



Contents lists available at ScienceDirect

## Journal of Orthopaedic Translation

journal homepage: [www.journals.elsevier.com/journal-of-orthopaedic-translation](http://www.journals.elsevier.com/journal-of-orthopaedic-translation)

## Advancing medical device regulatory reforms for innovation, translation and industry development in China



Xu Song<sup>a,1</sup>, Minxia Hu<sup>b,1</sup>, Bin Li<sup>c</sup>, Kai Zhang<sup>a,\*</sup>, Xingdong Zhang<sup>a</sup>, Lanming Wang<sup>d,\*\*</sup>

<sup>a</sup> College of Biomedical Engineering, Institute of Medical Device Regulatory Science, and National Engineering Research Center for Biomaterials, Sichuan University, China

<sup>b</sup> College of Foreign Languages and Cultures, Sichuan University, China

<sup>c</sup> Orthopaedic Institute, Department of Orthopaedic Surgery, The First Affiliated Hospital, Suzhou Medical College, Soochow University, Suzhou, China

<sup>d</sup> Department of Medical Device Registration, National Medical Products Administration, China

## ARTICLE INFO

## Keywords:

Medical devices  
Regulatory science  
Safety  
Efficacy  
Biocompatibility

## ABSTRACT

The blossoming Chinese medical device market calls for a science-based regulatory system in China. Consistent efforts have been made to advance the medical device regulatory reforms for innovation, translation and industry development. In this article, we report both the latest regulatory requirements which aim to ensure safety and efficacy for patients while encouraging innovation of the medical device industry, and the key programs on medical devices covered in the Regulatory Science Action Plan (RSAP) of the National Medical Products Administration of China (NMPA). The main features of the revised regulations are first elucidated before the opportunities for translational research are interpreted, including those for additive manufacturing and customized devices, drug–device combination products, artificial intelligence-powered software and surgical robots, and nanomaterials for medical devices. Finally, a regulatory perspective is provided to researchers who expect to translate their technologies in the Chinese medical device market. Important issues including early attention to critical market and clinical needs, understanding the true principle and spirit underlying the changing regulations and standards, and protecting intellectual property rights with comprehensive measures, are discussed. These developments warrant further investigations into the distinct role of regulatory science in shaping medical devices research and development.

*The translational potential of this article:* This article provides a new insight into how the changing regulations and the emerging regulatory science contribute to promoting innovation and translation of safe and effective medical devices in China. It could open up avenues for global regulatory science-based research and development of medical devices, and serve as an introduction for overseas medical products for exploration in translation and registration in China.

### 1. Introduction

Since its promulgation in 2000, the *Regulation for the Supervision and Administration of Medical Devices* of China has undergone revision in 2014, 2017 and 2021 [1–5]. A review of the main updates of the 2021 and earlier revisions offers a significant perspective to researchers who expect to have their medical devices approved for the Chinese market.

The updates of *Regulation* promote safe and effective medical devices for public health and economic development. In August 2015, the State Council of China issued the *Opinions on Reforming the Review and Approval System for Drugs and Medical Devices* [6]. In October 2017, the General Office of the Central Committee of the Communist Party of China and the General Office of the State Council issued the *Opinions on Deepening the Reform of the Review and Approval System and Encouraging the Innovation of Drugs and Medical Devices*, which clarified the requirements for furthering the reform of medical device registration and encouraging the innovation of drugs and medical devices [7]. Since then, the National Medical Products Administration of China (NMPA) has adopted a series of new measures for optimizing the medical device regulatory system and promoting technical innovations, in order to improve the safety, effectiveness and accessibility of medical devices in China [8].

The current *Regulation* were revised and came into force on June 1,

\* Corresponding author.

\*\* Corresponding author.

E-mail addresses: [kaizhang@scu.edu.cn](mailto:kaizhang@scu.edu.cn) (K. Zhang), [wanglm@nmpa.gov.cn](mailto:wanglm@nmpa.gov.cn) (L. Wang).

<sup>1</sup> The authors contributed equally.

<https://doi.org/10.1016/j.jot.2022.09.015>

Received 30 May 2022; Received in revised form 9 September 2022; Accepted 28 September 2022

Available online xxx

2214-031X/© 2022 Published by Elsevier B.V. on behalf of Chinese Speaking Orthopaedic Society. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

2021 [5]. “This revision reflects the *Four Strict Requirements* of General Secretary Xi Jinping of the CPC Central Committee, the State Council and the expectations of the people by encouraging innovative and high-quality medical devices as well as industrial development.” [8]. “The *Regulation* fully implement the decisions and arrangements made by the CPC Central Committee and the State Council on the reform of the drug and medical device review and approval system. A legal basis is provided to consolidate previous reforms. The principle is to enhance the quality of medical devices, protect the legitimate rights and interests of the public for safe and effective devices, and stimulate the innovative development of the industry.” [5].

There are four main features in the latest *Regulation*. First, new systems, mechanisms, and methods are included to improve regulatory capacity. Second, simplification and optimization of the evaluation and approval procedures are adopted to enhance regulatory efficiency. Third, targeted responsibilities for quality and safety are clarified to manage the whole life cycle of the medical devices. Last but not the least, more and stricter punishment is incorporated for violations of the laws and regulations [9].

“The *Regulation* adheres to the principles of risk management, whole-process control, evidence-based regulation, and social co-governance. The reform included the establishment of a registrant and filer system to define the main responsibility of the businesses. Additionally, administrative services were streamlined with more delegation, decentralization and deregulation to empower industry innovation and development of the market. The *Regulation* explicated on the establishment of the medical device registrant and filer system. Requirements were clarified for clinical evaluation, conditional approval, emergency use, unique device identification and traceability, professional inspectors, the investigation of responsibilities and punishment for violation of the registration and filing system. The regulation of production, operation and handling, product recall, and adverse events reporting was strengthened. To sum up, the latest updates aimed to support innovation based on the regulatory lifecycle management.” [8].

## 2. NMPA's Regulatory Science Action Plan (RSAP)

NMPA launched the first Regulatory Science Action Plan (RSAP) in 2019. The main progress in China's regulatory science for medical devices is discussed in this section.

In April 2019, nine regulatory research programs on drugs, medical devices and cosmetics were recognized in the first RSAP, including four device related projects. They are entitled the *Evaluation of Drug-device Combination Technology, Safety and Effectiveness of Medical Devices Driven by Artificial Intelligence, New Materials for Medical Devices* (as represented by the projects on additive manufacturing and custom devices), and *Methodological Approaches to Real-World Data for Clinical Evaluation of Medical Devices* [10]. Some of the achievements of the RSAP will be described below.

In the two years since the implementation of the RSAP, 103 new tools, methods and standards have been formulated, of which 31 or 1/3 of the total, have been published. Among them, Chinese national standard, “GB/T41672-2022 Surgical Implant: Osteoinductive Calcium Phosphate Bioceramics” represents a breakthrough of standards development for tissue-inducing biomaterials. In addition, more than 20 regulatory research reports have been released” [11]. In 2021, the second phase of the RSAP research programs was launched [12]. Through close collaboration with prestigious universities and institutes, 14 NMPA-affiliated regulatory science Centers were established, of which seven were related to medical devices. In July 2019, NMPA recognized 45 key laboratories for the RSAP [13]. In February 2021, another 72 key laboratories were included, reaching a total of 117 labs [14]. 29 of these laboratories specializes in medical devices, accounting for 26% of the total directory.

### 2.1. Additive manufacturing and customized devices

As defined by FDA, “additive manufacturing (AM), the broad category of manufacturing encompassing 3-dimensional (3D) printing, is a process that builds an object by sequentially building 2-dimensional (2D) layers and joining each to the layer below, allowing device manufacturers to rapidly produce alternative designs without the need for retooling and to create complex devices built as a single piece.” [15] The application of additive manufacturing technology in orthopaedic devices leads to personalized design and products that meet the precise patient demand during surgical operation. Their representative RSAP achievements are summarized below.

Projects of RSAP have generated new standards, guidance documents, and registration documents for additively manufactured medical devices of new materials. The resultant new tools and approaches will further facilitate the translation of scientific findings, providing patients with more adaptable products [16].

“NMPA attaches great importance to a science-based regulatory system for additively manufactured medical devices with targeted regulations, guidance documents, and standards” [16]. To ensure the safety and effectiveness of custom-made medical devices for individual patients, NMPA and the National Health Commission started to implement the *Provisions on Customized Medical Devices (tentative)* on January 1, 2020 [17]. “In October, 2020, NMPA issued the *Guidance Document for the Technical Review of the Registration of Personalized Additively Manufactured Passive Implantable Bones, Joints and Oral Hard Tissue Substitutes*. On this basis, NMPA provides other guidance documents for acetabular cups, artificial vertebral bodies, mandibular prostheses and spinal cages, and for innovative products derived from titanium, degradable magnesium, and polyether ether ketone (PEEK). A guidance document system for additive manufacturing of hard tissue substitutes has been established” [16].

In 2019, NMPA identified technical collaborators for the standardization of additively manufactured medical devices, covering the software, equipment, raw materials and processes of such products, to promote the healthy development of the emerging industry [18]. “Chinese experts are developing standards on 3D-printed surgical guides, such as the *Expert Consensus on Technical Standards for 3D-printed Orthopedic Surgical Guides, the Customized Orthopaedic Surgical Guides by Additive Manufacturing (3D printing), the Oral Implant Surgical Guides by Additive Manufacturing (3D printing)*, published by the Digital Orthopedics Group of the Medical Engineering Branch of the Chinese Medical Association and other professional organizations.” [16].

In February 2021, the NMPA key laboratory for the research and evaluation of additively manufactured medical devices (affiliated with Xi'an Jiaotong University) was included in the second phase of RSAP. The lab focuses on the research, development and evaluation of new materials and additive manufacturing technology for medical devices [12]. In addition, the performance evaluation of degradable magnesium, bioceramics, degradable bone repair materials, resorbable dental membranes becomes the new priority of the second RSAP [11,12].

“The standards, guidance documents, and registration documents for additively manufactured medical devices of new materials will facilitate the translation of scientific findings, providing patients with more adaptable products.” [16].

### 2.2. Drug-device combination products

Drug-Device combination products have become a unique medical product that are increasingly meeting clinical needs, especially those for cardiovascular, orthopedic, and neurological conditions. Combination products were included as one of the nine research programs published by the NMPA RSAP in April 2019 [10].

NMPA's regulation of the combination products started in 2002 [19, 20]. In November 2009, NMPA issued the *Notice on Matters Concerning the Registration of Drug-Device Combination Products*, which for the first time clarified the regulatory requirements for drug–device combination products [20,21]. In 2021, NMPA issued the *Announcement on the Registration of Drug-Device Combination Products* (No. 52, 2021), in which NMPA deleted the requirements that the drug components in the imported combination products that act mainly as devices should be approved by NMPA or regulator of the country of origin [20,22]. According to the announcement, when deciding whether a drug–device combination product is regulated as a device or a drug, the product's primary mode of action (PMOA) must be the determining factor. If the PMOA is a device, then the product shall follow the regulatory pathway of a device, and vice versa [23–26]. The Center for Medical Device Standards Administration (CMDSA) is responsible for validating the PMOA of the combination products.

To facilitate evidence-based market entry of the combination products with clear clinical value, NMPA included the combination products in the research programs of the second RSAP. On January 17, 2022, it issued the *Guidance Document for the Registration and Review of Devices as Combination Products* and the *Guidance Document for the Qualitative, Quantitative and In Vitro Release Research of Drug Components in Devices as Combination Products* [27].

Artificial intelligence, surgical robots, nanomaterials and tissue engineering for medical devices.

“NMPA encourages market entry of innovative medical products. It published the *Special Review Procedures for Innovative Medical Devices* and the *Priority Review Procedures of Medical Devices for Urgent Clinical Needs*. These regulations provide special approval channels for urgently needed medical devices. Safety and effectiveness are guaranteed while the launching of innovative medical devices is accelerated.” [28] These policies have promoted the development and commercialization of innovative medical products. As of March 2022, NMPA has approved 148 innovative medical devices, including orthopaedic surgical robots, and products based on artificial intelligence, tissue engineering and nanotechnology [29,30].

Medical devices driven by artificial intelligence were included in the first RSAP [10]. On July 17, 2019, the Conference on Artificial Intelligence for Medical Device Innovation was held in Beijing [31]. “At the conference the Cooperation Platform of the Artificial Intelligence for Medical Device Innovation was established. The platform was co-sponsored by 14 organizations, including the Center for Medical Device Evaluation of NMPA, the National Computer Network and Information Security Management Center, the China Academy of Information and Communications Technology, the Chinese Society of Biomedical Engineering, the China Biotechnology Development Center, the Chinese People's Liberation Army General Hospital, and Tsinghua University. The purpose was to manage the risks of rapid AI deployment in medical devices for the regulators and the industry. To encourage innovation and translation of AI-powered medical devices, a science-based evaluation system that covers data governance, standard setting, clinical evaluation, testing and inspection must be established.” [31].

October 18, 2019, NMPA identified a technical collaborator for the standardization of AI-powered medical devices [32]. NMPA released the *Guidance Document for the Classification and Definition of Artificial Intelligence-Based Software as a Medical Device* on July 8, 2021 [33]. On March 7, 2022, the Center for Medical Device Evaluation of the NMPA issued the *Guidance Document for the Registration and Review of Artificial Intelligence-Based Medical Devices*, filling the regulatory gap for review standards [34]. The research and evaluation laboratories for AI-powered medical devices were included in the second batch of 72 key laboratories of the NMPA RSAP, published on February 9, 2021 [14].

*The Evaluation of innovative medical devices based on remote transmission, flexible electronic technology and medical robots, and the Evaluation of safety, efficacy and quality assurance of innovative nanoscale drugs and medical devices* were included in the key research programs of the second

NMPA RSAP, published on June 28, 2021 [12]. NMPA released the *Guidance Document for the Safety and Efficacy Evaluation of Medical Devices Using Nanomaterials Part I: System Framework* on August 27, 2021 [35].

On December 28, 2007, NMPA issued a *notice on the requirements for research and application of tissue-engineered medical products* [36]. On February 9, 2021, laboratories related to tissue engineering technology were included in NMPA RSAP's second batch of 72 key laboratories [14]. According to the *Opinions of the National Standardization Administration of NMPA on Promoting the High-Quality Development of Medical Device Standardization* released on March 30, 2021, regulatory science should be strengthened for standards of biomaterials, drug–device combination products, additive manufacturing technology, and degradable materials, tissue engineering, recombinant collagen and nanomaterials [37].

### 3. A regulatory perspective

Broadly speaking, scientific research activities on medical devices includes basic, applied and development study. Medical device research and development aimed at clinical translation and market entry usually cover concepts, and prototypes, preclinical and clinical investigations, pre-market evaluation, industrialization, commercialization, and post-market surveillances. For authors and readers of JOT who are mainly engaged in basic and applied research but are interested in translating their innovations into medical devices, the following considerations might be useful for a regulatory compliance perspective.

#### 3.1. Tuning into market and clinical needs

All medical devices must fulfill clinical needs and solve practical problems [38–53]. The academic value of research findings is not always aligned with their clinical values. However, if an innovation is expected to bring new technologies and products to the market, then research on market and clinical demands should be conducted as early as possible [38–53]. The urgent clinical needs and unsolved problems should be pinpointed to refine the research program accordingly. Otherwise, it might be difficult for significant research findings to be translated into successful medical products [38–53].

To both address clinical needs and ensure safety and effectiveness, clinical evaluation must be conducted and submitted for all the Class II and Class III devices during their registration. Please note that clinical evaluation “is a set of ongoing activities that use scientifically sound methods for the assessment and analysis of clinical data to verify the safety, clinical performance and/or effectiveness of the medical device when used as intended by the manufacturer” [54]. Clinical evaluation may include, but is not equal to clinical trial.

#### 3.2. Attention to regulations and standards

All medical devices must comply with the framework and requirements of the national regulatory authority. Researchers are encouraged to learn and understand the differences/similarities of regulations and regulatory systems in China, US, Japan, and EU [55]. The general principle is that market access is only possible after the stringent reviews and procedures that ensure the safety and effectiveness of medical devices in the human body. This means that researchers should be mindful of their research methods and technical indicators, which should be consistent with the regulations, technical guidance documents and standards such as YY/T 0287 (i.e., ISO 13485) and YY/T 0316 (i.e., ISO 14971) issued by the chosen regulatory pathway. A careful evaluation of compliance requirements would facilitate the pre-market reviews and avoid duplicated efforts.

#### 3.3. Issues of intellectual property protection

All medical devices require high inputs characterized by heavy investment, big risks and lengthy cycles. Therefore, innovative medical



devices must be protected by patents and other necessary measures to preserve their commercial value. Researchers could protect their intellectual property rights by heeding the advice from professional institutions for intellectual property protection, formulating early patent protection plans at the project design stage, and applying for patent protection in a timely and optimized manner. In particular, it is essential to avoid public disclosure of key technical information in academic journals or conferences before applying for a patent. Such action risks losing the window of opportunity for patent protection.

#### 4. Conclusions

This article reported the regulatory progresses on medical devices in China. The revised Regulations of Medical Devices of China in 2021 is important to public health and economic development, and the innovation of medical devices. The RSAP of the NMPA was demonstrated in terms of several representative programs including additive manufacturing and customized devices, drug–device combination products, artificial intelligence-powered software and surgical robots, nano-materials and tissue engineering. Regulatory perspectives on the translation of medical devices from bench to clinic is also presented. The improvement of regulatory system and advancement of regulatory science further drives fast development, translation and innovation of safe and effective medical devices in China.

#### Conflict of interest

The authors have no conflict of interest.

#### Acknowledgements

This work was financially supported by the Natural Science Foundation of China (No. 32001002), the Sichuan Science and Technology Program (No. 2021YFS0020), and Sichuan University Graduate Education Reform Program (No. GSSCU2021007). This work was also supported by the second batch (“3.1 Investigating technologies of assessing the safety and effectiveness of nano-medical device products”, “5.3 Investigating innovative supervision and assessment technologies of tissue engineered medical device products”, “5.4 Research, development and translation of innovative biomaterials” and “5.5 Research on technical evaluation of recombinant collagens, cartilage-repair materials and antimicrobial orthopedic/dental materials”) of the Drug Regulatory Science Action Plan of the National Medical Products Administration of China.

#### References

- [1] National Medical Products Administration. The regulation for the supervision and administration of medical devices (order No. 276 of the state Council). Available at: <https://www.nmpa.gov.cn/xxgk/fgwj/flxzhfg/20000104094801612.html>. [Accessed 4 January 2000]. Accessed.
- [2] National Medical Products Administration. The regulation for the supervision and administration of medical devices (order No. 650 of the state Council). Available at: <https://www.nmpa.gov.cn/xxgk/fgwj/flxzhfg/20140307120001788.html>. [Accessed 7 March 2014]. Accessed.
- [3] National Medical Products Administration. Decision of the state Council on amending the regulation for the supervision and administration of medical devices of China. Available at: <https://www.nmpa.gov.cn/xxgk/fgwj/flxzhfg/20170519191701506.html>. [Accessed 9 May 2017]. Accessed.
- [4] Liu W, Shi X, Lu Z, et al. Review and approval of medical devices in China: changes and reform. *J Biomed Mater Res B Appl Biomater* 2018;106(6):2093–100.
- [5] National Medical Products Administration. A notice of on studying, publicizing and implementing the regulation for the supervision and administration of medical devices. Available at: <https://www.nmpa.gov.cn/directory/web/nmpa/xxgk/fgwj/gzwljyq/20210318173224192.html>. [Accessed 8 March 2021]. Accessed.
- [6] National Medical Products Administration. The state Council issued the Opinions on reforming the review and approval system for drugs and medical devices. Available at: <https://www.nmpa.gov.cn/directory/web/nmpa/ylqx/ylqxjgd/20150818200801163.htm>. [Accessed 18 August 2015]. Accessed.
- [7] National Medical Products Administration. The general Office of the central committee of the communist party of China issued the Opinions on deepening the reform of the review and approval system to encourage the innovation of drugs and medical devices. Available at: <https://www.nmpa.gov.cn/xxgk/fgwj/gzwljyq/20171009164201907.html>. [Accessed 9 October 2017]. Accessed.
- [8] Wang L. Review of the reform on the review and approval system of medical devices in China. *China Food & Drug Administration Magazine* 2021;1:16–27.
- [9] National Medical Products Administration. Authoritative interpretation of the latest updates of the regulation for the supervision and administration of medical devices. Available at: <https://www.nmpa.gov.cn/directory/web/nmpa/zwgk/xwfb/20210326221435168.html>. [Accessed 26 March 2021]. Accessed.
- [10] The State Council. The people's Republic of China. National medical products administration launches China's regulatory science action plan. Available at: [http://www.gov.cn/xinwen/2019-05/02/content\\_5388253.htm](http://www.gov.cn/xinwen/2019-05/02/content_5388253.htm). [Accessed 2 May 2019]. Accessed.
- [11] National Medical Products Administration. National medical products administration presenting the first batch of key projects under the regulatory science action plan. Available at: <https://www.nmpa.gov.cn/directory/web/nmpa/yaowen/ypjgyw/hyxx/20210428213149177.html>. [Accessed 28 April 2021]. Accessed.
- [12] National Medical Products Administration. A notice on implementing the second batch of key projects of regulatory science action plan. Available at: <https://www.nmpa.gov.cn/xxgk/fgwj/gzwljyq/20210628172854126.html>. [Accessed 8 June 2021]. Accessed.
- [13] National Medical Products Administration. A notice on recognizing the first batch of key laboratories, 2019. Available at: <https://www.nmpa.gov.cn/xxgk/ggts/qtggtg/20190715175401605.html>. [Accessed 15 July 2019]. Accessed.
- [14] National Medical Products Administration. National Medical Products Administration added another 72 key laboratories to support high-quality regulation of medical products. Available at: <https://www.nmpa.gov.cn/yaowen/ypjgyw/20210209161040190.html>. [Accessed 9 February 2021]. Accessed.
- [15] U.S. Food & Drug Administration. Technical considerations for additive manufactured medical devices. Available at: <https://www.fda.gov/regulatory-information/search-fda-guidance-documents/technical-considerations-additive-manufactured-medical-devices>. [Accessed December 2017]. Accessed.
- [16] Hao L, Du C, Zhao N. The advantages of adaptive new materials and standardization of quality management: a brief discussion on bone regeneration and repair materials and related regulatory science. *Exploration and Practice*. 7th ed. China Medical Journal; 2022. Available at: <http://bk.cnpharm.com/zgyyb/2022/04/2/321773.html>. [Accessed 20 April 2022]. Accessed.
- [17] National Medical Products Administration. Provisions on customized medical devices (tentative). Available at: <https://www.nmpa.gov.cn/directory/web/nmpa/xxgk/zhcjd/zhcjdyqx/20190704160801648.html>. [Accessed 4 July 2019]. Accessed.
- [18] National Medical Products Administration. Announcement on the establishment of three technical collaborators for medical device standardization. Available at: <https://www.nmpa.gov.cn/ylqx/ylqxgg/ylqxqgtg/20191018093501305.html>. [Accessed 18 October 2019]. Accessed.
- [19] National Medical Products Administration. A notice on the regulations of magnetic therapy and drug-containing medical devices. Available at: <https://www.nmpa.gov.cn/xxgk/fgwj/gzwljyq/20020816010101116.html>. [Accessed 16 August 2002]. Accessed.
- [20] Tian J, Song X, Wang Y, et al. Regulatory perspectives of combination products. *Bioact Mater* 2022;10:492–503.
- [21] National Medical Products Administration. Announcement on the registration of drug-device combination products. 2021. Available at: <https://www.nmpa.gov.cn/xxgk/ggts/qtggtg/20210727154135199.html?type=pc&m=>. [Accessed 23 July 2021]. Accessed.
- [22] National Medical Products Administration. Announcement on defining the primary mode of action of drug-device combination products. Available at: <https://www.nmpa.gov.cn/xxgk/ggts/qtggtg/20210727154135199.html>. [Accessed 27 July 2022]. Accessed.
- [23] Cheng W, Liu Y, Meng X, et al. PLGA/β-TCP composite scaffold incorporating cucurbitacin B promotes bone regeneration by inducing angiogenesis. *J Orthopaedic Translat* 2021;31:41–51.
- [24] Xu G, Hu X, Han L, et al. The construction of a novel xenograft bovine bone scaffold, (DSS)6-liposome/CKIP-1 siRNA/calcine bone and its osteogenesis evaluation on skull defect in rats. *J Orthopaedic Translat* 2021;28:74–82.
- [25] Shi G, Li Y, Luo Y, et al. Bioactive PLGA/tricalcium phosphate scaffolds incorporating phytomolecule icaritin developed for calvarial defect repair in rat model. *J Orthopaedic Translat* 2020;24:112–20.
- [26] Deng C, Chang J, Wu C. Bioactive scaffolds for osteochondral regeneration. *J Orthopaedic Translat* 2019;17:15–25.
- [27] National Medical Products Administration. Announcement on issuing two registration evaluation guidance document for drug-device combination products with PMOA as medical devices (2022 No. 3). Available at: <https://www.nmpa.gov.cn/ylqx/ylqxgg/20220117145645132.html>. [Accessed 17 January 2022]. Accessed.
- [28] National Medical Products Administration. Reply to recommendation No. 8591 of the second session of the thirteenth national People's congress by national pharmaceutical administration [No. 36, 2019]. Available at: <https://www.nmpa.gov.cn/directory/web/nmpa/zwgk/jyta/rdjy/20191018090101747.html>. [Accessed 18 October 2019]. Accessed.
- [29] National Medical Products Administration. Mobile head and neck MRI system approved for marketing. Available at: <https://www.nmpa.gov.cn/zhuanti/ypqxgg/gggzjh/20220303164047103.html>. [Accessed 3 March 2022]. Accessed.
- [30] Liu W, Xie Y, Zheng Y, et al. Regulatory science for hernia mesh: current status and future perspectives. *Bioact Mater* 2021;6(2):420–32.

- [31] National Medical Products Administration. Artificial intelligence medical device innovation promotion conference was held in Beijing. Available at: <https://www.nmpa.gov.cn/directory/web/nmpa/yaowen/ypjgyw/20190717210701958.html>. [Accessed 17 July 2019]. Accessed.
- [32] National Medical Products Administration. Announcement on the establishment of three technical collaborators for medical device standardization (No. 82, 2019). Available at: <https://www.nmpa.gov.cn/ylqx/ylqxgggtg/ylqxqtgg/20191018093501305.html>. [Accessed 18 October 2019]. Accessed.
- [33] National Medical Products Administration. A notice of on issuing guidance document for the classification and definition of artificial intelligence-based software as a medical device (2021 No. 47). Available at: <https://www.nmpa.gov.cn/xxgk/ggtg/qtgggtg/20210708111147171.html>. [Accessed 8 July 2021]. Accessed.
- [34] National Medical Products Administration. A circular of the center for medical device evaluation (CMDE) on issuing guidance document for the registration and review of artificial intelligence medical devices (No. 8, 2022). Available at: <https://www.cmde.org.cn/xwdt/shpgzgg/gztg/20220309090800158.html>. [Accessed 9 March 2022]. Accessed.
- [35] National Medical Products Administration. Guidance document for the safety and efficacy evaluation of medical devices using nanomaterials Part I: system framework. Available at: <https://www.nmpa.gov.cn/directory/web/nmpa/yaowen/ypjgyw/20210827113537138.html>. [Accessed 27 August 2022]. Accessed.
- [36] National Medical Products Administration. A notice on the requirements for research and application of tissue engineered medical products. Available at: <https://www.nmpa.gov.cn/directory/web/nmpa/xxgk/ggtg/qtgggtg/20071218120001912.html>. [Accessed 18 December 2022]. Accessed.
- [37] National Medical Products Administration. Opinions of the national standardization administration on promoting the high-quality development of medical device standardization. Available at: <https://www.nmpa.gov.cn/xxgk/fgwj/gzwj/gzwjylqx/20210330170905141.html>. [Accessed 30 March 2021]. Accessed.
- [38] Zhang K, Mikos AG, Reis RL, et al. Translation of biomaterials from bench to clinic. *Bioact Mater* 2022;18:337–8.
- [39] Zhang K, Ma B, Hu K, et al. Evidence-based biomaterials research. *Bioact Mater* 2022;15:495–503.
- [40] Song X, Tang Z, Liu W, et al. Biomaterials and regulatory science. *J Mater Sci Technol* 2022;128:221–7.
- [41] Zhang J, Jiang Y, Shang Z, et al. Biodegradable metals for bone defect repair: a systematic review and meta-analysis based on animal studies. *Bioact Mater* 2021;6:4027–52.
- [42] Liu W, Lin H, Zhao P, et al. A regulatory perspective on recombinant collagen-based medical devices. *Bioact Mater* 2022;12:198–202.
- [43] Cheng M, Liu W, Zhang J, et al. Regulatory considerations for animal studies of biomaterial products. *Bioact Mater* 2022;11:52–6.
- [44] Wang L, Guo X, Chen J, et al. Key considerations on the development of biodegradable biomaterials for clinical translation of medical devices: with cartilage repair products as an example. *Bioact Mater* 2022;9:332–42.
- [45] Li Z, Chen J, Zhu Q, et al. A preliminary study of a novel robotic system for pedicle screw fixation: a randomized controlled trial. *J Orthopaedic Translat* 2020;20:73–9.
- [46] Xia R, Zhai Z, Zhang J, et al. Verification and clinical translation of a newly designed “Skywalker” robot for total knee arthroplasty: a prospective clinical study. *J Orthopaedic Translat* 2021;29:143–51.
- [47] Zhang J, Shang Z, Jiang Y, et al. Biodegradable metals for bone fracture repair in animal models: a systematic review. *Regenerat Biomater* 2020;8:rbaa047.
- [48] Fu L, Yang Z, Gao C, et al. Advances and prospects in biomimetic multilayered scaffolds for articular cartilage regeneration. *Regenerat Biomater* 2020;7:527–42.
- [49] De Witte TM, Fratila-Apachitei LE, Zadpoor AA, et al. Bone tissue engineering via growth factor delivery: from scaffolds to complex matrices. *Regenerat Biomater* 2018;5:197–211.
- [50] Tang Z, Li X, Tan Y, et al. The material and biological characteristics of osteoinductive calcium phosphate ceramics. *Regenerat Biomater* 2018;5:43–59.
- [51] Hench LL, Polak JM. Third-generation biomedical materials. *Science* 2002;295:1014–7.
- [52] Service RF. Self-assembling materials. Coated nanofibers copy what's bred in the bone. *Science* 200;294:1635–1637.
- [53] Zhang B, Montgomery M, Chamberlain MD, et al. Biodegradable scaffold with built-in vasculature for organ-on-a-chip engineering and direct surgical anastomosis. *Nat Mater* 2016;15:669–78.
- [54] IMDRF MDCE WG/N56FINAL. Formerly GHTF/SG5/N2R8:2007). Clinical evaluation. Available at: <https://www.imdrf.org/documents/clinical-evaluation>. [Accessed 10 October 2019]. Accessed.
- [55] Ann Fiedler Beth, editor. Managing medical devices within a regulatory framework. Elsevier; 2017. p. 343–56.