Review Article

https://doi.org/10.36377/ET-0144

Methods for preventing fragmentation of endodontic instruments: a systematic review

Alexander V. Mitronin, Diana A. Ostanina, Kirill A. Archakov ✉, Yuriy A. Mitronin

Russian University of Medicine, Moscow, Russia

✉ kirarchakov692@gmail.com

Abstract

INTRODUCTION. Endodontics is one of the most dynamically developing areas of dentistry. The introduction of rotary instrumentation has revolutionized the mechanical treatment of the root canal system, significantly increasing the effectiveness of endodontic treatment. However, the incidence of complications associated with rotary instrumentation has also increased, the most common of which is file fragmentation. That is why it is really important to know the existing methods for preventing the occurrence of this complication.

AIM. To systematize the information presented in scientific articles on methods for preventing fragmentation of endodontic instruments during root canal preparation.

MATERIALS AND METHODS. A search of literature sources was carried out in the PubMed, dissercat.com, elibrary.ru, database.ru, cyberleninka.ru by keywords “endodontic treatment”, “iatrogenic events”, “fracture of endodontic instruments”, «prevention of an instrument fractures» with a choice of article types “Clinical Trial”, “Meta-Analysis”, “Review”, “Systematic Review”.

RESULTS. After analyzing the literature review, an idea about the methods of preventing instrument fragmentation in the root canal system was obtained.

CONCLUSIONS. Methods for preventing fragmentation of endodontic instruments are aimed at ensuring the safest possible operation of instruments in the root canal system; however, there is still no reliable way to prevent the occurrence of such a complication.

Keywords: endodontic treatment, iatrogenic events, fracture of endodontic instruments, prevention of an instrument fractures

Article info: received – 13.10.2025; revised – 19.11.2025; accepted – 27.11.2025

Conflict of interest: The authors report no conflict of interest.

Acknowledgments: There are no funding and individual acknowledgments to declare.

For citation: Mitronin A.V., Ostanina D.A., Archakov K.A., Mitronin Yu.A. Methods for preventing fragmentation of endodontic instruments: a systematic review. *Endodontics Today.* 2025;23(4):672–677. https://doi.org/10.36377/ET-0144

Методики профилактики фрагментации эндодонтических инструментов: систематический обзор

А.В. Митронин, Д.А. Останина, К.А. Арчаков ✉, Ю.А. Митронин

Российский университет медицины, г. Москва, Российская Федерация

✉ kirarchakov692@gmail.com

Резюме

ВВЕДЕНИЕ. Эндодонтия является одним из наиболее динамично развивающимся направлением в стоматологии. Внедрение машинных вращающихся инструментов произвело настоящую революцию в вопросе механической обработки системы корневых каналов, позволив существенной повысить эффективность всего эндодонтического лечения. Однако, увеличился и процент осложнений, связанных с машинной инструментацией, наиболее распространенным из которых стала фрагментация файлов. Именно поэтому важно знать существующие способы профилактики возникновения данного осложнения.

ЦЕЛЬ ИССЛЕДОВАНИЯ. Систематизировать представленную в научных статьях информацию о методах профилактики фрагментации эндодонтических инструментов в ходе препарирования корневых каналов зубов.

МАТЕРИАЛЫ И МЕТОДЫ. Проведен поиск литературных источников в базе данных PubMed, elibrary.ru, cyberleninka.ru, по ключевым словам, «эндодонтическое лечение», «ятрогенные ошибки», «фрагментация файлов», «профилактика отломов инструментов» с выбором типов статей «Clinical Trial», «Meta-Analysis», «Review», «Systematic Review».

РЕЗУЛЬТАТЫ. После анализа обзора литературы, получено представление о методах профилактики фрагментации инструментов в системе корневых каналов.
ВЫВОДЫ. Существующие методики профилактики фрагментации эндодонтических инструментов направлены на обеспечение максимально безопасной работы инструментов в системе корневых каналов, однако, до сих пор не существует ни одного достоверного способа предупреждения возникновения подобного осложнения.

Ключевые слова: эндодонтическое лечение, ятрогенные ошибки, фрагментация файлов, профилактика отломов инструментов

Информация о статье: поступила – 13.10.2025; исправлена – 19.11.2025; принята – 27.11.2025

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Митронин А.В., Останина Д.А., Арчаков К.А., Митронин Ю.А. Методики профилактики фрагментации эндодонтических инструментов: систематический обзор. *Эндодонтия Today.* 2025;23(4):672–677. https://doi.org/10.36377/ET-0144

INTRODUCTION

Endodontics is one of the most rapidly advancing fields in dentistry [1]. A genuine breakthrough in this area occurred with the introduction of engine-driven endodontic instruments for mechanical root canal preparation [2]. The undeniable advantages of these files include faster and more comprehensive instrumentation of the root canal system compared to conventional manual techniques, as well as controlled rotational speed and cutting efficiency (torque) of the instrument [3]. However, this progress has also led to an increased risk of one of the most common complications associated with root canal shaping – separation of endodontic instruments [4].

According to scientific literature, the incidence of this complication varies widely, ranging from 0.4% to 23% [5]. Management includes either removal of the separated fragment or bypassing it with subsequent obturation of the canal to full working length. Both approaches involve removal of root dentin around the fractured instrument, which inevitably results in a reduction of the residual strength of the tooth [6].

Therefore, prevention of instrument separation in the root canal system remains a relevant clinical issue, requiring practitioners to be fully aware of existing preventive strategies to improve the quality and safety of endodontic treatment.

AIM

The objective is to systematize the information presented in scientific publications regarding existing methods for preventing endodontic instrument separation within the root canal system. This includes analyzing and categorizing preventive strategies based on their clinical applicability, technological features, and impact on treatment quality. The results of this systematization are intended to strengthen decision-making protocols and minimize risks associated with mechanical root canal instrumentation.

MATERIALS AND METHODS

A literature search was conducted in the PubMed, dissercat.com, eLibrary.ru, and CyberLeninka databases using the keywords “endodontic treatment”, “iatrogenic errors”, “instrument separation”, and “prevention of file fracture”, with filtering by article types including “Clinical Trial”, “Meta-Analysis”, “Review”, and “Systematic Review”.

RESULTS

The prevention of instrument separation is inevitably linked to the underlying causes of its occurrence, as only a thorough analysis of the failure source can determine the appropriate strategies for avoiding it. All known causes of endodontic file fracture can be categorized into two major groups: operator-related errors and insufficient monitoring of instrument condition [7].

Errors attributable to the clinician represent the most diverse category and include multiple factors that should be considered in the chronological sequence of the endodontic treatment procedure.

The first factor is inadequate access to the root canal, specifically incomplete opening of the pulp chamber with remaining overhanging enamel and dentin edges that obstruct a straight-line path of the instrument to the canal orifice [8]. In such situations, the file is consistently introduced into the canal at an angle with a coronal curvature, which not only increases torsional stresses on the instrument but also leads to difficulties in determining the working length.

The second factor is the absence of preliminary enlargement of the canal orifice and failure to remove so-called dentin triangles, which hinder entrance into the root canal (Fig. 1) [9].

This condition results in coronal binding of the instrument, increased torsional load, and a higher risk of fracture [10]. Removal of dentin triangles can be performed using ultrasonic tips such as Start-X No. 3 (Dentsply/Maillefer, Switzerland), while orifice enlargement may be achieved using dedicated burs for handpieces such as Largo Peeso Reamers/Gates-Glidden drills (Dentsply/Maillefer, Switzerland), or specific orifice openers included in endodontic instrument systems [11]. These instruments are shorter compared with the primary files and have greater taper, which facilitates adequate coronal access for subsequent mechanical instrumentation of the canals. An example is the ProTaper Universal Shaping File SX, 19 mm (Dentsply/Maillefer, Switzerland), which features progressive taper.

The third factor is improper instrument handling, including excessive apical pressure, prolonged work in a single canal, and failure to adjust working parameters individually for each specific file system [12]. It must be emphasized that the influence of torsional loading and cyclic fatigue varies significantly among different systems. For example, in the dissertation of T.S. Belyaeva, "Comprehensive Clinical and Laboratory Comparative Analysis of Rotary Endodontic Systems Made of Nickel-Titanium Alloy," the following ranking was presented: increasing resistance to cyclic fatigue – FlexMaster < ProTaper < RaCe < ProFile ≈ Mtwo; increasing resistance to torsional stress – RaCe < ProFile ⩽ ProTaper < FlexMaster [13]. Therefore, when selecting a particular NiTi file system, the clinician must be aware of the specific characteristics regarding flexibility, torsional strength, and cyclic fatigue resistance. Additionally, the so-called "screw-in effect," which depends on the cutting blade design, should be considered. This effect increases in the following order: BioRaCe < Mtwo < ProTaper < FlexMaster < ProFile. Accordingly, clinicians must always pre-set torque values individually for each file system, based on these performance parameters.

The fourth factor is the lack of consideration for the anatomical features of the root canal. Instrumentation in curved or sclerotic canals is significantly complicated; the clinician often applies excessive apical pressure in an attempt to reach the working length, which leads to the formation of ledges, perforations, and file separation (Fig. 2) [14].

In such cases, it is essential to perform targeted intraoral periapical radiographs before and during endodontic treatment, create a glide path to ensure safe operation with the main files, and pre-curve the instrument tip toward the canal curvature to facilitate its negotiation through complex anatomy [15].

The absence of proper monitoring of endodontic instruments represents the second major group of factors leading to separation. With each clinical use, stainless steel and nickel-titanium instruments accumulate metal fatigue. This results in progressive microstructural damage that will ultimately cause fracture [16].

Two primary preventive methods are used in contemporary practice: visual inspection and the so-called "daisy system". Visual inspection involves examining the instrument after use with the naked eye to detect gross structural alterations such as unwinding, excessive deformation, or distortion of the cutting flutes [17]. The limitation of this method is the inability to reliably assess micro-level structural changes that precede failure.

One of the most widely used tools for the second method is the silicone SafetyMemoDisc (FKG Dentaire, Switzerland) (Fig. 3), which contains 4 or 8 detachable petals.

These petals are removed manually depending on the complexity of the treated canal. For straight or slightly curved canals, one petal is removed; for more curved or narrow canals, two are removed; and for very narrow, highly curved, or S-shaped canals, three petals are removed. Once all petals have been detached, the instrument must be discarded. However, this technique also has limitations, as it does not detect structural defects occurring within the material, and file separation may still occur despite remaining petals on the disc.

Fig. 1. Inadequate preparation of access to the root canal, deviation of the file in the apical third, accompanied by the formation of a step
Sourse: [9]

Рис. 1. Несоответствующая подготовка доступа к корневому каналу, отклонение файла в апикальной трети, сопровождающееся образованием ступени
Источник: [9]

Fig. 2. An example of the fragmentation of an endodontic instrument in the curvature of a root canal
Source: [15]

Рис. 2. Пример фрагментации эндодонтического инструмента в изгибе корневого канала
Источник: [15]

Fig. 3. The system for monitoring the number of uses of endodontic files – SafetyMemoDisc (FKG Dentaire, Switzerland)

Рис. 3. Система для контроля количества использований эндодонтических файлов SafetyMemoDisc (FKG Dentaire, Швейцария)

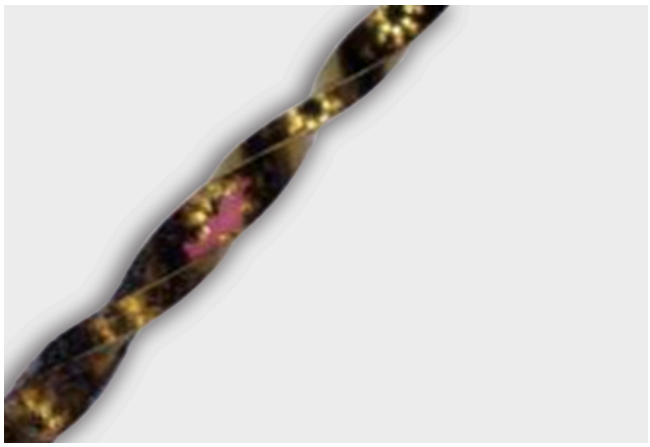

Fig. 4. Detection of defects during during capillary flaw detection of the ProTaper Gold F3 instrument
Source: [18]

Рис. 4. Прокрашивание дефекта при проведении капиллярной дефектоскопии инструмента ProTaper Gold F3
Источник: [18]

A laboratory technique for assessing the structural integrity of endodontic instruments is known as capillary defectoscopy. Khabadze et al. propose the use of special dyes capable of penetrating and accumulating within disrupted areas of the nickel-titanium crystalline lattice [18]. Following thorough cleaning and drying, the instrument surface is coated with a penetrant via aerosol application. Excess material is removed using an organic-solvent technique by immersing the file into a disinfectant sponge (Klinstend) saturated with SKC-S cleaner. Immediately thereafter, a developer (SKD-S2, sensitivity class III) designed for capillary defect detection is sprayed on. The exposure time is 17 minutes. Visual examination may reveal distinct colored markings on the file surface (Fig. 4), which indicate structural defects in the metal.

The methodology has significant limitations: the procedural duration and operational complexity associated with the handling of specialized consumables such as penetrants. Evaluation of a single instrument requires 30–45 minutes and involves several chemical agents and aerosols, necessitating a specially equipped environment. Essentially, this technique represents a modified form of visual inspection; however, its applicability under routine clinical conditions remains highly constrained due to the aforementioned drawbacks.

CONCLUSION

Thus, the issue of preventing instrument separation remains complex and multifactorial. On the one hand, it is essential to enhance manual skills and eliminate iatrogenic errors during the use of endodontic files. On the other hand, the development and improvement of control methods for instrument condition, enabling their timely withdrawal from use, are required. This approach will significantly reduce the risk of file fracture within the root canal system.

REFERENCES / СПИСОК ЛИТЕРАТУРЫ

1. Yanushevich O.O. (ed.). *Therapeutic dentistry: national guide*. 3rd ed. Moscow: GEOTAR-Media; 2024. 1024 p. (In Russ.)
   Янушевич О.О. (ред.). *Терапевтическая стоматология: национальное руководство.* 3-е изд. перераб. и доп. М: ГЭОТАР-Медиа; 2024. 1024 с.
2. Maximovsky_Yu.M, Mitronin A.V. *Therapeutic dentistry. A guide to practical exercises.* Moscow: GEOTAR-Media; 2011. 422 p. (In Russ.)
   Максимовский Ю.М., Митронин А.В. *Терапевтическая стоматология: руководство к практическим занятиям*. М.: ГЭОТАР-Медиа; 2011. 422 с.
3. Deviatnikova V.G., Manak T.N. Experimental study of factors affecting the failure of the cyclical nature of rotary endodontic instruments. *Endodontics Today*. 2020;18(1):4–14. (In Russ.) https://doi.org/10.36377/1683-2981-2020-18-1-4-14
   Девятникова В.Г., Манак Т.Н. Экспериментальное исследование факторов, влияющих на поломку циклического характера у ротационных эндодонтических инструментов. *Эндодонтия Today*. 2020;18(1):4–14. https://doi.org/10.36377/1683-2981-2020-18-1-4-14
4. Roda-Casanova V., Pérez-González A. Computerized Generation of Endodontic Files by Reproducing the Flute Grinding Manufacturing Process. *Bioengineering*. 2024;11(8):751. https://doi.org/10.3390/bioengineering11080751
5. Hargreaves K.M., Berman L.H. [eds] *Endodontics* [trans. ed. Mitronin A.V.]. Moscow: GEOTAR-Media; 2022. 1040 p. (In Russ.) https://doi.org/10.33029/9704-5359-9-EDD-2020-1-1040
   Харгривз К.М., Берман Л.Г. (ред.) *Эндодонтия* [пер. с англ. А.В. Митронин]. М.: ГЭОТАР-Медиа; 2022. 1040 с. https://doi.org/10.33029/9704-5359-9-EDD-2020-1-1040
6. Terauchi Y., Ali W.T., Abielhassan M.M. Present status and future directions: Removal of fractured instruments. *Int Endod J*. 2022;55(S3):685–709. https://doi.org/10.1111/iej.13743
7. Serafin M., Biasi M., Franco V., Generali L., Angerame D. Influence of different motions on the cyclic fatigue resistance of Reciproc and Reciproc Blue endodontic instruments. *J Conserv Dent*. 2019;22(5):449–453. https://doi.org/10.4103/JCD.JCD_430_19
8. Gambarini G., Seracchiani M., Zanza A., Miccoli G., Del Giudice A., Testarelli L. Influence of shaft length on torsional behavior of endodontic nickel-titanium instruments. *Odontology*. 2021;109(3):568–573. https://doi.org/10.1007/s10266-020-00572-2
9. Fan B., Yang J., Gutmann J.L., Fan M. Root canal systems in mandibular first premolars with C-shaped root configurations. Part I: Microcomputed tomography mapping of the radicular groove and associated root

canal cross-sections. *J Endod*. 2008;34(11):1337–1341. https://doi.org/10.1016/j.joen.2008.08.006

10. Puiu D. D.A. Analysis of reasons of fracture of endodontic instruments in the tooth root canal – extra motivation for the introduction of new technologies. *Natsionalnaya Assotsiatsiya Uchenykh.* 2015;(2-8):64–66. (In Russ.)
Пую Д.А. Анализ причин отлома эндодонтических инструментов в корневом канале зуба – дополнительная мотивация к внедрению новейших технологий. *Национальная ассоциация ученых.* 2015;(2-8):64–66.
11. Rzhanov E.A, Kopyev D.A. Method for estimating the probability of the nickel- titanium instrument failure depending on the duration of its work in a curved channel. *Endodontics Today.*2011;9(2):66–72. (In Russ.) Available at: https://www.endodont.ru/jour/article/view/759 (accessed: 11.08.2025).
Ржанов Е.А., Копьев Д.А. Метод оценки вероятности поломки никель-титанового инструмента в зависимости от продолжительности его работы в условиях искривленного канала. *Эндодонтия Today*. 2011;9(2):66–72. Режим доступа: https://www.endodont.ru/jour/article/view/759 (дата обращения: 11.08.2025).
12. Maqbool M., Tirmazi S.S.M., Shakoor A., Akram Z., Nazir R., Chohan A.N. et al. Perception of dental house officers regarding endodontic file separation during endodontic treatment. *Biomed Res Int*. 2023;2023:1044541. https://doi.org/10.1155/2023/1044541
13. Mitronin A.V, Belyaeva T.S, Zablockaya N.V, Alimukhamedova S.Sh. Effect of nickel-titanium alloy type on cyclic loading resistance of reciprocating endodontic instruments. *Russian Journal of Stomatology.* 2024;17(1):56–57. (In Russ.)
Митронин А.В., Беляева Т.С., Заблоцкая Н.В., Алимухамедова С.Ш. Влияние типа никель-титанового сплава на устойчивость к циклической нагрузке реципрокных эндодонтических инструментов. *Российская стоматология*. 2024;17(1):56–57.
14. Pedir S.S., Mahran A.H., Beshr K., Baroudi K. Evaluation of the factors and treatment options of separated endodontic files among dentists and undergraduate students in Riyadh area. *J Clin Diagn Res*. 2016;10(3):ZC18–23. https://doi.org/10.7860/JCDR/2016/16785.7353
15. Eskibağlar M., Özata M.Y., Ocak M.S., Öztekin F. Investigation of fracture prevalence of instruments used in root canal treatments at a faculty of dentistry: a prospective study. *Restor Dent Endod*. 2023;48(4):e38. https://doi.org/10.5395/rde.2023.48.e38
16. Mitronin A.V., Ostanina D.A., Mitronin Yu.A. Morphometric analysis of surface changes in XP-endo group files after root canal instrumentation. *Endodontics Today*. 2019;17(2):9–16. (In Russ.) https://doi.org/10.33925/1683-2981-2019-17-2-9-16
Митронин А.В., Останина Д.А., Митронин Ю.А. Морфометрический анализ рабочей поверхности инструментов группы XP-endo после препарирования каналов корня. *Эндодонтия Today*. 2019;17(2):9–16. https://doi.org/10.33925/1683-2981-2019-17-2-9-16
17. Shen S.M., Deng M., Wang P.P., Chen X.M., Zheng L.W., Li H.L. Deformation and fracture of K3 rotary nickel-titanium endodontic instruments after clinical use. *Int Endod J*. 2016;49(11):1088–1094. https://doi.org/10.1111/iej.12561
18. Khabadze Z.S., Ismailov F.R., Dashtieva M.Y., Omarova K.O., Zoryan A.V., Umarov A.Y. et al. *Method for determination of feature of endodontic instrument breakage*. Patent RU2794631C1 Russian Federation. Date of publication: 24.04.2023. Available at: https://patents.google.com/patent/RU2794631C1/ (accessed: 11.08.2025).
Хабадзе З.С., Исмаилов Ф.Р., Даштиева М.Ю., Омарова Х.О., Зорян А.В., Умаров А.Ю. и др. *Способ определения признака отлома эндодонтического инструмента*. Патент РФ RU2794631C1. Опубл.: 24.04.2023. Режим доступа: https://patents.google.com/patent/RU2794631C1/ (дата обращения: 11.08.2025).

INFORMATION ABOUT THE AUTHORS

Alexander V. Mitronin – Dr. Sci. (Med.), Professor, Deputy Director of the A.I. Evdokimov Institute of Dentistry, Head of the Department of Therapeutic Dentistry and Endodontics, Honored Doctor of the Russian Federation, Russian University of Medicine, 4 Dolgorukovskaya St., Moscow 127006, Russian Federation; https://orcid.org/0000-0002-3561-6222

Diana A. Ostanina – Cand. Sci (Med.), Associate Professor of the Department of Therapeutic Dentistry and Endodontics, Russian University of Medicine, 4 Dolgorukovskaya St., Moscow 127006, Russian Federation; https://orcid.org/0000-0002-5035-5235

Kirill A. Archakov – Postgraduate Student, Laboratory Assistant of the Department of Therapeutic Dentistry and Endodontics, Russian University of Medicine, 4 Dolgorukovskaya St., Moscow 127006, Russian Federation; https://orcid.org/0000-0002-5181-1546

Yuriy A. Mitronin – Postgraduate Student, Assistant of the Department of Propaedeutics of Therapeutic Dentistry, Russian University of Medicine, 4, Dolgorukovskaya St., Moscow 127006, Russian Federation; https://orcid.org/0000-0002-3118-2869

ИНФОРМАЦИЯ ОБ АВТОРАХ

Митронин Александр Валентинович – д.м.н., профессор, заместитель директора НОИ стоматологии им. А.И. Евдокимова, заведующий кафедрой терапевтической стоматологии и эндодонтии, Заслуженный врач РФ, ФГБОУ ВО «Российский университет медицины», 127006, Российская Федерация, г. Москва, ул. Долгоруковская, д. 4; https://orcid.org/0000-0002-3561-6222

Останина Диана Альбертовна – к.м.н., доцент кафедры терапевтической стоматологии и эндодонтии, ФГБОУ ВО «Российский университет медицины», 127006, Российская Федерация, г. Москва, ул. Долгоруковская, д. 4; https://orcid.org/0000-0002-5035-5235

Арчаков Кирилл Андреевич – аспирант, лаборант кафедры терапевтической стоматологии и эндодонтии, ФГБОУ ВО «Российский университет медицины», 127006, Российская Федерация, г. Москва, ул. Долгоруковская, д. 4; https://orcid.org/0000-0002-5181-1546

Митронин Юрий Александрович – аспирант, ассистент кафедры пропедевтики терапевтической стоматологии, ФГБОУ ВО «Российский университет медицины», 127006, Российская Федерация, г. Москва, ул. Долгоруковская, д. 4; https://orcid.org/0000-0002-3118-2869

AUTHOR'S CONTRIBUTION

Alexander V. Mitronin – has made a substantial contribution to the concept or design of the article; revised the article critically for important intellectual content; approved the version to be published.

Diana A. Ostanina – has made a substantial contribution to the concept or design of the article; the acquisition, analysis, or interpretation of data for the article; drafted the article; revised the article critically for important intellectual content.

Kirill A. Archakov – the acquisition, analysis, or interpretation of data for the article; drafted the article.

Yuriy A. Mitronin – the acquisition, analysis, or interpretation of data for the article; drafted the article.

ВКЛАД АВТОРОВ

А.В. Митронин – существенный вклад в замысел и дизайн исследования, критический пересмотр статьи в части значимого интеллектуального содержания; окончательное одобрение варианта статьи для опубликования.

Д.А. Останина – существенный вклад в замысел и дизайн исследования, сбор данных, анализ и интерпретация данных, подготовка статьи, критический пересмотр статьи в части значимого интеллектуального содержания.

К.А. Арчаков – сбор данных, анализ и интерпретация данных, подготовка статьи.

Ю.А. Митронин – сбор данных, анализ и интерпретация данных, подготовка статьи.