogo in three layers: porous polyurethane layer, hydrogel with keratinocytes and hydrogel with fibroblasts.

Tsel is a maximally accurate contour face and simultaneously ensures the regeneration of the epidermis and the dermis, with excellent functional and aesthetic results.

Sovremennye obzory iz Yuzhnoy Korei i Evropy systematiziruyut dostizheniya v 3D-biopechati koji, vklyuch

Pokashinstvo takikh rabot — doklinicheskie, no dlya chelyustno-litsovoy hirurgii eto, po suti, idealy scenario: kombinirovat tochnoe vosproizvedenie relefa litsa s regenatsiey mnogoslonoj koji.

6. Primenenie kojnyx zameniteley v chelyustno-litsovoy oblasti.

Tselenapravlennyy analiz rabot po chylyustno-litsovoy rekonstruktsii pokazyvaetsya, chto kojnye i yagkotkannyye zameniteli primenyayutsya:

- pri reconstruction postlestviy tyajyolyx trauma litsa;
- pri ojogax litsa i shei;
- pri defectakh posle onkologicheskoy reseksii;
- pri vtorychnykh deformatsiyax i rubtsax.

Obzor po ispolzovaniyu kojnyx i myagkotkannyx zameniteley v chylyustno-litsovoy rekonstruktsii podchyorkivaet znachenie dermalnyx matrits i bioinjenernyx equivalentov kak popolneniya k traditsionnym loskutnym metodikam.

Examples:

application of Integra® and analogue dermal matrix in one-moment and two-stage reconstruction of the facial lens (Europe, Colombia); otmecheno uluchshenie podvijnosti, umenshenie contractur i luchshaya textura koji po sravneniyu s simple autodermoplastikoy.

ispolzovanie UBM (urinary bladder matrix) kak gibkogo dermalnogo zameniteleya pri slojnykh traumacheskikh defectakh litsa; The authors support the perspective of the UBM for the soft reconstruction of the head and the body.

Chinese work on "accurate reconstruction of soft tissue" underlines the trend of combining flaps, dermal matrices and 3D planning.

For a practicing maxillofacial surgeon, it means that the cochlear replacement is:

- ispolzuyutsya kak dopolnenie, a ne alternative loskutam;
- osobenno polezny dlya uluchsheniya kachestva kojnogo pokora i snizheniya rubtsevaniya;
- pozvolayut umenshit obyom donorskoy trauma pri obshirnyx defectakh.

7. Regional peculiarities (USA, Europe, China, Colombia, South Korea).

In the USA and Europe: commercial skin substitutes (Integra®, AlloDerm®, Dermagraft®, Apligraf®) are widely used, RKI is actively used for chronic wounds and eye injuries, systemic diseases and dermal substitutes.

China: emphasis on the combination of decellularized matrices, polymer hydrogels and stem cells, as well as the development of prevascularized and bioprinted structures.

South Korea: leadership in 3D-bioprinting, development of individualized masks and skin analogs (BioMask), research on large animal models and the first clinical stage.

Colombia and Latin America: focus on available dermal matrices (GADM, Integra®) and autotransplantation in eye patients; pokazany uluchshennye rannie rezultaty i kachestvo rubtsa, formiruetsya local proof base.

Comparison table with replacement parts and TIK (dlya defectov koji ChLO)

Nije - primer tablitsy, kotoruyu mojno vstavit v statyu (Vy smojete dopolnit svoimi komentariami i primerami iz kliniki):

Table 1. Comparative characteristics of the basic types of bone replacement and tissue engineering construction during reconstruction of the maxillary and mandibular region

Substitute type	Example/group	Cellular component	Basic material	Preimushchestva dlya ChLO	Restrictions
Decellularized dermal matrices	AlloDerm®, GADM, Integra®	Net (acellular)	Collagen matrix, ECM	Good integration, uluchshenie kachestva rubtsa, elastichnost	Stoimost, neokhodimos kombinatsii s autoloskutom
Biological placental matrices	Amnion, chorion	May contain residual cells	Collagen, laminin, factor-cohesive ECM	Vysokaya biosovmestimost, modulation vospaleniya	Neodnorodnost syrya, voprosy standardizatsii
Synthetic polymer matrices	Polyurethane, PLA/PLGA	No	Synthetic polyether, PU	Kontroliruemyaya mechanics and degradation, 3D-formuemo	Menshaya biologichnost, neokhodimos modifikatsii poverkhnosti
Hybrid polymer-biopolymer matrices	Collagen+PCL, chitosan+alginate	Net year is minimal	Combination of natural and synthetic polymers	Balance prochnosti and biosovmestimost, vozmojnost 3D-formovaniya	Технологическая сложност, stoimost
Jivye dermal equivalents	Apligraf®, Dermagraft®	Fibroblasty, keratinocyte	Collagen/polymeric matrix	Active secretion of faktorov rosta, uluchshenie epitelizatsii	Complexity of storage, high speed, regulatory barriers
Stem cell construction	MSC + dermal matrix	Mesenchymal or	Collagen, fibrin, GelMA and dr.	Potential muscle regeneration,	V stage issledovaniy, otsutstvie

		epidermal SK		angiogenesis, vascular fibrosis	standardizirovannyx protokolov
Analogue of 3D bioprinting skin	BioMask , 3D-printed skin	Fibroblasty, keratinotsity , endoteliotsity	Biochernila na osnove GelMA , dECM , polymerov	Individualizatsion po contour litsa, mnogosloynnaya architecture	Vysokaya stoimost, tekhnicheskaya slojnost, doklinichesky etap
UBM and other matrix organs	UBM (urethral/vesical matrix)	No	Decellularized organic ECM	Gibkost, horoshaya adaptatsiya k reliefsu defecta	Ogranichennyy opyt v ChLO, neobhodimost dalneyshikh issledovaniy

Conclusion

Kojnye zameniteli i tkaneinjenernye konstruksii predstavlyayut soboy odno iz naibolee perspektivnyx navlenii rekonstruksii kojnyx defectov chylyustno-lytsevoy oblasti.

Basic principles:

Biological dermal matrixes (AlloDerm ®, Integra ®, GADM, etc.) are more effective in the reconstruction of eye and facial trauma, and have higher elasticity, mobility, and aesthetic results compared to simple autodermoplasty .

Biological equivalents of skin and cellular constructions and the basis of fibroblasts, keratinocytes and stem cells give the possibility of active regeneration of the dermis and epidermis, and the application of jaw and lip surgery is limited by high cost and organizational layers.

Polymers and hybrid matrixes allow fine tuning of mechanical properties and degradation, which is necessary for dynamic heating zones (guby, veky), especially when combined with cellular components and factors.

3D-bioprinting and personalized skin constructions (BioMask and analogue technologies) open fundamentally new possibilities for individualized plastic face, but they are mainly at the experimental and early clinical research stages.

Dlya lystno-litsevoy chirurgii na blijayshuyu perspektivu naibolee realistichnym viditsya kombinirovanny approach:

- ispolzovanie dermalnyx matrity i kojnyx zameniteley v popolnenie k traditsionnym loskutam;
- local primemenie tkaneinjenernyx i stvolovo-kletochnyx construction and naibolee critical zones (veki, nos, guby);
- postepennoe vnedrenie 3D-biopechatnyx technology and framex klinicheskix issledovaniy.

Spisok literatury.

1. Zorin V.L., Zorina A.I., Petrakova O.S., Cherkasov V.R. Dermal fibroblasts for the treatment of defects // Kletochnaya transplantologiya i tkanevaya injeneriya. - 2009. - T. 4, No. 4. - S. 26–40.
2. Konstantinova M.V., Khaitsev N.V., Kravtsova A.A., Balashov L.D. Osnovnye problemy zazhivleniya ran i spolzovanie zameniteley koji // Pediatr. - 2015. - T. 6, No. 2. - S. 85–95.
3. Korolyova T.A. Kletochnye tekhnologii v lechenii detey s glubokimi ojogami koji (obzor literatury) // Rossiyskiy vestnik detskoy hirurgii, anesthesiologii i reanimatologii. - 2013. - T. 3, No. 3. - S. 35–42.
4. Legonkova O.A., Belova M.S., Asanova L.Yu., Aliev A.D., Chalykh A.E. Polimery v lechenii ran: realii i horizonty // Wounds and ranevye infektsii. Journal im. prof. B.M. Kostyuchyonka . - 2016. - T. 3, No. 1. - S. 12–21.
5. Meleshina A.V., Bystrova A.S., Rogovaya O.S., Vorotelyak E.A., Vasiliev A.V., Zagaynova E.V. Tkaneinjenernye konstrukty koji i ispolzovanie stvolovyx kletok dlya zdaniya kojnyx equivalentov (overview) // Sovremennye tekhnologii v meditsine. - 2017. - T. 9, No. 1. – S. 198–212.

6. Patshina M.V., Voroshilin R.A., Osintsev A.M. Analiz mirovogo rynka biomaterialov s tselyu opredeleniya potencialnykh vozmozhnostey sryya jivotnogo proiskhojdeniya // *Technika i tekhnologiya pishchevyx proizvodstv.* - 2021. - T. 51, No. 2. - S. 270–289.
7. Smirnov S.V., Zhirkova E.A., Sychevsky M.V. Primenenie biotekhnologiy v lechenii ojogovyx ran: problems and perspectives (overview of literature) // *Neotlojnaya meditsinskaya pomoshch.* – 2011. – No. 1. – S. 32–35.
8. Sroslova G.A., Zimina Yu.A., Nesmeyanova E.N., Postnova M.V. Natural polymers for 3D bioprinting of organs // *Natural systems and resources.* - 2019. - T. 9, No. 4. - S. 30–40.
9. Shapovalova E.Yu., Boyko T.A., Baranovsky Yu.G., Vasilenko S.A. Soderzhanie tuchnykh kletok v strukturax ishemizirovannoy modelnoy rany na 12 sutki posle stimuliacii regeneratornogo potentsiala auto- i heterofibroblastami i dermalnym ekivotelom // *Kubanskii nauchnyi meditsinskii vestnik.* - 2017. - T. 24, No. 5. – S. 96–102.
10. Meleshina A.V., Bystrova A.S., Rogovaya O.S. i dr. Tkaneinjenernye konstrukty koji i ispolzovanie stvolovyx kletok dlya sozdaniya kojnyx equivalentov (review). *Modern technologies and medicine* . 2017;9(1):198–218.
11. The main problems of zajivleniya ran i ispolzovanie zameniteley koji. Overview. (PDF iz Vasikh material). lechenii ran: realii i horizonty. *Wound and wound infection. Journal im. prof. B.M. Kostyuchyonka* . 2016;3(1):12–21.
12. Vyas KS, Vasconez HC. Wound healing: biologics, skin substitutes, biomembranes and scaffolds. *Surg Clin North Am* . 2014;94(4):793–829.
6. Adv Wound Care *. 2009;1(2):13–22.
13. Oualla-Bachiri W, et al. From grafts to human bioengineered vascularized skin: advances and perspectives. *Int J Mol Sci* . 2020;21(21):8197.
14. Vecin NM, et al. Skin substitutes as treatment for chronic wounds: current concepts and future directions. *Front Med* . 2023;10:1154567 .
15. Kang MS, et al. Advances and innovations of 3D bioprinting skin. *Biomolecules* . 2022;13(1):55.
16. Seol YJ, et al. 3D Bioprinted BioMask for facial skin reconstruction. *Biofabrication* . 2018;10(3):035017.
17. Maggioletto F, et al. 3D bioprinting of a perfusable skin-on-chip model. *Acta Biomaterial* . 2025 (online publication).
18. Teixeira Dos Santos R, et al. Skin substitutes: current concepts and a new classification. *Burns* . (god po dannym obzora).
19. Van den Bosch AS, et al. Outcomes of dermal substitutes in burns and burn scar reconstruction. 2024.
20. Avila León JL, et al. Immediate results of the use of split-thickness skin autografts with and without acellular dermal matrix in patients with burns: a comparative study in a Colombian population. 2023.
21. Gaviria JL, et al. One-stage reconstruction of neck burns with single
22. Suárez- Cañon N, et al. Monolayer acellular dermal matrix for reconstruction of facial burns. *Burns Open* . 2024.
23. Use of Skin and Soft Tissue Substitutes in Ma
24. Amin D, et al. UBM as dermal substitute in maxillofacial soft tissue reconstruction. *J Craniofac Surg* . (po dannym stati).
25. Some aspects of the creation of tissue engineering constructs in the treatment of skin burn injuries. (Ukrainian obzor).
26. Riabinin A, et al. Ideal living skin equivalents: from old technologies and modern opportunities. 2024.