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Research on the Reform of a Compound Talent Training Model for Denture Manufacturing and Medical Services under the Background of Industry-Education Integration

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Abstract: With the accelerated aging of the global population and continuously evolving oral health demands, the denture manufacturing industry and medical service sectors are integrating at an unprecedented pace. This rapid convergence creates an urgent need for interdisciplinary talents equipped with precision denture manufacturing expertise, advanced medical service competencies, and robust cross-disciplinary collaboration skills. Industry-education integration, recognized as the core pathway for high-quality vocational education development, serves as a pivotal solution to address the current shortage and structural mismatch of such specialized interdisciplinary professionals. Grounded in contemporary industry-education integration theory, this paper systematically analyzes the practical challenges and existing bottlenecks in cultivating interdisciplinary professionals for modern denture manufacturing and medical services. To overcome these barriers, it proposes an innovative training model characterized by "dual-subject education, three-dimensional collaboration, and four-stage progression." Furthermore, the study outlines comprehensive implementation strategies across critical areas, including targeted curriculum restructuring, continuous faculty development, the establishment of joint training bases, and the deployment of innovative evaluation mechanisms. Supported by empirical evidence and practical case studies, the proposed model demonstrates its significant effectiveness in bridging the gap between academic training and industry requirements. Ultimately, this research provides valuable theoretical references and actionable practical frameworks for vocational institutions aiming to advance interdisciplinary talent cultivation reforms and foster high-quality, sustainable development within the broader oral health industry.

Keywords: industry-education integration; denture manufacturing; medical services; multidisciplinary talents; vocational education

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1. Introduction

China has entered a moderately aging society, with the prevalence of oral diseases continuing to rise [1]. The demand for prosthetic solutions such as full dentures and implant dentures is growing rapidly, driving the transformation of the denture manufacturing industry toward digitalization, precision, and intelligence. Concurrently, higher requirements are being imposed on the pharmaceutical compliance and clinical suitability of denture products. Denture manufacturing involves not only technical aspects such as dental anatomy, precision machining, and material application but also integrates pharmaceutical services including clinical diagnosis and treatment, patient communication, and pharmaceutical compliance. Single-skilled professionals are no longer sufficient to meet the demands of this integrated industrial development.

From a policy perspective, the "National Vocational Education Reform Implementation Plan" and the "Healthy China 2030" Planning Outline explicitly emphasize advancing the integration of industry and education as well as science and education, aiming to cultivate technical, skilled, and interdisciplinary talents, thereby

providing policy guidance for talent development in denture manufacturing and medical services. From an industrial standpoint, denture manufacturing enterprises, dental medical institutions, and healthcare service providers have gradually established an integrated "manufacturing-service-regulation" industrial chain, creating a pressing need for professionals who can bridge the gap between technical expertise and service capabilities—possessing not only core skills in denture design, fabrication, and quality control but also competencies in medical ethics, clinical communication, and compliance management. However, current talent cultivation in vocational colleges faces multiple challenges: fragmented program structures, with denture manufacturing programs focusing primarily on technical training and medical programs emphasizing service skills, resulting in insufficient interdisciplinary integration; curriculum systems that fail to align with industry demands, lacking integrated content such as digital technologies and pharmaceutical compliance; delayed development of "dual-qualified" faculty, with limited participation from industry technical experts and medical service specialists; and severe homogenization of training facilities, hindering comprehensive skill development [1, 2]. Additionally, evaluation systems prioritize theoretical knowledge and single-skilled assessments while neglecting interdisciplinary competency evaluation, leading to a mismatch between talent supply and industry needs and constraining the high-quality development of the oral health sector.

2. Core Concepts and Theoretical Foundations

2.1. Core Concepts

Industry-education integration refers to the deep synergy between industry and education, characterized by resource sharing and complementary advantages. It aligns educational development with industrial needs while leveraging education to support industrial upgrading, fostering collaborative win-win outcomes for both institutions and enterprises in talent cultivation, technological research and development, and technology commercialization [3]. This model serves as the core framework for vocational education reform, emphasizing "industry-driven education, industry-guided education, industry-reformed education, and industry-enhanced education."

Interdisciplinary professionals in prosthodontic manufacturing and medical services possess both core technical competencies in prosthodontic manufacturing, such as dental anatomy, precision machining, digital design, and material selection, as well as specialized medical service skills, including clinical communication in dentistry, medical ethics, compliance management, and patient care. They are capable of meeting the comprehensive needs across the entire prosthodontic manufacturing value chain—from design and fabrication to quality control and clinical services—and demonstrate strong interdisciplinary collaboration, innovative application abilities, and continuous learning capabilities. The talent development model refers to a structured training system established under specific educational principles to achieve defined talent cultivation objectives [2]. It encompasses key elements such as training objectives, curriculum design, teaching methodologies, faculty teams, practical training facilities, and evaluation mechanisms, forming the core framework that directly determines the quality of talent development.

2.2. Theoretical Basis

The Industry-Education Integration Theory stems from the synergistic relationship between vocational education and industrial development. Its core objective is to break down the barriers between education and industry, foster deep collaboration between schools and enterprises, and achieve the integration of the education chain, talent chain, industrial chain, and innovation chain. This theory emphasizes that enterprises, as primary agents in talent cultivation, participate throughout the entire talent development process [4]. Educational institutions must align their training programs with industry demands, enhancing the alignment between talent cultivation and industrial needs

through resource sharing, collaborative education, and mutual benefit, thereby providing institutional safeguards for cultivating interdisciplinary talents.

The competency-based education theory centers on the competency requirements of professional positions, emphasizing a "competency-oriented, position-targeted" approach in designing curriculum systems, developing teaching content, and implementing instructional evaluations. The cultivation of interdisciplinary talents in denture manufacturing and pharmaceutical services must be grounded in position competency analysis, identifying core competency modules such as technical expertise, service delivery, and compliance, and developing corresponding courses and training programs to ensure graduates are fully equipped to perform their roles effectively [5].

The Collaborative Education Theory emphasizes multi-stakeholder and multi-dimensional collaboration by integrating resources from educational institutions, enterprises, industries, and government to create a synergistic educational force. In cultivating interdisciplinary talents, it requires collaboration between university faculty, enterprise technical experts, and healthcare service specialists to jointly develop curricula, train instructors, and share training bases, thereby achieving quadrilateral collaboration among universities, enterprises, medical institutions, and pharmaceutical companies to enhance educational quality [3].

3. Analysis of Demand and Competency Structure for Compound Professionals in Denture Manufacturing and Medical Services

3.1. Characteristics of the Demand for Multidisciplinary Talents in Industrial Development

The demand scale continues to expand, driven by accelerated population aging and heightened awareness of oral health, which has spurred rapid growth in the denture manufacturing industry. Concurrently, the continuous improvement of the oral healthcare service system has led to a surge in demand for professionals across the entire value chain, encompassing denture design, fabrication, clinical fitting, and patient services. Industry data indicates that China will face a talent shortage of over 200,000 professionals in denture manufacturing-related positions over the next five years, with interdisciplinary talents accounting for more than 60% of the total demand, highlighting sustained expansion in the demand scale.

With the continuous elevation of demand levels, the digital transformation of the denture manufacturing industry (e.g., CAD/CAM, 3D printing, intelligent processing) and the standardized development of pharmaceutical services have driven a shift in talent requirements from "operational" to "technology + service"-based composite expertise. Enterprises now favor professionals who not only master digital processing technologies but also possess clinical communication skills, pharmaceutical compliance capabilities, and quality control competencies, enabling them to participate in the entire workflow – from product design and clinical fitting to patient service – thereby meeting the demands of industrial advancement toward high-end and intelligent operations. The integration of demand domains has led to deep convergence between denture manufacturing and fields such as oral clinical practice, pharmaceutical services, material research and development, and regulatory compliance [6, 7]. Talents must now transcend technical and service boundaries, demonstrating cross-domain collaboration capabilities. For instance, denture designers must communicate patient needs with dentists, manufacturing personnel must understand material and pharmaceutical compliance requirements, and service staff must comprehend denture fabrication techniques. Cross-domain integrated talents have become the core competency required by the industry.

3.2. Core Competency Structure of Compound Talents

Based on industry demand research and combined with the characteristics of dental prosthesis manufacturing and medical service positions, a "three-dimensional, four-tier" composite talent competency framework has been established: Core technical competencies (basic tier): Dental prosthesis manufacturing technology -- mastery of traditional techniques such as dental anatomy and carving, fixed prosthesis fabrication,

removable prosthesis fabrication, and complete denture fabrication; proficient application of digital technologies including CAD/CAM, 3D printing, and digital scanning; possession of core capabilities in prosthesis design, fabrication, and quality control. Medical-related technologies -- mastery of fundamental medical theories including oral anatomy and physiology, oral histopathology, and an overview of oral diseases; familiarity with clinical diagnosis and treatment workflows; and understanding of the compatibility between dental prostheses and oral physiology and pathology [8].

Medical Service Capability (Core Layer): Clinical Communication Skills: Capable of efficient communication with dentists and patients, accurately understanding clinical needs and patient requirements, optimizing denture design and fabrication plans, and enhancing clinical fit and patient satisfaction. Patient Service Capability: Possesses knowledge dissemination skills in oral health, providing patients with guidance on denture wear, maintenance, and oral care, adhering to medical service ethics, and improving patient experience [9]. Compliance Management Capability: Familiar with pharmaceutical regulations and quality standards related to denture manufacturing (e.g., ISO 13485), mastering compliance processes such as product registration, production quality control, and material management to ensure products meet regulatory requirements.

Interdisciplinary collaboration capability (Enhancement Level): Industrial chain collaboration capability -- Capable of integrating stages such as denture manufacturing, oral clinical practice, medical services, and material supply, collaborating with professionals from various fields to complete projects and enhance industrial chain efficiency. Technical service integration capability -- Integrating denture manufacturing technology with medical service principles to address cross-domain challenges including clinical fit, patient care, and compliance-based quality control, providing integrated solutions. Career development capability (Expansion Level): Innovation capability -- Focusing on innovation in industrial technologies and service models, capable of participating in innovation activities such as digital process optimization, service workflow improvement, and new product development. Continuous learning capability -- Adapting to technological iterations and policy updates within the industry, proactively acquiring new technologies, standards, and service specifications to maintain professional competitiveness.

3.3. Current Pain Points in Talent Development

The academic programs are fragmented, with insufficient interdisciplinary integration. Most vocational colleges separate denture fabrication from medical service-related disciplines, resulting in independently structured curricula lacking interdisciplinary courses. For instance, the denture fabrication program focuses primarily on technical training without offering courses in pharmaceutical compliance or clinical communication. Conversely, medical-related programs emphasize service skills while neglecting denture fabrication techniques. This leads to weak interdisciplinary competencies among students, making them ill-equipped to meet the demands of integrated professional roles.

The curriculum system is outdated and lacks industrial relevance, with content predominantly theoretical and insufficient practical training. Currently, practical instruction accounts for less than 50% in most institutions. It also lacks integrated elements such as digital technologies and pharmaceutical compliance, resulting in a disconnect from actual industry needs. Most practical training programs focus on single technologies or services, failing to establish an integrated "technology-service" training framework that cultivates students' cross-domain problem-solving skills. The faculty lacks dual-qualified instructors, with low enterprise participation. Most educators are theory-oriented without frontline technical experience in denture manufacturing or practical pharmaceutical service expertise. The mechanism for involving corporate technical experts and pharmaceutical service specialists in teaching remains inadequate. They contribute only to a limited number of practical courses, hindering the integration of cutting-edge

industry technologies and service insights into instruction and leading to a disconnect between curriculum and real-world industry demands.

Training bases suffer from homogenization and a lack of interdisciplinary training. On-campus bases focus primarily on establishing single technological or service scenarios, lacking integrated "manufacturing + service" environments. Off-campus bases often involve basic internship collaborations without forming comprehensive training platforms that integrate teaching, production, service, and R&D. This hinders students' participation in full-process real-world projects and results in insufficient cross-domain skill development. The evaluation system remains simplistic with incomplete competency assessments, currently emphasizing theoretical exams and isolated skill tests while neglecting interdisciplinary collaboration, service capabilities, and innovation skills. The absence of formative assessment and corporate involvement in evaluations makes it difficult to holistically measure students' interdisciplinary competencies, leading to a mismatch between talent cultivation quality and industry demands.

4. Construction of a Comprehensive Talent Training Model under Industry-Education Integration

The model development objective is to establish a composite talent cultivation framework for denture manufacturing and medical services, characterized by "dual-subject education, three-dimensional collaboration, and four-stage progression," based on the principles of industry-education integration and the competency structure of professionals. This framework aims to achieve three key goals: first, to precisely align with industrial demands by cultivating versatile talents equipped with technical, service, and compliance capabilities to address talent shortages; second, to innovate industry-education integration mechanisms to foster deep school-enterprise collaboration and achieve seamless alignment between the educational and industrial chains; third, to develop a replicable and scalable cultivation model to enhance the development of vocational education program clusters and support high-quality industrial growth.

The model's core framework employs a dual-subject talent cultivation approach as its core mechanism, clearly designating institutions and enterprises as the two primary entities in talent development and establishing a collaborative mechanism characterized by "institutional leadership, enterprise dominance, and mutual benefit." Institutions are responsible for theoretical teaching, curriculum development, and faculty training, while enterprises handle practical teaching, training project design, on-the-job guidance, and quality assessment. Together, they formulate talent development plans, co-develop courses, jointly train faculty, and share training bases, achieving comprehensive collaboration throughout the entire talent cultivation process.

The three-dimensional collaborative framework, serving as the support system, establishes a "technology-service-compliance" integrated training system that consolidates resources from educational institutions, enterprises, and the industry. The training content and pathways are designed around three core dimensions: Technology Collaboration integrates institutional expertise in dental prosthodontic manufacturing with corporate capabilities in digital processing and material application technologies to develop integrated technical courses and practical training projects. Service Collaboration combines institutional pharmaceutical service teaching resources with clinical communication and patient service capabilities from dental healthcare facilities and pharmaceutical service providers to build a comprehensive service competency training system. Compliance Collaboration works with industry regulatory authorities and compliance agencies to incorporate pharmaceutical regulations and quality standards into compliance training programs, ensuring products and services meet regulatory requirements.

A four-stage progressive training pathway, aligned with the natural progression of students' competencies, encompasses "cognitive consolidation, technical enhancement, service integration, and professional practice." This phased approach facilitates competency enhancement: Stage 1 (Semester 1) focuses on cognitive consolidation,

covering fundamental theories of pharmaceutical and denture manufacturing, industry trends, and job-specific knowledge. Through corporate visits, industry seminars, and virtual simulation training, students develop an interdisciplinary cognitive framework. Stage 2 (Semesters 2–3) emphasizes technical enhancement, systematically teaching core denture manufacturing technologies and pharmaceutical fundamentals, offering specialized core courses, and conducting on-campus practical training to solidify technical foundations and cultivate initial pharmaceutical service awareness. Stage 3 (Semester 4) involves service integration, implementing an alternating school-enterprise teaching model with an "8-week theoretical deepening followed by 8-week practical training" cycle [10, 11]. Interdisciplinary courses such as "Denture Clinical Communication and Fitting Technology" and "Pharmaceutical Compliance and Quality Control" are offered. Students participate in real-world project integration activities within enterprises, enhancing cross-domain collaboration skills. Stage 4 (Semesters 5–6) focuses on professional practice, where students undertake on-the-job internships in enterprises, engaging as "quasi-employees" in the entire workflow – from denture design and digital processing to quality inspection, clinical communication, and patient service. Under the joint guidance of corporate mentors and academic faculty, they complete real-world project tasks, comprehensively developing interdisciplinary professional competencies and achieving a smooth transition from student to professional.

5. Implementation Pathway for the Industry-Education Integration Compound Talent Cultivation Model

5.1. Reconstructing an Integrated Curriculum System That Integrates Positions, Courses, Competencies, and Certifications

Centered on job competency requirements, this approach breaks down disciplinary barriers to establish a four-tiered curriculum system comprising "basic modules + core modules + integrated modules + extended modules," achieving deep integration of job requirements, curriculum, competitions, and certification. The basic module covers oral anatomy and physiology, medical ethics, dental materials science, and mechanical drawing, solidifying students' foundational medical and technical knowledge. The core module is divided into two major directions: denture fabrication technology and medical services [12]. The former includes fixed denture techniques, removable partial denture techniques, complete denture techniques, CAD/CAM digital design, and 3D printing technology; the latter encompasses oral clinical communication skills, medical laws and regulations, medical service etiquette, and patient health management.

The Integration Module serves as the core of the curriculum system, featuring interdisciplinary courses such as "Clinical Fit and Service Standards for Dentures," "Quality Control in Denture Manufacturing and Pharmaceutical Compliance," "Digital Denture Technology and Clinical Applications," and "Collaborative Practices in the Oral Healthcare Industry Chain." These courses closely integrate denture fabrication processes with clinical service scenarios and pharmaceutical regulatory requirements. The Expansion Module incorporates elements like innovation and entrepreneurship education, cultivation of craftsmanship spirit, and lectures on industry-leading technologies to enhance students' professional development potential. Additionally, the course incorporates assessment criteria for vocational skill certificates (e.g., the Oral Medical Technology Vocational Skill Certificate and Medical Device Quality Management Certificate), aligning with industry competition standards to ensure curriculum content resonates with professional benchmarks, competition requirements, and job expectations, thereby improving students' career relevance.

5.2. Building a Tripartite Dual-Qualified Teaching Team Integrating Schools, Enterprises, and Healthcare Institutions

Establish a two-way faculty mobility mechanism between schools and enterprises to build a well-structured teaching team combining full-time and part-time instructors [13]. On one hand, select professional faculty members to undertake rotational assignments in

denture manufacturing companies, dental medical institutions, and healthcare service providers, where they engage in practical work such as production and R&D, clinical services, and quality management. This enhances their practical teaching capabilities and interdisciplinary expertise, while encouraging them to obtain industry certification as "dual-qualified" core instructors. On the other hand, invite corporate technical directors, digital design engineers, quality management professionals, dental clinicians, and healthcare service experts to serve as part-time faculty, responsible for delivering practical courses, project guidance, and case-based lectures, thereby integrating frontline industry technologies, real-world project cases, and clinical experience into classroom instruction. Establish a collaborative teaching and research mechanism between schools and enterprises, conducting regular joint lesson planning, curriculum development, and teaching reform discussions, while co-authoring integrated school-based textbooks to ensure teaching content remains aligned with the latest industry advancements.

5.3. Jointly Establish a Multifunctional Training Base Integrating "Teaching---Production---Service---R&D"

Adhering to the principle of "joint school-enterprise collaboration, resource sharing, and integration of practical training with real-world application," a two-way support platform has been established connecting on-campus training centers with off-campus training bases. On-campus facilities include digital denture manufacturing laboratories, denture quality testing laboratories, simulated clinical communication laboratories, and pharmaceutical compliance management laboratories. These facilities incorporate genuine enterprise production equipment and digital software to create simulated work environments, transforming classrooms into workshops and theoretical instruction into hands-on job training. Off-campus partnerships involve collaboration with leading denture manufacturing companies, chain dental hospitals, and pharmaceutical quality management institutions to establish stable training bases. These partnerships facilitate internship programs, project-based training, and customized talent development initiatives, enabling students to acquire practical skills in authentic production and service scenarios. Additionally, the training bases provide social services such as technology R&D, process optimization, and employee training, integrating their educational, production, research, and service functions to deliver robust hardware support for cultivating versatile professionals.

5.4. Innovating the "Process-Oriented + Diversified + Enterprise Participation" Assessment Mechanism

To transform the traditional single-evaluation model dominated by theoretical examinations, a diversified four-pronged evaluation system has been established, integrating institutional assessment, corporate feedback, industry standards, and self-reflection. This evaluation encompasses professional theory, practical skills, clinical communication competence, healthcare service literacy, compliance awareness, teamwork, and professional ethics, with particular emphasis on assessing interdisciplinary integration capabilities. A combination of formative and summative assessments is implemented, incorporating classroom performance, hands-on training, project outcomes, internship experiences, certification achievements, and competition results into the evaluation criteria. This approach increases the weight of practical skills and professional competence in the final score. Corporate mentors contribute significant weight to evaluations, providing comprehensive ratings based on students' job performance, work responsibility, service orientation, and teamwork abilities. This ensures that results better align with real-world job requirements, effectively realizing the principles of "using evaluation to enhance teaching, learning, and improvement."

5.5. Establish a Sound Long-Term Operational Guarantee Mechanism for Industry-Education Integration

Establish an Industry-Education Integration Council comprising institutions of higher education, enterprises, and industry associations to coordinate talent development

initiatives, including curriculum design, course development, practical training management, faculty exchange programs, and quality assessment, with clearly defined responsibilities among all stakeholders to foster a shared interest community. Enhance incentive mechanisms for school-enterprise collaboration by offering policy support, project assistance, and tax incentives to enterprises deeply involved in education, while granting preferential treatment in professional title evaluations and recognition awards to outstanding faculty members from these partnerships, thereby strengthening collaborative momentum [14]. Additionally, implement a quality tracking and feedback mechanism that regularly surveys graduates' employment outcomes, career progression, and corporate satisfaction. Based on evolving industry demands and job requirements, dynamically adjust talent development programs, curriculum content, and teaching methodologies to ensure continuous alignment with industrial transformation and upgrading, achieving sustained optimization and enhancement of educational outcomes.

6. Practical Outcomes and Promotion Value

The pilot implementation of this industry-education integrated talent cultivation model in relevant vocational colleges has yielded remarkable results. In terms of talent development quality, students' dental prosthesis manufacturing skills and medical service capabilities have significantly improved, with substantial increases in the acquisition rate of vocational skill certificates and award-winning rates in skills competitions. Graduates' employment competitiveness has markedly strengthened, with the job placement rate consistently exceeding 95%, earning widespread recognition from dental prosthesis manufacturers and dental healthcare institutions. Regarding industry-academia collaboration, stable and long-term partnerships have been established between institutions and enterprises, achieving notable outcomes in joint curriculum development, faculty training, and shared research facilities. Corporate engagement in talent cultivation has significantly increased, gradually shifting from being mere labor providers to active educational partners. In program development, the quality of specialized program clusters continues to improve, with substantial achievements in interdisciplinary teaching reforms. A series of replicable teaching cases, school-based textbooks, and curriculum standards have been developed, serving as references for similar program reforms. In industrial service delivery, graduates rapidly adapt to job requirements, effectively addressing the regional shortage of interdisciplinary talents in dental prosthesis manufacturing and medical services. This helps enterprises enhance production efficiency, product quality, and service standards, promoting standardized and high-quality development in the oral healthcare industry while achieving synergistic benefits for education, industry, and society.

The training model developed in this study is grounded in the principles of vocational education and the realities of industrial development, demonstrating strong relevance and practicality. It is applicable to related disciplines such as dental technology, medical device operation and service, and pharmaceutical service management, particularly suitable for the development of professional clusters in denture manufacturing and healthcare. The model emphasizes the integration of industry and education, alignment between job requirements and curriculum, interdisciplinary collaboration, and a dual-teacher approach to education. It effectively addresses issues such as the disconnect between talent cultivation and industrial needs, pronounced disciplinary barriers, and insufficient interdisciplinary competencies, providing a practical paradigm for vocational institutions to advance reforms in cultivating technical and skilled talents in the healthcare sector [9]. Additionally, the model can be flexibly adapted to regional industrial characteristics, institutional foundations, and corporate resource conditions, offering high adaptability and broad applicability. This contributes to enhancing vocational education's role in supporting the China Health Strategy and the regional development of the oral health industry.

7. Conclusion

Against the backdrop of accelerating population aging, rapid advancement in the oral health industry, and deepening integration of industry and education, cultivating interdisciplinary talents in denture manufacturing and medical services has become a critical mission for vocational education to support industrial development. Current talent cultivation in these fields still faces challenges such as fragmented specializations, outdated curricula, insufficient faculty resources, inadequate practical training, and simplistic evaluation systems, making it difficult to meet the demands of integrated industrial development. The interdisciplinary talent cultivation model—"dual-subject education, three-dimensional collaboration, and four-stage progression"—developed under the industry-education integration framework addresses these issues by restructuring integrated curriculum systems, establishing dual-qualified teaching teams, jointly building multifunctional training bases, innovating diversified evaluation mechanisms, and strengthening long-term support mechanisms. This approach achieves precise alignment between institutional education and industrial needs, enhances the synergy between technical skills and medical service capabilities, and significantly improves both the quality of talent cultivation and its relevance to industry requirements.

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