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13.00.02 Ta'lim va tarbiya nazariyasi va metodikasi (sohalar bo'yicha)
13.00.03 Maxsus pedagogika
13.00.04 Jismoniy tarbiya va sport mashg'ulotlari nazariyasi va metodikasi
13.00.05 Kasb-hunar ta'limi nazariyasi va metodikasi
13.00.06 Elektron ta'lim nazariyasi va metodikasi (ta'lim sohalari va bosqichlari bo'yicha)
13.00.07 Ta'limda menejment
13.00.08 Maktabgacha ta'lim va tarbiya nazariyasi va metodikasi
13.00.09 Ijtimoiy pedagogika
07.00.00 Tarix fanlari
19.00.00 Psixologiya fanlari
01.00.00 Fizika-matematika fanlari
02.00.00 Kimyo fanlari
03.00.00 Biologiya fanlari
09.00.00 Falsafa fanlari
10.00.00 Filologiya fanlari
11.00.00 Geografiya fanlari

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MUNDARIJA CONTENTS СОДЕРЖАНИЕ

MUNDARIJA

Tinglovchilarga axloqiy-estetik tarbiya berishda notiqlik madaniyatini shakllantirishning samaradorlik ko'rsatkichlari 10
Fazliddin Abdunabiyevich Abdurazaqov

Professor-o'qituvchilarning ilmiy-pedagogik salohiyatini xalqaro mezonlar asosida rivojlantirish yo'llari 15
Maxmudov Qudratbek Shavkat o'g'li

Orfografik kompetensiyaning mohiyati va boshlang'ich sinflarda shakllanish bosqichlari 21
Abduvaliyeva Nodira Alisherovna, Mo'minjonova Gulnoraxon Abdupatto qizi

Tabiiy fanlarni o'qitishda uch o'lchamli vizualizatsiyalarning boshlang'ich ta'limdagi ahamiyati 25
Nabijonova Feruza Valijon qizi

Loyiha texnologiyasi asosida bo'lajak o'qituvchilarda ijtimoiy tashabbuskorlikni rivojlantirish mazmuni 28
O'rinova Nilufar Muxammadovna

Sinfdan tashqari o'qish darslarida badiiy asar bilan ishlashning kompetensiyaviy yondashuv asosidagi metodikasi 32
Qilichova Billura Yorqinxuja qizi, Homidov H. K.

Kasbiy-kommunikativ madaniyat fenomenining pedagogik talqini va rivojlanish tendensiyalari 37
Tashpulatova Nodira Olimjon qizi

Tabiiy fanlarni o'qitishda kompetensiyaviy yondashuv 41
Umbarova Nasiba Xolboy qizi

Xorijiy tillarni o'rganishda shaxs nutqining shakllanishida psixolingvistikaning ahamiyati 44
Ahmedov Shavkat Asadilloevich, Ataboev Navruz Ilhombek o'g'li

Boshlang'ich sinf o'quvchilarida matnni tushunish va tahlil qilish ko'nikmalarini rivojlantirish metodikasi (PIRLS dasturi misolida) 47
Abduraxmanova Charos Burxanovna

Lesson Planning in English Language Teaching at Technical Universities 51
Aitbaeva Nursuliu Tairbekovna

Lingvistik intellekt asosida individual o'qitish yondashuvining samaradorligi 55
Allanazarova Sadoqat Azimovna

Xorij tadqiqotlarida zamonaviy oila transformatsiyasida farzandlar taraqqiyotining ijtimoiy-psixologik asoslari 59
Bo'riyeva Mahbuba Shavkatovna

Теоретико-методологические подходы к изучению эмоциональных концептов в литературе: (на материале английских и немецких фразеологизмов) 63
Сайёра Улашевна Тагаева, Азиза Анкаевна Уразкулова

The Importance of Forming a Schedule for High School Students 67
D. T. Atabayeva, X. I. Abduraymova

Milliy cholg'u ansambllari orqali o'quvchilar musiqiy dunyoqarashini shakllantirish 70
Dadamirzayeva Gulshanoy To'lanjon qizi

Umumiy o'rta ta'lim muassasalarida ma'naviy-axloqiy tarbiyaga yondashuvning texnologik xususiyatlari 75
Jumanov Sherzod Saloyevich

Adabiyot darsliklari uchun yangi o'zbek adabiyoti namunalarini saralashning ilmiy-metodik asoslari 78
Musaboyeva Zulfira Iqboljon qizi

Maktab geometriyasida ko'pyoqlilar mavzusini o'rganishning innovatsion usullari 83
Pirlepesov Umrbek Baxtiyor o'g'li

Generativ AI vositalarining mustaqil ta'lim jarayonidagi didaktik funksiyalari 86
Qahramonova Xumora Qahramonovna

O'quvchi-sportchilar uchun individual mashg'ulot yuklamalarini avtomatik rejalashtirish va optimallashtirish imkoniyatini yaratish ahamiyati 91
Qosimov Faxriddin Jo'raqulovich

Когнитивный диссонанс как социально-психологический феномен в контексте высшего образования: теоретический анализ 95
Мансурова Гульмира Рафаэловна

Регуляторный произвол или необходимый порядок? Влияние новых регуляторных механизмов на свободу расследовательской журналистики 101
Рауфова Озода

Qizlar tarbiyasida mahalla–oila–maktab hamkorligi mexanizmlari 105
Choriyeva Dildora Ismat qizi

Oliy ta'lim muassasalarida jismoniy tarbiya mashg'ulotlarini individuallashtirishning samaradorligi: kompetensiyaviy yondashuv asosida 109
Tangriyev Abdukarim Tovashevich

O'qish savodxonligi darslarida matn bilan ishlash orqali o'quvchilarda muammoli vaziyatlarni hal etish ko'nikmalarini rivojlantirish texnologiyasi 114
Boymurodova Nodirabegim Bahodir qizi

Raqamli transformatsiya sharoitida STEAM ta'limi orqali talabalarda tanqidiy fikrlash kompetensiyasini shakllantirish 120
Kozimova Mehriniso Akbarali qizi

Oliy ta'limda kvest texnologiyasi yordamida fizika fanining murakkab tushunchalarini o'zlashtirish samaradorligini oshirish metodikasi 125
O'rinboyeva Kumushoy Sultonbek qizi

Tasvirlarga raqamli ishlov berish texnologiyalari va ularning amaliy qo'llanilishi 129
Sharipov Nodir Botir o'g'li

Management of Medical Emergencies in Outpatient Dental Clinics 133
Adurazzoqov Kamoliddin, Umarov Maruf, Buzrukzoda Javohir

Psixologik farovonlikning asosiy komponentlari, ta'sir qiluvchi omillar va zamonaviy baholash usullari 138
Aliyev Samariddin Murotali o'g'li

Boshlang'ich sinf o'quvchilarining nutqiy kompetensiyasini rivojlantirishning ilmiy-nazariy asoslari 142
Boymurodova Sadoqat Istam qizi

O'zbekiston Respublikasi ta'lim tizimi 146
Gadoymurodova Kamola Sunnatulloyevna

Oilada bola tarbiyasining ahamiyati va uning shaxs kamolotiga ta'siri 151
Galdiyeva Mehribon Durdiyevna, Oilimova Mushtariy Xaydarali qizi

Art-pedagogika vositasida boshlang'ich sinf o'quvchilarida estetik dunyoqarashni shakllantirishning pedagogik ahamiyati 154
Gulboyev Akbar Tuxytayevich

Boshlang'ich sinf o'quvchilarida ma'naviy tadbirlar orqali vatanparvarlik tuyg'usini shakllantirish 158
Homidov Husniddin Kupaysinovich, Yusupova Gulzor Yunusjon qizi, Norbekova Sevinch Musurmon qizi

Bone-Grafting Materials in Oral Surgery: Classification, Biological Properties, and Clinical Application 161
Jumaqulova Mashhura Alishevrovna, Buzrukzoda Javohir Davronovich

Mediatsiya va o'qib tushunish kompotensiyasi o'rtasidagi o'zaro aloqadorlik 166
Karimova Dilyoraxon Raximjon qizi

Using STEM Technologies to Foster Rational Thinking in the Dentistry 169
Khonimqulov Javlon, Burkhonova Zarafruz

Boshlang'ich sinf o'quvchilarini montessori metodikasi vositasida til o'rganish ko'nikmalarini shakllantirish usullari modeli 173
Mahbuba Yusupova Rustam qizi

Maktabgacha yoshdagi bolalarda tayanch kompetensiyalarni integrativ yondashuv asosida shakllantirish metodikasining samaradorligi 177
Nasimova N. Q.

Analysis of Scanning Techniques Used in Orthodontic Dentistry 182
Nasrullayev Javlonbek Tal'atonovich, Rahimberdiyev Rustam Abdunosirovich

Zamonaviylik - ta'lim konsepsiyasida asosiy mezon sifatida 187
Ochilova Gulnoza Odilovna

MUNDARIJA СОДЕРЖАНИЕ CONTENTS

O‘qish savodxonligi darslarida xalq og‘zaki ijodidan foydalanish metodikasi 191
Qahhorova Sojida Bahodir qizi, Zokirov Javoxir G‘aybullo o‘g‘li

Diqqat va xotira jarayonlarida raqamli texnologiyalarning roli 196
Salomova Nargiza Sattorovna

Talabalarda kasbiy refleksiya rivojlanishiga ta’sir etuvchi psixologik omillarning empirik tahlili 200
Shukurova Nargiza Ikramovna

Gimnastikachi qizlarda egiluvchanlik jismoniy sifatini rivojlantirish jarayonida shikastlanishlarning oldini olish 205
Sultanova Musharafxon Xudoyqul qizi

Maktabgacha katta yoshdagi bolalarda ekologik bilimlarni raqamli texnologiyalar yordamida rivojlantirish ... 210
Sayfetdinova Dildora Ikramitdinovna

Maktabgacha yoshdagi bolalarning rivojlanishida shaxsga yo‘naltirilgan texnologiyalardan foydalanishning o‘ziga xos xususiyatlari, imkoniyatlari va yo‘nalishlari 216
Uralova Nurxon Maxadovna

Naqshbandiya qadriyatlarini bo‘lg‘usi o‘qituvchi shaxsini shakllantirishdagi o‘rni 220
Xalmuxamedova Maxbuba Aslanovna

Boshlang‘ich ta’limda raqamli texnologiyalardan foydalanishning ilmiy-metodik asoslari 223
Xo‘jamberdiyeva Maftuna Norqobilovna, Sanaqulova Sevinch Baxtiyor qizi

Developing Logical Thinking via the Use of STEM Technology 226
Yarmuhammedov Nabijon Navruzovich, Burkhonova Zarafruz

Jismoniy tarbiya darslarida innovatsion metodlardan foydalanishning ahamiyati 229
Yo‘ldoshboyeva Zulfiya Ravshan qizi, Jumayev Abdilxakim Turdiyevich

Значение предмета физического воспитания и спортивной метрологии в физическом воспитании молодежи 233
Маматкулов Равшанжон Солижонович

Аксиологические аспекты диалога культур в романе Сухбата Афлатуни “Рай Земной” 237
Чернова Татьяна Алексеевна, Худойназаров Сардорбек

ANALYSIS OF SCANNING TECHNIQUES USED IN ORTHODONTIC DENTISTRY

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Abstract: The development of dental scanning technologies has significantly expanded the possibilities for long-term data storage. Rapid advances in digital technologies have enabled the widespread use of both intraoral and extraoral scanners. These devices differ in terms of scanning accuracy and reliability. Therefore, selecting an affordable and high-quality scanner has become a critical issue in modern prosthetic dentistry. The relevance of this study is supported by an analysis of the available scientific literature.

The aim of this study was to determine the current state of scanner selection in prosthetic dentistry and evaluate its practical significance. A review of scientific publications from the last 30 years was conducted using databases such as PubMed, CyberLeninka, eLIBRARY, and catalogs of medical dissertations and abstracts. The selection process was based on keyword searches followed by an analysis of article titles, abstracts, and full texts. Particular attention was given to studies describing the development of CAD/CAM systems, comparing modern digital systems, and assessing their accuracy relative to conventional prosthetic techniques.

A total of 11 scientific sources were identified, including two literature reviews and one meta-analysis. The findings indicate that scanning technologies play a crucial role in contemporary prosthetic dentistry. However, identifying a universal "gold standard" among existing CAD/CAM systems remains a challenge due to variations in accuracy and reliability. Furthermore, economic efficiency and practical applicability continue to be important evaluation criteria.

In conclusion, there is a growing need for the development of new scanning technologies that provide high accuracy and reliability while minimizing the cost and time required for professional training.

Key words: modern dentistry, accuracy, reliability, digital impressions, CAD/CAM technologies.

Annotatsiya: Uzoq muddatli ma'lumotlarni saqlash imkoniyati stomatologik skanerlash texnologiyalarining rivojlanishi bilan sezilarli darajada kengaydi. Zamonaviy texnologiyalarning jadal taraqqiyoti intraoral (og'iz ichi) va ekstraoral (og'izdan tashqari) skanerlardan samarali foydalanish imkonini yaratdi. Mazkur qurilmalar skanerlash aniqligi va ishonchliligi jihatidan bir-biridan farq qiladi. Shu sababli zamonaviy ortopedik stomatologiyada hamyonbop va yuqori sifatli skanerni tanlash muhim ahamiyat kasb etadi. Tadqiqotning dolzarbligi mavzuga oid ilmiy adabiyotlar tahlili bilan asoslanadi.

Tadqiqotning maqsadi ortopedik stomatologiyada skaner tanlash muammosining hozirgi holatini va uning amaliy ahamiyatini aniqlashdan iborat. Tadqiqot jarayonida so'nggi 30 yil davomida chop etilgan ilmiy manbalar tahlil qilindi. Maqolalar PubMed, CyberLeninka, eLIBRARY ma'lumotlar bazalari hamda tibbiyot dissertatsiyalari va avtoreferatlari kataloglaridan izlab topildi. Materiallarni saralashda kalit so'zlardan foydalanildi, maqolalarning nomlari, annotatsiyalari va to'liq matnlari o'rganildi. Asosiy e'tibor CAD/CAM tizimlarining rivojlanishi, zamonaviy CAD/CAM tizimlarini taqqoslash va ularning aniqligini an'anaviy protezlash usullari bilan qiyosiy baholashga qaratildi.

Tahlil natijasida 11 ta ilmiy manba, jumladan, 2 ta adabiyotlar sharhi va 1 ta meta-tahlil aniqlandi. Natijalar shuni ko'rsatdiki, skanerlash texnologiyalari ortopedik stomatologiyada muhim o'rin tutadi. Shu bilan birga, mavjud CAD/CAM tizimlari orasida aniqlik va ishonchlilik bo'yicha yagona "oltin standart"ni aniqlash hanuz murakkab masala bo'lib qolmoqda. Bundan tashqari, CAD/CAM texnologiyalarining iqtisodiy samaradorligi va amaliy foydaliligi ham muhim mezon sifatida baholanmoqda.

Xulosa qilib aytganda, zamonaviy stomatologiya uchun yuqori aniqlik va ishonchlilikka ega, shu bilan birga qimmat yoki uzoq muddatli tayyorgarlikni talab qilmaydigan yangi skanerlash texnologiyalarini ishlab chiqish dolzarb vazifa hisoblanadi.

Kalit so'zlar: zamonaviy stomatologiya, aniqlik, ishonchlilik, raqamli otisklar, CAD/CAM texnologiyalari.

Аннотация: Развитие технологий стоматологического сканирования значительно расширило возможности долговременного хранения данных. Стремительное совершенствование цифровых технологий позволило широко использовать как интраоральные, так и экстраоральные сканеры. Данные устройства различаются по показателям точности и надежности сканирования. В связи с этим выбор доступного и высококачественного сканера приобретает особую значимость в современной ортопедической стоматологии. Актуальность исследования подтверждается анализом научной литературы по данной проблематике.

Цель исследования заключается в определении современного состояния проблемы выбора сканеров в ортопедической стоматологии и оценке их практической значимости. В ходе исследования был проведен анализ научных публикаций за последние 30 лет. Поиск материалов осуществлялся в базах данных PubMed, CyberLeninka, eLIBRARY, а также в каталогах медицинских диссертаций и авторефератов. Отбор публикаций проводился по ключевым словам с последующим анализом названий, аннотаций и полных текстов статей. Основное внимание уделялось работам, посвящённым развитию CAD/CAM-систем, сравнению современных цифровых систем и оценке их точности относительно традиционных методов протезирования.

В результате анализа было выявлено 11 научных источников, включая 2 обзора литературы и 1 метаанализ. Полученные данные свидетельствуют о том, что технологии сканирования занимают важное место в современной ортопедической стоматологии. Вместе с тем поиск единого "золотого стандарта" среди существующих CAD/CAM-систем по-прежнему остаётся актуальной задачей. Кроме того, важными критериями оценки выступают экономическая эффективность и практическая полезность данных технологий.

Таким образом, для современной стоматологии актуальным направлением является разработка новых методов сканирования, обеспечивающих высокую точность и надежность при минимальных затратах времени и ресурсов на обучение специалистов.

Ключевые слова: современная стоматология, точность, надежность, цифровые оттиски, CAD/CAM-технологии.

INTRODUCTION

In the modern world, computer technologies are increasingly being used in medicine to accelerate diagnostic processes, improve treatment effectiveness, monitor outcomes, and facilitate disease prevention planning. Over the past 30 years, prosthodontics has undergone significant development owing to the introduction of various scanning systems, standalone scanners, and 3D-printing technologies. Numerous open- and closed-architecture scanning systems are currently used for these purposes. In addition, both intraoral and in vitro scanning techniques are available [1].

These technologies enable prosthodontists and dental technicians to reduce working time considerably, thereby lowering operational and transportation costs. Some scanning systems also require the application of specialized gypsum powders or scanning sprays to ensure accurate recognition of the scanned object by the device's camera. However, the high cost of scanners remains a major challenge. Furthermore, most closed-system solutions supplied by foreign manufacturers require the purchase of an entire product ecosystem to ensure full functionality [2, 3].

The aim of this review was to determine the current state of this issue and evaluate the significance of scanner selection in prosthodontic practice.

LITERATURE REVIEW

Over the last three decades, prosthetic dentistry has undergone a fundamental transformation through the integration of Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM) technologies. Initially developed to improve chairside procedures, digital dentistry has evolved into an essential standard for diagnosis, treatment planning, and the fabrication of highly precise prosthetic restorations. The capabilities of both laboratory (in vitro) and intraoral scanning (IOS) devices are central to the contemporary digital workflow, effectively bridging the gap between clinical preparation and automated manufacturing.

Historical Development and the Legacy of Early CAD/CAM Systems

The introduction of the groundbreaking Chairside Economical Restoration of Esthetic Ceramics (CEREC) system in the mid-1980s established the clinical foundation for digital impressions. Early generations of CEREC technology enabled the scanning, design, and milling of single-tooth ceramic restorations, including veneers, inlays, and crowns, during a single clinical appointment.

Long-term retrospective studies and meta-analyses have demonstrated that single-tooth restorations fabricated using early CAD/CAM systems achieved clinical survival rates comparable to those of conventionally manufactured gold and metal-ceramic restorations. This milestone validated the clinical applicability of digital data acquisition and stimulated continuous improvements in both hardware and software, ultimately leading to modern high-resolution optical scanners and multi-axis milling systems.

Closed versus Open Architectural Systems: A Paradigm Shift

The software architecture and data management infrastructure of dental scanning systems significantly influence their clinical adoption and commercial success. Historically, proprietary closed-system platforms dominated the market. These systems required clinicians to purchase a complete ecosystem consisting of an intraoral scanner, dedicated design software, and proprietary milling equipment from a single manufacturer.

Although closed systems provided a highly standardized and predictable workflow, they limited clinical flexibility, created substantial financial barriers, and restricted users to specific product lines. In contrast, the emergence of open-system scanning technologies has transformed digital dental workflows. Open systems export data in universally compatible formats such as Standard Tessellation Language (STL) and Polygon File Format (PLY). This interoperability allows prosthodontists to share high-resolution three-dimensional datasets with independent CAD/CAM laboratories and third-party manufacturing centers worldwide, thereby eliminating dependence on proprietary supply chains and significantly expanding clinical possibilities.

Accuracy of Digital Scans: Trueness and Precision

As digital impressions increasingly replace conventional elastomeric impression materials, such as polyvinyl siloxane and polyether, ensuring the geometric accuracy of virtual models has become essential for achieving optimal marginal fit and long-term prosthetic success. In dental metrology, scanning accuracy is defined by two key parameters:

1. **Trueness** - the ability of a scanner to reproduce oral structures with minimal dimensional distortion and maximum fidelity to the actual anatomy.
2. **Precision** - the degree of consistency and repeatability achieved when repeated scans are performed under identical clinical conditions.

Modern intraoral scanners exhibit high levels of trueness and precision for single crowns and short-span fixed partial dentures. However, challenges remain when scanning complete dental arches due to cumulative stitching errors generated during the digital assembly of sequential images. Earlier optical scanning technologies also required the application of homogeneous titanium dioxide powder to reduce reflective glare from saliva and tooth surfaces.

Contemporary open-system scanners have largely overcome these limitations through advanced technologies such as active wavefront sampling and high-definition video fringe projection, which enable powder-free surface acquisition. Nevertheless, capturing deep and narrow anatomical structures, such as post-space preparations used in endodontic post-and-core restorations, remains technically challenging because scanner accuracy decreases with increasing depth.

Economic Barriers and Emerging Technological Directions

Despite the substantial advantages of CAD/CAM integration-including reduced treatment time, lower transportation costs, elimination of gypsum model storage, and enhanced patient comfort-economic and educational barriers continue to limit widespread adoption. High-end scanners and five-axis milling units capable of submillimeter accuracy require significant initial investment. In addition, successful implementation demands highly trained personnel skilled in digital design, virtual articulation, and anatomical modeling.

At the same time, digital dentistry continues to evolve rapidly. Three-dimensional printing, or additive manufacturing, has become routine for producing surgical guides, provisional restorations, and polymer-based frameworks, although its application in definitive ceramic restorations remains under active development. Future innovations are increasingly focused on non-invasive, fluid-independent ultrasonic impression techniques. These technologies employ ultrasonic waves capable of penetrating subgingival areas without soft-tissue retraction, potentially overcoming the optical limitations associated with current intraoral scanning systems.

MATERIALS AND METHODS

According to the literature reviewed, the differences among scanning systems are evident not only in their names but also in their software capabilities, scanning procedures, and methods of virtual model fabrication [8, 9]. Recently, domestic scanners such as VT Dental have been introduced in Russia. Open-type scanners are capable of scanning both models and impressions without the need for special powders and can generate optical images in the standard STL digital format, which can be transferred to any CAD/CAM laboratory. Consequently, the question of scanning accuracy and its impact on treatment outcomes becomes particularly important [6].

Two major advantages of CAD/CAM technology are the creation of digital model images and the use of virtual articulators. However, the implementation of these technologies remains costly and requires highly qual-

ified personnel. Software applications are currently being developed for a wide range of prosthetic treatments, including complete and partial removable dentures. Five-axis milling machines are considered the most effective solution for achieving high manufacturing accuracy in dental restorations.

Three-dimensional (3D) printing technology is already used in dentistry; however, its application is currently limited primarily to polymer-based materials and does not yet fully include ceramic restorations. In the future, conventional visual impressions may be replaced by ultrasonic impressions generated using ultrasonic waves capable of penetrating gingival tissues non-invasively and independently of fluid conditions. For many practicing prosthodontists, one of the most promising developments is the use of a digital camera connected to a computer system with dedicated software, allowing images to be transmitted directly to the dental laboratory [4].

The current state of commercially available dental CAD/CAM systems worldwide is primarily assessed through their effectiveness in manufacturing ceramic veneers, inlays, and crowns. Despite the considerable potential of CAD/CAM technology, its current clinical application remains largely limited to fixed prosthetic restorations. The further development of CAD/CAM technology for advanced prosthodontic applications is expected to contribute significantly to maintaining long-term oral health in present and future generations [7].

The relatively recent application of CAD/CAM technology in prosthetic dentistry can be divided into three principal categories:

1. **3D Reconstruction** - the analysis, modeling, planning, and evaluation of orthopedic procedures using imaging techniques such as CT, MRI, or radiographic imaging without the need for immediate surgical intervention.
2. **Model Production** - the fabrication of plastic or wax models that provide surgeons with a comprehensive understanding of complex craniofacial bone conditions and serve as templates for allograft preparation.

Optimization and Improvement - the production of geometrically accurate implants, including both custom-made and standardized designs.

Beyond clinical practice, CAD/CAM technologies also serve as valuable tools for professional education and training. Although these technologies currently may be perceived as expensive, complex, and not yet widely accessible, ongoing technological advancements are expected to make them more practical, user-friendly, and cost-effective in the future [6].

Traditional impression-taking procedures using expensive impression materials and gypsum casts present considerable limitations for the fabrication of high-precision prostheses because they do not completely eliminate distortion and may result in information loss during storage. Intraoral scanners offer an effective solution to these challenges. These devices generate three-dimensional digital models that facilitate data storage and computerized processing. Accuracy is evaluated according to two parameters: precision, defined as the consistency of repeated scans under identical conditions, and trueness, defined as the degree to which a digital model reproduces the original dentition. Previous studies have demonstrated a high level of agreement between digital scan data and conventional gypsum models, indicating excellent accuracy [5].

RESULTS

A comprehensive review and meta-analysis of original studies published between 1985 and 2007 and indexed in Medline/PubMed and Embase databases were conducted. The collected data were independently evaluated by two examiners. The findings demonstrated that the long-term survival rates of single-tooth restorations fabricated using the Cerec 1, Cerec 2, and Celay systems were comparable to accepted clinical standards. However, during the period covered by the review, insufficient long-term evidence was available regarding more contemporary CAD/CAM systems [11].

CONCLUSION

The reviewed literature indicates that dental scanning technologies, together with issues related to accuracy, reliability, and cost-effectiveness, remain highly relevant topics in modern dentistry. The development of a novel scanning technology that is affordable, user-friendly, highly accurate, and reliable is essential for the continued advancement of contemporary dental practice.

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13.00.00 Pedagogika fanlari
13.00.01 Pedagogika nazariyasi. Pedagogik ta’limotlar tarixi
13.00.02 Ta’lim va tarbiya nazariyasi va metodikasi (sohalar bo‘yicha)
13.00.03 Maxsus pedagogika
13.00.04 Jismoniy tarbiya va sport mashg‘ulotlari nazariyasi va metodikasi
13.00.05 Kasb-hunar ta’limi nazariyasi va metodikasi
13.00.06 Elektron ta’lim nazariyasi va metodikasi (ta’lim sohalari va bosqichlari bo‘yicha)
13.00.07 Ta’limda menejment
13.00.08 Maktabgacha ta’lim va tarbiya nazariyasi va metodikasi
13.00.09 Ijtimoiy pedagogika
07.00.00 Tarix fanlari
19.00.00 Psixologiya fanlari
01.00.00 Fizika-matematika fanlari
02.00.00 Kimyo fanlari
03.00.00 Biologiya fanlari
09.00.00 Falsafa fanlari
10.00.00 Filologiya fanlari
11.00.00 Geografiya fanlari

MAKTABGACHA VA MAKTAB TA'LIMI

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Ingliz tili muharriri: Murod Xoliyorov
Musahhih: Alibek Zokirov
Sahifalovchi va dizayner: Iskandar Islomov

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O'zbekiston Respublikasi Prezidenti Adminstratsiyasi huzuridagi
Axborot va ommaviy kommunikatsiyalar agentligi tomonidan
№C–5669363 reyestr raqami tartibi bo'yicha ro'yxatdan o'tkazilgan.
Litsenziya raqami: № 136361.

Manzilimiz: Toshkent shahar, Yunusobod tumani
19-mavze, 17-uy.