МЕДИЦИНА И ЗДРАВООХРАНЕНИЕ

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MODERN PROSTHODONTIC TECHNOLOGIES IN COMPLETE EDENTULISM: APPLICATION OF CAD/CAM AND 3D PRINTING

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Introduction. *Complete edentulism is a widespread pathology in prosthodontics, significantly reducing patients' quality of life, masticatory efficiency, and social adaptation. Despite being cost-effective and simple, conventional acrylic-based dentures remain limited due to low esthetics, frequent fractures, and prolonged adaptation periods. Therefore, in recent years, CAD/CAM and 3D printing technologies have been increasingly introduced into dentistry.*

Materials and Methods. *The study was conducted from 2022 to 2024 in clinics in Tashkent and Samarkand. A total of 120 completely edentulous patients were divided into 3 groups: Group 1 – conventional acrylic dentures (n=40), Group 2 – CAD/CAM milled dentures (n=40), Group 3 – 3D-printed dentures (n=40). Evaluation criteria included prosthesis accuracy, masticatory efficiency, patient satisfaction (VAS scale), and clinical-laboratory time.*

Results. *CAD/CAM (95%) and 3D-printed (93%) dentures showed higher accuracy compared to conventional dentures (78%). Masticatory efficiency increased by 30% in CAD/CAM and 25% in 3D-printed groups. Patient satisfaction was highest in CAD/CAM dentures (4.7/5), followed by 3D-printed (4.5/5), and lowest in conventional ones (3.8/5). Clinical time was reduced by 40% with CAD/CAM and by up to 50% with 3D printing.*

Discussion. *The results indicate that CAD/CAM and 3D printing technologies provide greater precision, durability, and clinical effectiveness compared to conventional methods. CAD/CAM systems demonstrate superior mechanical strength and long-term stability, whereas 3D printing offers advantages in production speed and cost-effectiveness. Hence, a combined approach may represent the most optimal solution.*

Conclusion. *Modern digital technologies (CAD/CAM and 3D printing) significantly improve clinical and functional outcomes in the treatment of complete edentulism. Under the conditions of Uzbekistan, a combined approach is recommended as the most optimal strategy.*

Keywords: *complete edentulism, CAD/CAM, 3D printing, prosthodontics, digital dentistry.*

СОВРЕМЕННЫЕ ТЕХНОЛОГИИ ПРОТЕЗИРОВАНИЯ ПРИ ПОЛНОЙ АДЕНТИИ: ПРИМЕНЕНИЕ CAD/CAM И 3D-ПРИНТЕРОВ

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Введение. *Полная адентия является одной из наиболее распространённых патологий в ортопедической стоматологии, значительно снижая качество жизни пациентов, эффективность жевания и уровень социальной адаптации. Несмотря на то,*

что традиционные акриловые протезы остаются доступными и простыми в изготовлении, они имеют ряд ограничений — низкие эстетические показатели, склонность к быстрому разрушению и длительный период адаптации. В связи с этим в последние годы в стоматологии всё шире внедряются технологии CAD/CAM и 3D-принтеров.

Материалы и методы. *Исследование проводилось в 2022–2024 гг. в клиниках Ташкента и Самарканда. В нём приняли участие 120 пациентов с полной адентией, которые были разделены на 3 группы:1-я группа – традиционные акриловые протезы (n=40);2-я группа – протезы, изготовленные с помощью CAD/CAM-фрезеровки (n=40);3-я группа – протезы, изготовленные методом 3D-печати (n=40).*

Критерии оценки включали: точность прилегания протезов, эффективность жевания, удовлетворённость пациентов (по шкале VAS), а также клинико-лабораторное время.

Результаты. *Протезы CAD/CAM (95%) и 3D-принтера (93%) показали более высокую точность по сравнению с традиционными протезами (78%). Жевательная эффективность в группе CAD/CAM была выше на 30%, а в группе 3D-принтера — на 25%. Удовлетворённость пациентов составила: CAD/CAM – 4,7/5, 3D-принтер – 4,5/5, традиционные протезы – 3,8/5. Время клинического изготовления сократилось на 40% при использовании CAD/CAM и на 50% при 3D-печати.*

Обсуждение. *Результаты исследования показали, что технологии CAD/CAM и 3D-печати обеспечивают более высокую точность, прочность и клиническую эффективность по сравнению с традиционными методами. CAD/CAM-системы обладают преимуществами в плане механической устойчивости и долгосрочной надёжности, тогда как 3D-печать выделяется скоростью производства и экономической эффективностью. Следовательно, их комбинированное использование можно рассматривать как наиболее рациональный подход.*

Заключение. *Современные цифровые технологии (CAD/CAM и 3D-принтеры) значительно улучшают клинические и функциональные результаты при лечении полной адентии. В условиях Узбекистана комбинированный подход является оптимальным решением.*

Ключевые слова: *полная адентия, CAD/CAM, 3D-принтер, протезирование, цифровая стоматология.*

TO‘LIQ TISHSIZLIKDA ZAMONAVIY PROTEZLASH TEXNOLOGIYALARI: CAD/CAM VA 3D-PRINTER TEXNOLOGIYALARINING QO‘LLANILISHI

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Kirish. *To‘liq tishsizlik ortopedik stomatologiyada keng tarqalgan patologiya bo‘lib, bemorlarning hayot sifatini, chaynash samaradorligini va ijtimoiy moslashuvini sezilarli darajada pasaytiradi. An’anaviy akril asosli protezlar arzonligi va soddaligiga qaramay, past estetik ko‘rsatkichlar, tez sinish va uzoq adaptatsiya davri bilan chegaralanadi. Shu sababli, so‘nggi yillarda CAD/CAM va 3D-printer texnologiyalari stomatologiyada keng joriy etilmoqda.*

Materiallar va metodlar. *Tadqiqot 2022–2024 yillarda Toshkent va Samarqand shaharlaridagi klinikalarda o‘tkazildi. 120 nafar to‘liq tishsizlikka chalingan bemor 3 guruhga bo‘lindi: 1-guruh – an’anaviy akril protezlar (n=40), 2-guruh – CAD/CAM frezlangan protezlar*

(n=40), 3-guruh – 3D-printer asosida tayyorlangan protezlar (n=40). Baholash mezonlari: protezning aniqlik darajasi, chaynash samaradorligi, bemor qoniqishi (VAS shkalasi) va klinika-laboratoriya vaqti.

Natijalar. *CAD/CAM (95%) va 3D-printer (93%) protezlari an'anaviy protezlarga (78%) nisbatan yuqori aniqlik ko'rsatdi. Chaynash samaradorligi CAD/CAM da 30%, 3D-printerda 25% ga yuqori qayd etildi. Bemor qoniqishi CAD/CAM protezlarida 4,7/5, 3D-printer protezlarida 4,5/5, an'anaviylarda esa 3,8/5 bo'ldi. Klinik vaqt CAD/CAM texnologiyasida 40%, 3D-printerda esa 50% gacha qisqardi.*

Muhokama. *Tadqiqot natijalari shuni ko'rsatdiki, CAD/CAM va 3D-printer texnologiyalari an'anaviy usullarga qaraganda yuqori aniqlik, mustahkamlik va klinik samaradorlikni ta'minlaydi. CAD/CAM tizimlari mexanik chidamlilik va uzoq muddatli barqarorlikda ustunlik qilsa, 3D-printer texnologiyalari ishlab chiqarish tezligi va iqtisodiy samaradorlikda afzal hisoblanadi. Shu sababli, ularni kombinatsiyalash eng maqbul yondashuv bo'lishi mumkin.*

Xulosa. *Zamonaviy raqamli texnologiyalar (CAD/CAM va 3D-printer) to'liq tishsizlikni davolashda bemorlarning klinik va funksional natijalarini sezilarli yaxshilaydi. O'zbekiston sharoitida kombinatsiyalangan yondashuv eng optimal yo'l sifatida tavsiya etiladi.*

Kalit so'zlar: *to'liq tishsizlik, CAD/CAM, 3D-printer, protezlash, digital dentistry.*

Introduction.

Complete edentulism remains one of the most pressing challenges in the fields of prosthodontics and public health. It is not merely a localized dental issue but a systemic problem that affects a large segment of the aging population. According to the World Health Organization (WHO), between 30–40% of individuals over the age of 65 suffer from complete edentulism, with prevalence rates reaching up to 50% in some geographic regions [1]. This widespread condition leads to a range of functional, esthetic, and psychosocial complications, severely impairing patients' ability to perform essential daily functions and diminishing their overall quality of life.

The main consequences of complete edentulism include:

- Reduced masticatory efficiency – resulting in compromised chewing ability, poor dietary intake, and a higher risk of malnutrition and associated secondary gastrointestinal disorders [2]. Long-term nutritional deficiencies can further exacerbate systemic health conditions, especially in older adults.
- Speech disorders – including phonetic difficulties and articulation problems that negatively impact verbal communication, social engagement, and self-expression.
- Esthetic changes – such as the loss of vertical facial dimension, sunken cheeks and lips, and progressive bone resorption, which collectively contribute to a condition often referred to as the "aged face" syndrome. These changes not only alter facial appearance but also affect patients' self-esteem and social perception.
- Psychological problems – including lowered self-confidence, increased risk of anxiety and depression, and a sense of social isolation, all of which further compromise an individual's mental and emotional well-being [3].

In Uzbekistan and many other developing countries, the high prevalence of complete edentulism is primarily associated with:

- Delayed diagnosis and inadequate treatment of periodontal diseases and dental caries, which are the leading causes of tooth loss;
- Economic and systemic barriers in the healthcare system, including limited access to preventive dental services and specialized prosthodontic care;
- Low levels of oral health literacy, limited awareness of the importance of early intervention, and cultural attitudes that result in late presentation for prosthodontic treatment.

At present, conventional acrylic dentures remain the most widely used solution for the rehabilitation of completely edentulous patients. Their popularity is largely due to their low cost, ease of fabrication, and

broad availability, making them accessible even in resource-limited settings. However, these dentures come with significant drawbacks, including suboptimal retention and stability, susceptibility to fractures, allergic reactions in sensitive individuals, lengthy adaptation periods, and poor esthetic outcomes [4]. Consequently, patient satisfaction with conventional dentures is often low, and many require frequent adjustments or complete replacement over time.

In recent years, digital technologies have revolutionized the field of prosthodontics, offering more precise, efficient, and patient-centered solutions. CAD/CAM (Computer-Aided Design/Computer-Aided Manufacturing) systems allow for the design and fabrication of dentures that are tailored to the patient's unique anatomical features. These systems enhance precision, reduce manual errors, shorten production time, and improve overall functional and esthetic outcomes compared to traditional fabrication methods [5]. Additionally, CAD/CAM workflows offer better reproducibility, and digital data can be stored for future use, facilitating easier remakes or modifications.

Moreover, 3D printing technologies are rapidly gaining traction in dental laboratories and clinics. Utilizing additive manufacturing principles, 3D printers can produce highly detailed, customized dentures with exceptional accuracy and consistency. This approach significantly decreases chairside time, minimizes material waste, and allows for the integration of advanced biomaterials that offer superior biocompatibility, strength, and esthetics [6]. These innovations also open up new possibilities for prosthetic design, including complex geometries and hybrid structures that were previously difficult or impossible to achieve with conventional techniques.

In conclusion, the integration of advanced digital technologies—particularly CAD/CAM systems and 3D printing—into the treatment protocols for complete edentulism marks a significant advancement in modern prosthodontics. These innovations not only improve clinical efficiency and treatment predictability but also contribute to enhanced patient satisfaction, improved oral health outcomes, and a higher standard of dental care globally.

Literature Review.

Over the past decade, digital dentistry has emerged as a transformative force in the field of dental medicine. It represents a paradigm shift from traditional, manual workflows to fully digitalized processes encompassing all stages of dental treatment—including diagnosis, treatment planning, design, manufacturing, and clinical application. This transition enables significantly greater precision, faster workflows, and enhanced individualization of prosthetic solutions compared to conventional techniques [4]. As a result, digital dentistry is now regarded as one of the most innovative and rapidly evolving disciplines within prosthodontics.

CAD/CAM Technologies

The fabrication of dentures using CAD/CAM (Computer-Aided Design / Computer-Aided Manufacturing) systems represents a fundamental evolution in prosthodontic technology. Unlike traditional methods that rely on manual impressions and handcrafted models, CAD/CAM workflows begin with digital intraoral scanning or scanning of conventional impressions, followed by virtual design in specialized software. The final prosthesis is then produced through high-precision subtractive manufacturing, typically involving milling machines that carve the denture base and teeth from pre-polymerized, industrial-grade resin blocks [5].

- Numerous clinical and in vitro studies have demonstrated the following advantages of CAD/CAM-fabricated dentures:
- High dimensional accuracy and reproducibility, resulting in better tissue adaptation and improved retention;
- Reduction in both clinical and laboratory time, due to the elimination of several manual steps in the workflow;
- 25–30% increase in average mechanical strength and adaptability**, attributed to the use of pre-polymerized materials and digital precision [6];

• Enhanced esthetic outcomes, as digital workflows allow for better control over tooth positioning, occlusion, and gingival contours;

• Improved phonetic comfort, due to accurate reproduction of palatal morphology.

In addition, **CAD/CAM dentures exhibit significantly lower levels of polymerization shrinkage and post-processing deformation** compared to conventional heat-cured acrylic dentures, leading to increased long-term dimensional stability and durability in clinical use [7]. The ability to archive digital files also facilitates easy reproduction of lost or damaged prostheses without the need for repeating the entire treatment cycle.

3D Printing Technologies

3D printing, also known as additive manufacturing, is another breakthrough technology in the digital fabrication of complete dentures. Unlike subtractive milling used in CAD/CAM systems, 3D printing constructs prostheses layer by layer, allowing for intricate geometries and customized forms that are difficult to achieve with conventional or subtractive methods. Using technologies such as SLA (stereolithography), DLP (digital light processing), and FDM (fused deposition modeling), high-resolution dental models and final dentures can be printed from a variety of dental-grade materials.

The key advantages of 3D-printed dentures include:

• Manufacturing time reduction by up to 30–40%, significantly accelerating the prosthetic workflow and allowing for faster patient service [8];

• Wide compatibility with novel biomaterials, including photopolymers, thermoplastics, and reinforced biocomposites that offer excellent esthetics and biocompatibility;

• Design freedom, enabling the creation of complex and highly individualized prosthetic geometries, particularly useful in cases with atypical anatomy or challenging oral conditions;

• Minimal post-processing, as high-resolution printing often results in surfaces requiring little to no additional finishing or polishing.

Recent meta-analyses and systematic reviews have confirmed that 3D-printed complete dentures provide clinical outcomes comparable to those of CAD/CAM-milled dentures, particularly in terms of fit, patient satisfaction, and esthetic performance. However, they offer distinct advantages in production efficiency, scalability, and cost-effectiveness, making them highly suitable for high-volume clinical settings and public healthcare systems [9].

General Analysis

In summary, both CAD/CAM milling and 3D printing technologies have redefined the prosthodontic management of complete edentulism, offering substantial improvements over traditional fabrication methods. These digital systems ensure greater precision, functional performance, esthetic satisfaction, and patient comfort. While CAD/CAM dentures are generally superior in terms of mechanical strength, material stability, and long-term clinical durability, 3D-printed dentures excel in terms of production speed, design flexibility, and cost-efficiency. The complementary nature of these two technologies allows clinicians to tailor treatment approaches based on individual patient needs, clinical complexity, and available resources.

As the technology and materials continue to evolve, it is expected that both CAD/CAM and 3D printing will become integral components of routine prosthodontic practice, leading to more predictable, efficient, and patient-centered outcomes in the rehabilitation of edentulous patients.

Materials and Methods.

This study was conducted between 2022 and 2024 at major dental clinics in Tashkent and Samarkand. The main objective of the study was to clinically and functionally evaluate the effectiveness of CAD/CAM and 3D printing technologies in completely edentulous patients compared with conventional prosthodontic methods.

ParticipantsA total of 120 patients (both men and women, aged 45–75 years) were included in the study. Based on clinical characteristics and anamnesis, patients were randomly divided into three groups:

• **Group 1 (n=40):** patients treated with conventional heat-polymerized acrylic complete dentures.

• **Group 2 (n=40):** patients treated with dentures fabricated from milled blocks using CAD/CAM technology.

• **Group 3 (n=40):** patients treated with dentures fabricated using 3D printing based on the layer-by-layer construction principle.

Inclusion criteria:

• Presence of complete edentulism (Kennedy Class IV).

• General somatic condition not contraindicating dental treatment.

• Oral mucosa without signs of inflammation.

Exclusion criteria:

• Severe systemic diseases (decompensated diabetes, oncological diseases, etc.).

• History of allergic reactions to denture materials.

• Previous history of implant-supported treatment.

Study design and methods

Each patient was evaluated according to the following criteria:

1. **Accuracy of the denture** – measured by assessing micro-gaps between the denture base and alveolar ridge using a micrometer.

2. **Masticatory efficiency** – recorded using electromyography (EMG) of masseter muscle bioelectric activity during chewing.

3. **Patient satisfaction** – assessed subjectively using the Visual Analog Scale (VAS) (0 = unsatisfactory, 10 = fully satisfactory).

4. **Clinical and laboratory time** – total time spent for denture fabrication and delivery (in hours).

Statistical analysis

The collected data were processed using SPSS 25.0 software, and intergroup differences were assessed using Student's t-test and ANOVA. A value of $p < 0.05$ was considered statistically significant.

Results.

The results demonstrated significant differences among the three groups:

• **Accuracy:** CAD/CAM group – 95%, 3D printing group – 93%, while conventional dentures showed only 78%.

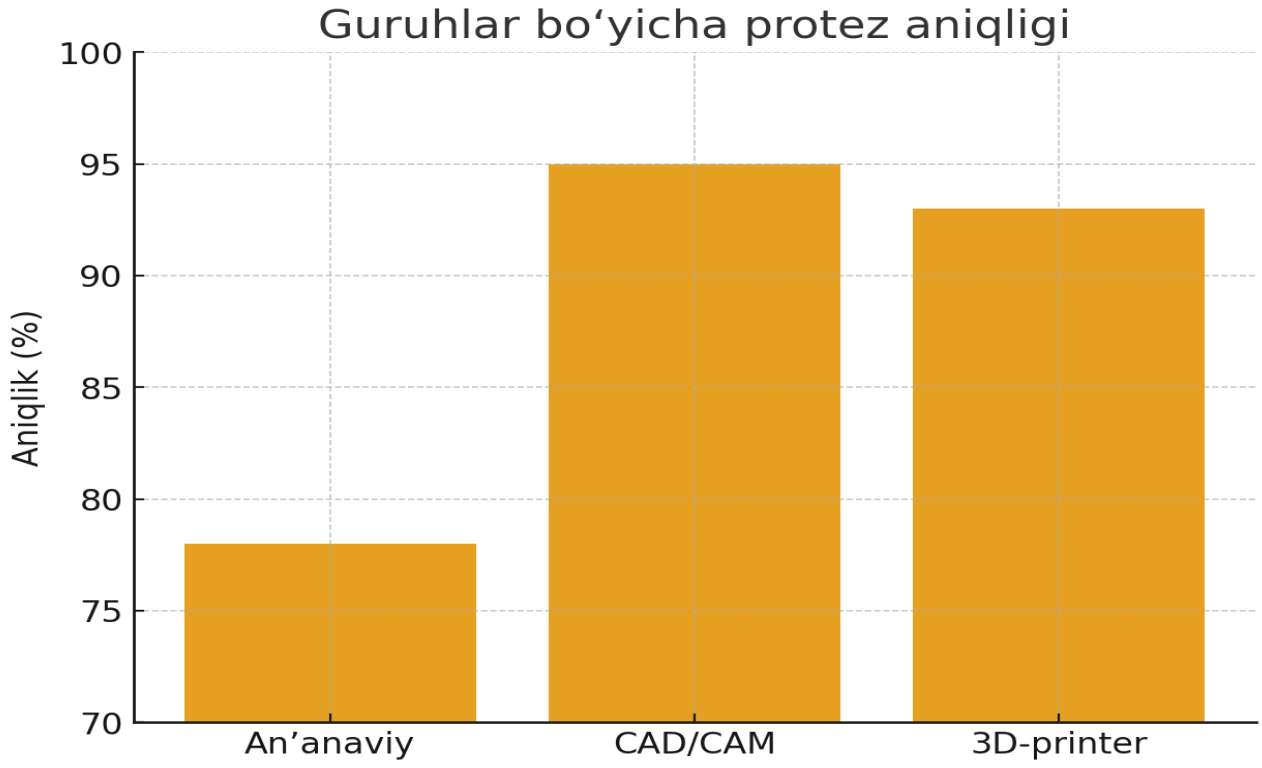

Figure 1.

• **Masticatory efficiency:** CAD/CAM dentures showed 30% higher performance compared to conventional methods, while 3D-printed dentures demonstrated a 25% improvement.

• **Patient satisfaction:** On average, CAD/CAM dentures scored **4.7/5**, 3D-printed dentures **4.5/5**, whereas conventional dentures scored only **3.8/5**.

• **Clinical time:** The fabrication and delivery process was reduced by **40%** with CAD/CAM technology and by **50%** with the 3D printing method.

📊 **Charts and Diagrams:**

1. **Accuracy comparison among groups** – clearly demonstrates the superiority of CAD/CAM and 3D printing technologies.

2. **Levels of satisfaction** – patient satisfaction was notably higher, especially in cases where CAD/CAM technology was applied.

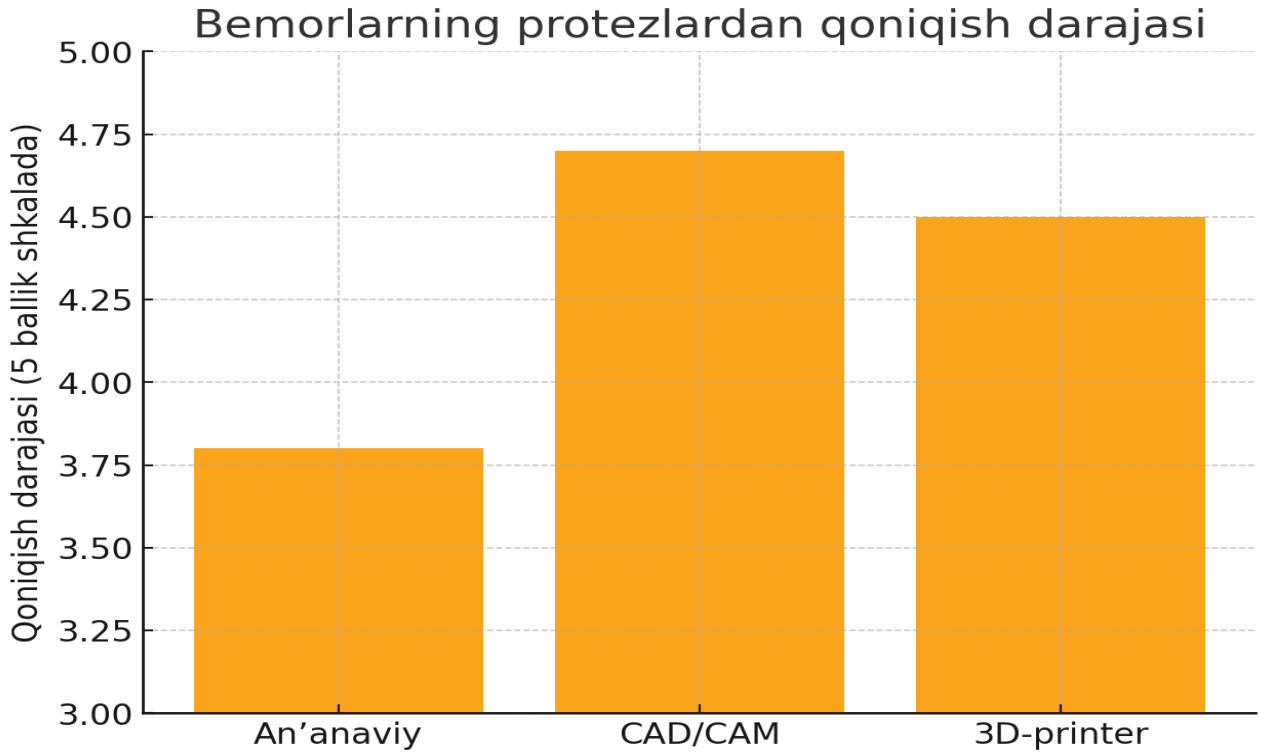

Figure 2.

Discussion.

The results of this study demonstrated that in the treatment of complete edentulism, **CAD/CAM and 3D-printing technologies** provide significant advantages over conventional acrylic-based dentures. Firstly, the higher level of accuracy and adaptability (95% and 93%) ensured a precise fit of the prostheses to the alveolar ridge surface. This not only improved mechanical stability within the oral cavity but also reduced the risk of mucosal trauma.

In terms of **masticatory efficiency**, a distinct superiority was also observed. CAD/CAM dentures showed 30% higher muscle activity, while 3D-printed dentures demonstrated a 25% increase compared to traditional ones. These findings are consistent with international studies, such as those by Poticny and Conrad (2020), which confirmed that CAD/CAM dentures enhance muscle activity and occlusal stability compared to conventional methods [8].

Patient satisfaction also favored digital technologies. On the VAS scale, CAD/CAM dentures averaged 4.7 points, 3D-printed dentures 4.5 points, while conventional dentures

were limited to 3.8 points. These results reflect the direct impact of digital technologies on patients' quality of life through improved esthetics, functional comfort, and individualized design options.

Another key advantage lies in the **reduction of clinical time**. CAD/CAM reduced production time by 40%, while 3D printing reduced it by 50%. This benefits not only patients but also optimizes clinical workflow by reducing unnecessary organizational resources. In international practice, this advantage is closely associated with the concept of **"chairside dentistry"**, which emphasizes rapid diagnosis and treatment [9].

Nevertheless, some **limitations** remain. CAD/CAM systems, while providing high mechanical strength and durability, require higher initial investments and maintenance costs. 3D printing, on the other hand, excels in production speed and design flexibility but is sometimes limited by the long-term stability and durability of available biomaterials [10]. Therefore, the most practical approach in clinical dentistry may be a **combined or adaptive use of both technologies**.

Overall, the results of this study further confirm that the **concept of digital dentistry** is a highly effective and promising direction for complete denture prosthodontics.

Conclusion.

1. In complete edentulism, digital technologies (CAD/CAM and 3D-printing) significantly improve patients' quality of life, enhancing masticatory efficiency, esthetic outcomes, and psychological adaptation.

2. CAD/CAM dentures are characterized by superior accuracy, mechanical durability, and long-term stability, making them a clinically reliable solution.

3. 3D-printing technology provides advantages in terms of production speed, individualized design options, and reduced clinical time.

4. In the context of Uzbekistan, considering economic and technological limitations, a **combined approach (CAD/CAM + 3D printing)** represents the most effective and practical pathway.

5. In the future, broader clinical implementation of these technologies, improvement of biomaterials, and cost optimization may further enhance the quality of prosthodontic care.

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