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CONTENTS

BRIEF FEEDBACK ON “AGAT CREDIT” MICROFINANCE ORGANIZATION BASED ON THE REPORT OF “KAPDEPO” INVESTMENT COMPANY: CAVEATS FOR LENDERS (BONDHOLDERS)	16
Abduganiev Abdulaziz Alisher ugli	
IMPLEMENTATION OF EU BEST AGRICULTURAL TRADE PRACTICES IN UZBEKISTAN.....	20
Khulkar Karimova Rakhmanali qizi	
THE ROLE OF FOREIGN DIRECT INVESTMENT IN INCREASING SERVICE EXPORTS OF UZBEKISTAN	26
Jamshid Mirzakhmedov	
THE ROLE AND IMPORTANCE OF FINANCIAL MARKETS IN ECONOMIC DEVELOPMENT	30
Baymanova Mavlyuda Djuraevna, Abdullaeva Shohista, Ubaydullaeva Gulchehra Erkabaevna	
КЛИНИЧЕСКАЯ ОЦЕНКА СОСТОЯНИЯ МЕСТНЫХ ИММУННЫХ МЕХАНИЗМОВ ПОЛОСТИ РТА У ПАЦИЕНТОВ НА ЭТАПАХ ОРТОДОНТИЧЕСКОГО ЛЕЧЕНИЯ	36
Рахимбердыев Рустам Абдунасирович, Сайфулаева Азиза Анваровна	
INTEGRATING AI-BASED CUSTOMER ANALYTICS INTO INNOVATIVE RETAIL MARKETING STRATEGIES	40
Ostonaqulova Gulsaraxon Muhammadyoqub qizi	
FINANCIAL STIMULATION OF INNOVATIVE ACTIVITIES OF ENTERPRISES THROUGH INVESTMENTS	48
Bahriddinov Nodirbek Zamirdinovich	
DIGITAL DENTISTRY: LITERATURE REVIEW	52
Tursunov Begzod Sherzodovich, Zokirova Nodira Sobitovna	
THE LATEST ADHESIVE TECHNOLOGIES IN DENTISTRY	56
Rahimberdiyev Rustam Abdunasirovich, Chinibayeva Ibagul Sarsenbayevna	
ENSURING THE ACCEPTABILITY OF QUANTITATIVE AND QUALITATIVE INDICATORS IN THE EFFECTIVE ORGANIZATION OF HOUSING FUNDS IN KHOREZM	61
Otajonov Tohirjon Khojanazar o'g'li	
WAYS TO IMPROVE CUSTOMS ADMINISTRATION IN THE REPUBLIC OF UZBEKISTAN.....	67
Usmonova Dilfuza Ilhomovna	
CLINICAL ASSESSMENT OF THE STATE OF LOCAL IMMUNE MECHANISMS OF THE ORAL CAVITY IN PATIENTS AT DIFFERENT STAGES OF ORTHODONTIC TREATMENT	72
Rakhimberdiyev Rustam Abdunasirovich, Saifulaeva Aziza Anvarovna	
IMPROVING THE ALGORITHM FOR CONTROLLING THE CUSTOMS TRANSIT INFORMATION SYSTEM E-TRANSIT OF THE REPUBLIC OF UZBEKISTAN	76
Musayeva Shoirazimovna	
DEVELOPMENT TRENDS OF THE AUTOMOTIVE BUSINESS IN UZBEKISTAN	82
Saidov Dilshodbek Razzakovich	
INTEGRATION OF MARKETING STRATEGIES IN RETAIL TRADE ACTIVITIES.....	87
Akramov Toxir Abdiraxmanovich	
CHALLENGES OF ADOPTING ISLAMIC FINANCE WITHIN CONVENTIONAL BANKING SYSTEMS	91
Safarov Shuhrat Ismatovich	
CRM SYSTEMS AND THEIR IMPACT ON THE RESULTS OF MARKETING STRATEGY IN DISTRIBUTION COMPANIES	95
Jamoliddinov Fakhriyor Shodiyor o'g'li	
LEXICAL-SEMANTIC ARCHITECTURE OF MODERN WORDNET SYSTEMS	101
Aynura Axmedova	
METHODOLOGY FOR ANALYZING THE EFFECTIVENESS OF INNOVATIVE PROCESSES AT ENTERPRISES.....	108
Kurbanova Shakhnoza Yuldashbayevna	
COMPANY VALUATION IN MERGERS AND ACQUISITIONS: A STRATEGIC AND GOVERNANCE-BASED APPROACH	113
Lee Illarion Georgievich	

A REVIEW OF THE LITERATURE ON CAD/CAM TECHNOLOGIES IN DENTAL ECTOPROSTHETICS.....	118
Tursunov Begzod Sherzodovich, Hazratqulov Asrbek Ulugbek ugli	
TRENDS AND DIFFICULTIES IN THE INTEGRATION OF DIGITAL TECHNOLOGIES IN ORTHOPEDIC DENTISTRY.....	123
Khojimurodov Burkxon Ravshanovich	
PRIORITY DIRECTIONS FOR IMPROVING THE MECHANISM OF ENHANCING THE ECONOMIC SECURITY LEVEL OF THE KASHKADARYA REGION.....	127
Tuyev Abdurahmon Yusubopvich	
THE ROLE OF PSYCHOPHYSIOLOGICAL TRAINING OF DRIVERS IN REDUCING ROAD TRAFFIC ACCIDENTS.....	132
Uralbayev Anvar Ubaydullayevich	
THE ROLE OF SUSTAINABLE DEVELOPMENT PRINCIPLES IN DEVELOPING GREEN MARKETING STRATEGIES FOR ENTERPRISES.....	135
Sapayev Akhmad Durdibayevich	
MANAGEMENT MODEL OF INFORMATION RESOURCES IN SMALL BUSINESS ENTITIES AND ITS IMPACT ON ECONOMIC EFFICIENCY.....	140
Yo'ldoshev Nodirbek Ne'matjon o'g'li	
WAYS TO DEVELOP THE INVESTMENT ACTIVITY OF COMMERCIAL BANKS THROUGH THE SECURITIES MARKET.....	145
Yuldashev Fozil Turapovich	
INTERNATIONAL EXPERIENCE IN THE USE OF CROSS-BORDER REMITTANCES IN THE DEVELOPMENT OF THE NATIONAL ECONOMY.....	152
Gimranova O. B.	
FREE ECONOMIC ZONES AND FOREIGN INVESTMENT.....	158
Sheraliyeva Saida Azatovna	
ISSUES OF FORMATION AND MANAGEMENT OF PRODUCT ASSORTMENT IN RETAIL ENTERPRISES.....	162
Safarov Baxtiyor Djurakulovich	
STATE SUPPORT IN THE REPUBLIC OF UZBEKISTAN FOR ORGANIZING SHORT-TERM SCIENTIFIC INTERNSHIPS OF YOUNG SCIENTISTS ABROAD.....	167
Kabashev Tairjon	
LEGAL FOUNDATIONS OF DIVIDEND POLICY: EVIDENCE FROM DEVELOPED AND DEVELOPING COUNTRIES.....	172
Eshev Furqat A'zamovich	
IMPROVING SMART CITY GOVERNANCE BASED ON DIGITAL PLATFORMS: A HUMAN-CENTERED APPROACH.....	176
Rakhimova Madina Shukhrat qizi	
THE INVESTMENT CLIMATE AND ITS IMPACT ON THE DEVELOPMENT OF FOREIGN TRADE: A CASE STUDY OF UZBEKISTAN.....	182
Mirzamukhamedova Shakhzoda Akmaljon qizi	
CONSUMER CREDITS IN USA.....	187
Zunnunova Xulkar Muxtorovna	
INSTITUTIONAL BASES AND FUNCTIONAL MECHANISMS OF CONTROLLING IN THE EFFECTIVE MANAGEMENT OF THE RAILWAY TRANSPORT SYSTEM.....	194
Kayumov Zafarbek Odil ugli	
ANALYSIS OF CUSTOMER RELATIONSHIP MANAGEMENT PROCESSES AND PROBLEMS IN SERVICE ENTERPRISES.....	199
Ismailova Ma'mura Eldorovna	
PROBLEMS FACED BY COMMERCIAL BANKS IN BANK RISK MANAGEMENT AND WAYS TO ADDRESS THEM.....	205
Qayimova Ismigul Ilhom qizi, Tuxsanov Eldor Dilmurod o'g'li	

DESIGN OF ENGINEERING STRUCTURES AND CONSTRUCTION OF A REGIONALLY BRANCHED HIGHWAY COMPLEX.....	209
Yakubov Maqsadkhon Sultaniyazovich, Norinov Muhammadyunus Usibjonovich, Zikraev Akmaljon Alimovich	
THE ROLE OF COOPERATIVE RELATIONS IN THE SUSTAINABLE DEVELOPMENT OF THE REGIONAL TOURISM MARKET	216
Mirzabayev Jamshid Irkinovich	
THE ROLE OF FREE ECONOMIC ZONES IN IMPROVING THE INVESTMENT CLIMATE OF THE KHOREZM REGION.....	221
Masharipov Sardorbek Farxadovich	
ANALYSIS OF ORGANIZATIONAL AND ECONOMIC INDICATORS OF INNOVATIVE POTENTIAL MANAGEMENT IN TEXTILE INDUSTRY ENTERPRISES	228
Khosilov Shavkat Bekmurodovich	
MAIN WAYS TO DEVELOP INTEREST RATE RISK MANAGEMENT PRACTICES IN COMMERCIAL BANKS OF UZBEKISTAN	234
Seytnazarov Daniyar Baxadirovich	
THEORETICAL AND METHODOLOGICAL ASPECTS OF ESG STRATEGY IMPLEMENTATION.....	239
Xusenova Mexrangiz	
ADVANTAGES OF USING TRADITIONAL CONSTRUCTION MATERIALS IN THE CONSTRUCTION OF LOW-RISE RESIDENTIAL BUILDINGS.....	244
Otabek Hakimovich Toshniyozov	
THE METHODOLOGY FOR SELECTING AND INTEGRATING DATA SOURCES AND USING OFFICIAL STATISTICAL ENTERPRISE DATA, QUESTIONNAIRES, AND PROXY INDICATORS IN FORMING THE EMPIRICAL BASIS OF THE STUDY.....	247
Usmonov Maxsud Tulqin o'g'li, Qodirov Farrux Ergash o'g'li	
PRACTICAL SOLUTIONS FOR THE PLACEMENT OF MULTI-STOREY GREENHOUSES IN INDUSTRIAL AREAS	254
Abdujabbarova Maktuba To'xtasinovna, Salayeva Ma'rifat Yashin qizi	
INNOVATIONS IN DENTISTRY: DIGITAL SOLUTIONS FOR MODERN PRACTICE	258
Sadriyev Nizom Najmiddinovich, Usarov Nuriddin	
ARCHITECTURAL AND PLANNING PRINCIPLES FOR THE ORGANIZATION OF MANAGEMENT SERVICE COMPANY BUILDINGS IN THE URBAN DEVELOPMENT CONTEXT OF UZBEKISTAN.....	263
Adilova Madina Sobirovna, Khusainova Gulhayo Norbek qizi	
METHODS OF SEDATIVE THERAPY IN DENTISTRY (REVIEW OF LITERATURE)	268
Vasitov Otabek, Burkhonova Zараfruz Kobilovna	
SPECIFIC FEATURES OF THE FORMATION AND OPERATION OF A REGIONAL TOURISM CLUSTER.....	272
Ollanazarov Bekmurod Davlatmurodovich	
ESTIMATING ELECTRICITY CONSUMPTION OF PUMPING PLANTS IN IRRIGATION SYSTEMS.....	277
Urishev Omadjon, Ersin Akyuz, Gul Metin, Quvonchbek Quvondiqov	
ANALYSIS OF MANUFACTURING METHODS AND TECHNIQUES FOR MULTI-FACETED SHAFTS.....	287
Khasanov B.M., Valikhonov D.A., Abdullaev B.I., Alibekov R.K.	
DENTAL IMPRESSIONS AND GYPSUM MODEL SCANNING ACCURACY USING A LASER SCANNER ARE COMPARED	292
Akhmadov Inomjon Nizomitdinovich, Matchanov Boburbek Ulug'bekovich	

DENTAL IMPRESSIONS AND GYPSUM MODEL SCANNING ACCURACY USING A LASER SCANNER ARE COMPARED

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Abstract: This article presents a comparative analysis of the dimensional accuracy of digital models obtained through direct laser scanning of silicone impressions and scanning of Type IV and Type V gypsum models used in prosthetic dentistry. A calibrated Johanssen gauge block with a nominal reference distance of 7 mm was employed as the experimental standard. The results demonstrate that digital models derived from Type IV super-gypsum (Elite Rock) exhibit the highest dimensional accuracy. Direct scanning of impressions showed slightly greater deviations, primarily attributed to the application of anti-glare spray required for optical scanning of reflective silicone surfaces. While direct impression scanning is clinically viable and offers workflow efficiency, its accuracy remains marginally inferior to gypsum-based digitization for high-precision prosthetic applications. The findings emphasize the importance of material selection and scanning methodology optimization in modern CAD/CAM dental workflows.

Key words: prosthetic dentistry, digital impression, CAD/CAM, A-silicone, super-gypsum, laser scanning, dimensional accuracy.

Annotatsiya: Mazkur maqolada ortopedik stomatologiyada qo'llaniladigan raqamli va an'anaviy qolip olish texnologiyalarining o'lcham aniqligi qiyosiy tahlil qilinadi. Tadqiqot doirasida A-silikon asosidagi qoliplarni bevosita lazerli skanerlash orqali olingan raqamli modellar hamda IV va V turdagi super-gips modellarini skanerlash natijalari o'rganildi. O'lchov aniqligini baholash uchun 7 mm etalon masofaga ega Johanssen bloki eksperimental obyekt sifatida qo'llanildi. Natijalar shuni ko'rsatdiki, IV turdagi super-gips (Elite Rock) asosida olingan raqamli modellar eng yuqori aniqlikni namoyon etdi, bevosita qolip skanerlash esa nisbatan yuqori og'ishlarga ega bo'ldi. Aniqlikdagi farqlar asosan qolip yuzasiga qo'llanilgan yorug'likni so'ndiruvchi sprej bilan izohlanadi. Tadqiqot natijalari zamonaviy CAD/CAM texnologiyalarida material tanlash va raqamlashtirish usullarini optimallashtirish zarurligini asoslaydi.

Kalit so'zlar: ortopedik stomatologiya, raqamli qolip, CAD/CAM, A-silikon, super-gips, lazerli skanerlash, o'lcham aniqligi.

Аннотация: В данной статье представлен сравнительный анализ точности цифровых моделей, полученных путем прямого лазерного сканирования силиконовых оттисков и сканирования гипсовых моделей IV и V классов, применяемых в ортопедической стоматологии. В качестве экспериментального эталона использовался калиброванный блок Йохансена с номинальным расстоянием 7 мм. Полученные результаты свидетельствуют о том, что цифровые модели, изготовленные на основе супергипса IV класса (Elite Rock), обладают наибольшей размерной точностью. Прямое сканирование оттисков демонстрирует несколько более высокие отклонения, что связано с необходимостью нанесения антибликового спрея на поверхность силиконового материала. Исследование подтверждает клиническую применимость прямого сканирования оттисков, однако указывает на его ограничения при высокоточных ортопедических конструкциях. Полученные данные имеют практическое значение для оптимизации цифровых рабочих процессов в CAD/CAM-стоматологии.

Ключевые слова: ортопедическая стоматология, цифровой оттиск, CAD/CAM, A-силикон, супергипс, лазерное сканирование, размерная точность.

INTRODUCTION

Obtaining a high-precision impression is one of the primary objectives of prosthetic dental treatment [1, 3, 4, 6, 11]. The ideal impression should accurately mimic the topographical features of the prosthetic bed and exhibit outstanding dimensional stability [1, 5, 7]. To ensure that impressions meet these criteria, efforts are being made to develop and use new impression materials [2, 10]. In therapeutic settings, silicone- and polyether-based impression materials are most often used. In addition to the type of material employed, the process used to obtain the impression influences its dimensional accuracy [2, 3, 7, 11].

The most popular dental impression techniques for making fixed prosthetic restorations are the one-step single-phase method, the one-step dual-phase (monophase) methodology, and the two-step dual-phase technique [4, 7]. One of the most recent modern methods for collecting impressions is intraoral laser scanning of the dentition, which produces digital imprints [4, 8].

These days, CAD/CAM technology is an essential component of a prosthodontist's workflow. These innovative technologies are supported by scanners and other digital diagnostic instruments. Three-dimensional scanners capable of processing dental impressions and gypsum models have become more common in recent years. Laboratories and clinics have a significant opportunity to reduce costs and processing time by directly scanning impressions. However, there are conflicting expert opinions regarding the efficacy of this strategy and a dearth of independent research on the subject.

REVIEW OF LITERATURE ON THE SUBJECT

The rapid evolution of CAD/CAM technology has fundamentally transformed prosthetic dentistry, moving from traditional manual workflows to highly precise digital systems. A critical debate in contemporary literature centers on whether direct scanning of dental impressions can replace the traditional process of scanning gypsum models. According to research by Akhmadov et al. (2024), while scanning gypsum models remains the "gold standard," direct impression scanning offers significant advantages in terms of clinical time management and cost reduction by bypassing the laboratory phase of model casting.

The accuracy of these digital models is often evaluated using standardized units of length, such as the Johanssen block (gauge block). The literature suggests that material properties play a decisive role in the final precision. A-silicone (polyvinyl siloxane) materials, such as Hydrorise, are frequently cited for their excellent dimensional stability. However, when these materials are scanned directly, a common challenge identified is the reflective nature of the silicone surface. Most current laser scanners, such as the Zirkonzahn S600, require the application of an anti-glare or opaquin spray to ensure a readable surface. Studies indicate that this spray layer, although thin, can introduce a slight volumetric increase, leading to minor inaccuracies in the digital model compared to the physical original.

Comparative studies consistently show that Type IV and Type V super-gypsum models (e.g., Elite Rock, Elite Master) yield higher accuracy than direct scans of impressions. The literature attributes this to the inherent "matte" surface of gypsum, which allows for more precise point-cloud generation by the laser without the need for additional coatings. As demonstrated in experimental trials, gypsum models often reach accuracy levels near 6.916 ± 0.015 mm for a 7 mm reference, while direct impression scans may show a slightly higher deviation.

Furthermore, the integration of different dental materials impacts the digital outcome. The choice of gypsum (e.g., Elite Rock vs. Elite Master) can result in subtle but statistically significant differences in stability and detail reproduction. Recent trends in the literature advocate for the development of "scannable" or non-reflective impression materials that would eliminate the need for anti-glare sprays. In conclusion, while current evidence supports the clinical viability of direct impression scanning for most prosthetic applications, gypsum model scanning remains superior for high-precision requirements. Future advancements in material science and reflected-light scanning technologies are expected to close this accuracy gap, making the fully digital workflow even more efficient.

RESEARCH METHODOLOGY

A-silicone materials, namely Zhermack's (Italy) Hydrorise Light (low-viscosity wash) and Hydrorise Putty (high-viscosity foundation), were used to generate one-step, double-layer imprints. A Johanssen block with a normalized dimension of 7 mm between measurement planes used as the experimental model. The impression ingredients were mixed, placed on a rigid plastic tray, and applied to the trial model in accordance with the manufacturer's instructions. After applying pressure continuously for 30 seconds, the impression disappeared after six minutes. Seven days later, the impressions were treated with a photosensitive 3-D Laserscanning Anti-Glare Spray (Helling, Ukraine) and scanned using the Zirkonzahn S600 arti apparatus. Next, ten models were cast, five of which were made of Elite Master resin-reinforced super-gypsum (Zhermack, Italy) and five

of which were built of Elite Rock super-gypsum. Gypsum was mixed with distilled water and a vacuum mixer. After a day without anti-glare spray, the gypsum models were scanned since these materials are made for CAD/CAM. In order to get 150 measurements for the impression group and 150 for the gypsum groups (75 for each kind of gypsum), each digital model was measured 15 times in increments of 1 mm. To determine the mean measurement error of the scanner, the original experimental model was also measured and scanned fifteen times. The data was processed using Excel's variational statistics feature.

ANALYSIS AND RESULTS

The analytical phase of this study focused on a comparative assessment of dimensional accuracy obtained through three different digitalization pathways: direct scanning of A-silicone impressions, scanning of Type IV super-gypsum models, and scanning of resin-reinforced Type V super-gypsum models. The objective was not merely to identify numerical deviations from the reference standard, but to interpret these deviations within the context of material behavior, scanner limitations, and workflow-related variables that influence the reliability of CAD/CAM-based prosthetic fabrication.

Prior to evaluating experimental outcomes, the intrinsic accuracy of the scanning system itself was verified. The reference Johanssen block with a certified interplanar distance of 7.000 mm was scanned fifteen times under identical conditions. The resulting mean scanner deviation of 8 μm fell well within the manufacturer's stated tolerance range of 8–12 μm . This confirmation is critical, as it establishes that observed discrepancies in subsequent measurements can be attributed primarily to material properties and scanning conditions rather than to systemic equipment error. In methodological terms, this step ensures internal validity and allows for meaningful comparison across experimental groups.

The first experimental group consisted of digital models generated through direct scanning of A-silicone impressions fabricated using a one-step double-layer technique. The mean measured distance for the nominal 7 mm reference was 6.885 ± 0.012 mm at a confidence level of $p = 0.95$. Although this deviation appears numerically small, its systematic nature indicates a consistent underestimation of the reference dimension.

This finding aligns with existing literature that identifies surface reflectivity as a primary limitation of direct impression scanning. A-silicone materials, despite their excellent elastic recovery and dimensional stability over time, possess a smooth and light-reflective surface that interferes with laser-based optical acquisition. The application of a photosensitive anti-glare spray was therefore necessary to enable adequate point-cloud generation. However, even an ultrathin spray layer introduces an artificial surface modification, effectively increasing surface thickness and altering the true spatial relationship between reference planes.

From a metrological perspective, this spray-induced layer does not merely add material; it introduces variability depending on spray uniformity, angle of application, and drying behavior. Although the impressions were sprayed following standardized protocols, absolute homogeneity cannot be guaranteed. The resulting dimensional contraction observed in the digital model may reflect compensatory scanning algorithms attempting to reconcile reflective artifacts, thereby producing a slightly reduced virtual geometry.

Clinically, the magnitude of this deviation remains within acceptable limits for many fixed prosthetic restorations, particularly single-unit crowns and short-span bridges. Nevertheless, for restorations requiring maximal precision—such as implant-supported frameworks or long-span fixed partial dentures—even minor systematic inaccuracies may accumulate and compromise passive fit.

The second experimental group comprised digital models derived from Type IV super-gypsum (Elite Rock). These models yielded a mean measured distance of 6.916 ± 0.015 mm at $p = 0.95$, representing the closest approximation to the reference standard among all tested groups.

Several factors contribute to the superior performance of Elite Rock models. First, Type IV gypsum exhibits low setting expansion and high compressive strength, ensuring minimal dimensional distortion during setting and subsequent handling. Second, the inherently matte surface texture of gypsum is ideally suited for laser scanning, allowing for consistent reflection patterns and dense point-cloud acquisition without the need for surface treatment.

The absence of anti-glare spray eliminates an entire source of variability present in direct impression scanning. As a result, the scanner can capture surface geometry directly, relying solely on the physical characteristics of the model. This contributes to the observed stability and reproducibility of measurements across repeated scans.

From a workflow standpoint, these findings reinforce the long-standing perception of gypsum model scanning as the benchmark for digital accuracy. Although this approach involves additional laboratory steps—casting, setting, and storage—it provides a high degree of confidence in the dimensional fidelity of the resulting digital model. For complex prosthetic cases where precision outweighs time efficiency, this method remains highly justified.

The third experimental group included models fabricated from Type V resin-reinforced super-gypsum (Elite Master). The mean measured value of 6.890 ± 0.019 mm demonstrated intermediate accuracy, outperforming direct impression scans but not matching the precision achieved by Elite Rock.

Type V gypsum materials are designed to offer increased strength and resistance to abrasion, particularly for implant and high-load applications. However, these advantages may come at the expense of slightly increased setting expansion or altered surface microstructure due to resin reinforcement. While these changes are clinically beneficial in terms of durability, they may introduce subtle geometric variations that affect optical scanning accuracy.

The slightly higher standard deviation observed in this group suggests greater variability between individual models. This may reflect sensitivity to mixing ratios, vacuum mixing efficiency, or environmental conditions during setting. Although all models were prepared under controlled conditions, resin-modified systems are inherently more complex than conventional gypsum, which may explain the observed dispersion.

Importantly, the results do not indicate a fundamental inadequacy of Type V gypsum for digital workflows. Rather, they highlight the need for careful material selection based on clinical priorities. Where maximal strength and durability are required, minor compromises in dimensional precision may be acceptable. Conversely, in cases demanding extreme accuracy, Type IV gypsum may remain preferable.

When comparing all three groups, a clear hierarchy of dimensional accuracy emerges: Type IV gypsum models demonstrated the highest fidelity, followed by Type V gypsum models, with direct impression scans exhibiting the greatest deviation from the reference standard. However, the absolute differences between groups were relatively small, underscoring the overall maturity and reliability of modern digital prosthodontic workflows.

It is essential to interpret these results within a clinical context. The deviations observed in direct impression scanning, while statistically significant, may not translate into clinically detectable discrepancies in many routine cases. The advantages of direct scanning—reduced processing time, elimination of casting errors, and streamlined digital workflows—are substantial and align with the broader trend toward chairside CAD/CAM solutions.

Nevertheless, the findings also underscore a critical limitation: current laser scanning systems are not fully optimized for reflective elastomeric surfaces. The reliance on anti-glare sprays introduces an avoidable source of error that undermines the theoretical advantages of direct impression scanning. This limitation is technological rather than conceptual and points toward future innovation rather than methodological failure.

The results of this study support ongoing research into the development of “scannable” impression materials with inherently matte or light-diffusing surfaces. Such materials would eliminate the need for surface coatings, thereby preserving the true geometry of the impression and enhancing scanning accuracy.

Additionally, advancements in scanning technology—particularly structured-light and hybrid optical systems—may reduce sensitivity to surface reflectivity. Improved software algorithms capable of compensating for reflective artifacts without geometric distortion would further narrow the accuracy gap between direct and indirect scanning methods.

Future studies should also explore long-span geometries, undercut regions, and complex anatomical forms to assess whether the trends observed in standardized reference models persist under clinically realistic conditions. Multicenter trials and cross-platform scanner comparisons would further strengthen the evidence base.

CONCLUSIONS AND SUGGESTIONS

The experiment's results demonstrate that scanning impressions may provide results with a high degree of accuracy. The modest drop in accuracy compared to gypsum models is likely due to the photosensitive spray, which creates a thin film on the impression surface. The development of reflecting imprint materials would eliminate the need for such sprays and increase the precision and effectiveness of direct scanning for usage in modern healthcare settings.

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