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Virtual Reality in U.S. Dental Education: A Cross-Sectional Study of Faculty and Student Perceptions

Virtualna stvarnost u dentalnom obrazovanju u SAD-u: presječno istraživanje percepcija nastavnika i studenata

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Abstract

Objective: The aim of this study was to understand perceptions of faculty and student representatives on existing virtual reality (VR) technologies that are being integrated into U.S. dental school curriculum. **Methods:** Two validated (face and content) instruments were used for this cross-sectional study. National representatives (68 students and 68 Academic Deans) from U.S. dental schools were invited to participate in the Qualtrics surveys. The surveys were segmented into four parts: general information, knowledge about VR, institutional experience with VR, perception of VR's importance. **Results:** Faculty and student representatives from 30 dental schools (44%) participated in the study. Students and faculty unanimously agreed that VR technology should be integrated in the dental school curriculum. Some faculty with prior VR exposure perceived the greatest advantage of VR to be standardization and objectivity (55%, n=12). Students agreed with the faculty regarding the advantages of VR, but found the repeatability to be of greater importance (63%, n=5). The greatest limitation mentioned by faculty was cost, while students mentioned other limitations. **Conclusion:** The current study highlighted the differences and similarities in the faculty and students' perspective on the current use of VR in dentistry. The findings indicate that VR offers meaningful advantages for curricular integration, particularly by enabling standardized, objective assessment of learner performance and repeatable skill practice under controlled conditions. In the future, a mixed-methods study design is recommended to investigate further and to confirm the current findings.

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Introduction

In a world that is constantly evolving with new technological discoveries, dentistry is not exempt from this revolution. The transition from manual to digital technologies offers opportunities for greater standardization, efficiency, and convenience. Virtual reality (VR) is among these technologies, which has gained increasing application in the health field through a wide range of uses. VR is broadly defined as an immersive computer-generated technology that employs visual, auditory, and/or haptic enhancements to simulate real or imagined environments, creating a sense of physical presence for the user (1).

Studies have shown that the integration of tools, such as 3D tooth atlas and similar virtual tooth identification re-

Uvod

U svijetu koji se stalno razvija zahvaljujući novim tehnološkim otkrićima, dentalna medicina također nije iznimka. Prijelaz s manualnih tehnologija na digitalne omogućuje bolju standardizaciju, učinkovitost i praktičnost. Među takvim tehnologijama je i virtualna stvarnost (VR) koja se sve češće koristi u području zdravstva i ima velik raspon primjena. VR se općenito definira kao imerzivna računalno generirana tehnologija kod koje se, stvarajući osjećaj fizičke prisutnosti korisnika, primjenjuju vizualni, slušni i/ili haptički elementi za simulaciju stvarnih ili zamišljenih okruženja (1).

Istraživanja su pokazala da uvrštavanje alata poput 3D atlasa zuba i sličnih resursa u stomatološki kurikulum daje studentima i nastavnicima veliku prednost (2 – 5). Primjena

sources, into dental curriculum can provide a wide array of benefits for students and faculty alike (2-5). VR and augmented reality (AR) applications in dentistry include, but are not limited to virtual articulation and occlusion, digital scanning and impressions, 3D digital models, virtual implant placement, and anesthesia administration simulation (6, 7). In addition to their clinical utility for providers, these technologies deliver patient benefits as well. Evidence indicates that VR simulation goggles can markedly alleviate the anxiety and fear commonly associated with anticipation of dental procedures (8-10). Although virtual reality has been explored within the field of clinical dentistry, much of the existing literature is limited to a specific cohort. The findings of such studies have shown that the students' perspectives as well as objective results demonstrate beneficial and useful feedback provided from VR technology (6, 11-14). Conversely, evidence has shown that simulated dental technology fails to provide realistic haptic feedback or accurate finger rest position (15). Another study found that the dependence on self-correction through VR use significantly extends the time that is needed to learn and improve performance at preclinical tasks (16). Given the conflicting existing literature (17) and limited population pool, it is difficult for dental schools to make an evidence-based decision on whether or not to invest in these advancing technologies. There continues to be a need for further investigation of VR to provide long-term evidence, ranging from its use in remediation of clinical skills acquisition to the barriers to integration of VR into dental curriculum (18). As the pandemic created barriers to accessing comprehensive education, faculties considered VR technology an alternative or supplement to traditional education (19). Therefore, there is a need for evaluation of VR in dental education from a broader lens. This gap can be filled by the findings of a study that surveys students and faculty of accredited U.S. dental schools regarding virtual reality-based dental education. For the purpose of this study, virtual reality was defined as technology with visual, auditory, and/or haptic enhancement to simulate real-life environments (1) and includes applications that encompass but are not limited to virtual articulation and occlusion, digital scanning and impressions, 3D digital models, and virtual implant placement.

The objective of this study was to investigate the perceptions of faculty and student representatives on existing virtual reality (VR) technologies that are being integrated into the U.S. dental school curriculum.

Materials and Methods

This cross-sectional study (STUDY00000371) has been reviewed and approved by the Tufts Social, Behavioral and Educational Institutional Review Board (IRB). Two validated (face and content) surveys (one for students, one for faculty) were distributed via Qualtrics. Up to 68 student representatives and 68 faculty representatives of U.S. dental schools were invited via email to participate in the study. The student representatives included predoctoral students who were official American Dental Education Association Council of Students, Residents and Fellows (ADEA COSRF) represen-

VR-a i proširene stvarnosti u dentalnoj medicini uključuju, ali nisu ograničene na virtualnu artikulaciju i okluziju, digitalno skeniranje i otiske, 3D digitalne modele, virtualno postavljanje implantata i simulaciju aplikacije anestezije (6, 7). Osim kliničkih koristi od tehnologije koriste imaju i pacijenti. Dokazi upućuju na to da VR naočale znatno smanjuju anksioznost i strah povezan sa stomatološkim zahvatima (8 – 10).

Iako je VR istraživao u kliničkoj dentalnoj medicini, autori većine dosadašnjih studija usmjereni su na specifične skupine. Njihovi rezultati pokazali su da percepcije studenata i objektivni ishodi potvrđuju korisne povratne informacije koje omogućuje VR tehnologija (6, 11 – 14). S druge strane, dokazano je da simulacijska dentalna tehnologija ne osigurava realistični haptički doživljaj, ni precizno uporište za prst (15). U jednoj drugoj studiji autori su istaknuli da oslanjanje na samokorekciju na temelju VR-a značajno produljuje vrijeme potrebno za svladavanje pretkliničkih zadataka (16).

S obzirom na proturječne nalaze (17) i ograničenu populaciju u dosadašnjim studijama, stomatološkim fakultetima teško je donijeti odluku utemeljenu na dokazima o ulaganju u ove tehnologije. Potrebna su daljnja istraživanja VR-a kako bi se dobili dugoročni dokazi – od njegove primjene u usavršavanju kliničkih vještina do razumijevanja prepreka za njegovu integraciju u kurikulum (18). Tijekom pandemije VR je smatran alternativom ili nadopunom tradicionalnoj nastavi (19). Zato je potrebno procijeniti upotrebu VR-a na fakultetima dentalne medicine iz šire perspektive. Taj nedostatak može se nadomjestiti istraživanjem percepcija o VR-u nastavnika i studenata sa stomatoloških fakulteta u SAD-u. U ovoj je studiji VR definiran kao tehnologija s vizualnim, slušnim i/ili haptičkim elementima za simulaciju stvarnih okruženja (1), uključujući aplikacije poput virtualne artikulacije, digitalnog skeniranja i otisaka, 3D modela te virtualnog postavljanja implantata.

Cilj ove studije bio je istražiti percepcije nastavnika i predstavnika studenata o postojećim VR tehnologijama koje se uvrstavaju u kurikule stomatoloških fakulteta u SAD-u.

Materijali i metode

Ovo presječno istraživanje (STUDY00000371) pregledalo je i odobrilo Etičko povjerenstvo za društvena, bihevioralna i fakultetska istraživanja na Sveučilištu Tufts (Tufts Social, Behavioral and Educational Institutional Review Board – IRB). Dvije validirane ankete (valjanost izgleda i sadržaja) – jedna za studente, druga za nastavnike – distribuirane su putem platforme Qualtrics. Tako je 68 predstavnika studenata i 68 predstavnika nastavnika stomatoloških fakulteta u SAD-u dobilo e-poštom pozive za sudjelovanje u istraživanju.

tatives of their school or had been nominated by a student representative. The faculty representatives comprised of faculty members appointed as Associate Dean of Academic Affairs, Associate Dean of Education or those who have been nominated by that position.

The survey was adapted from a previously published instrument which was investigating the knowledge and attitudes of virtual reality-based technologies among dental medicine students and practitioners (6). The surveys are segmented into different parts: general information about the student or faculty member, knowledge about VR, experience with VR, opinion/perception of importance of VR and summary. The surveys consisted of different type of questions (Likert scale, multi-select, single answer and true/false questions) and took approximately 7 to 10 minutes for a participant to complete.

Descriptive statistics (frequencies and percentages) were calculated for each survey item. Student and faculty responses were assessed separately. The statistical significance of knowledge, experience and nominal scale opinion questions for both students and faculty were assessed using the Chi-square test or Fisher's exact test. P-values less than 0.05 were considered significant for overall tests. SAS version 9.4 (SAS Institute Inc., Cary, NC) was used for analyses.

Results

Overall survey findings

Survey responses from faculty and student representatives were collected from 30 out of 68 U.S. dental schools, with 22 faculty and 15 student responses (27%, n=37). An overlap of faculty and student respondents was observed in five dental schools. The schools that participated in the survey were a combination of public and privately funded institutions.

Survey findings from faculty

Knowledge

When asked what the most reliable way was to oversee a students' progress and evaluate their performance in practical tasks as part of preclinical training, the greatest number of faculty reported it to be VR technology and computer simulation (50%, n=11). The rest of the participants mentioned either acrylic or extracted teeth mounted on a mannequin (32%, n=7). The remainder of faculty participants responded that they "do not know" (18%, n=4).

Experience

The majority of faculty respondents (77%, n=17) reported working as instructors for sixteen years or more and having used a minimum of three or greater technologies in their teaching activities. Nearly a quarter of the faculty (23%, n=5) participating in the study had minimal experience with technology (Figure 1) in their instruction.

Opinion/Perception

An overwhelming majority of Academic Deans (95.45%, n=21) stated that investing in VR technologies is important.

Predstavници studenata bili su preddiplomci, službeni predstavnici svojega fakulteta u Američkom udruženju za dentalno obrazovanje (American Dental Education Association Council of Students, Residents and Fellows – ADEA COSRF), ili ih je ta udruga predložila. Predstavnici nastavnika bili su članovi fakulteta imenovani na dužnosti prodekana za akademska pitanja, prodekana za obrazovanje ili osobe koje su predložili ti dužnosnici.

Anketa je prilagođena prema ranije objavljenom instrumentu kojim su se istraživali znanje i stajališta o tehnologijama temeljenima na virtualnoj stvarnosti među studentima i praktičarima dentalne medicine (6). Sastojala se od više dijelova: općih informacija o studentu ili nastavniku, znanja o VR-u, iskustva s VR-om, mišljenja/percepcija o važnosti VR-a te završnoga dijela. Upotrijebljena su različita tipološka pitanja (Likertova ljestvica, višestruki odabir, pojedinačni odgovor i točno/netočno). Sudionicima je za ispunjavanje ankete u prosjeku trebalo od 7 do 10 minuta.

Deskriptivna statistika (frekvencije i postotci) izračunata je za svaku anketnu stavku. Odgovori studenata i nastavnika analizirali su se odvojeno. Statistička značajnost znanja, iskustva i nominalnih stajališta za obje je skupine ispitana korištenjem hi-kvadrat testa ili Fisherova egzaktnog testa. P-vrijednosti manje od 0,05 smatrane su statistički značajnima. Za sve analize korištena je SAS verzija 9.4 (SAS Institute Inc., Cary, NC).

Rezultati

Opći nalazi istraživanja

Odgovori nastavnika i studenata stigli su iz 30 od ukupno 68 stomatoloških fakulteta u SAD-u, uz 22 odgovora nastavnika i 15 odgovora studenata (27 %, n = 37). Preklapanje odgovora nastavnika i studenata zabilježeno je na pet fakulteta. U istraživanju su sudjelovale i javne i privatne institucije.

Nalazi istraživanja – nastavnici

Znanje

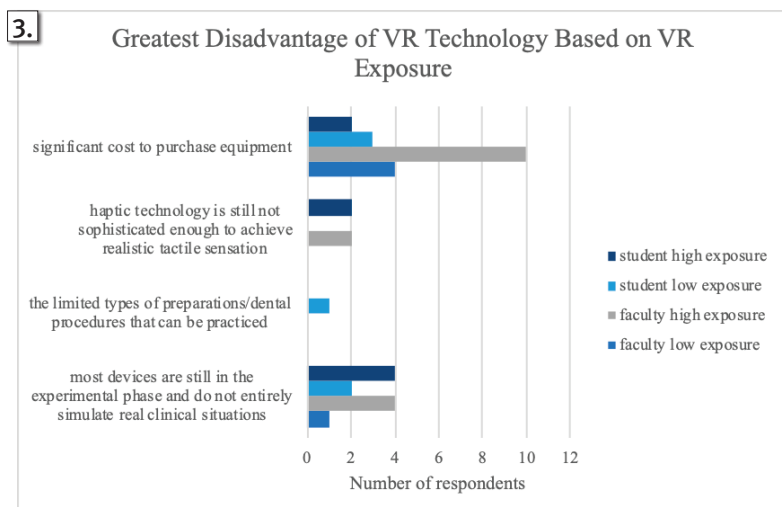
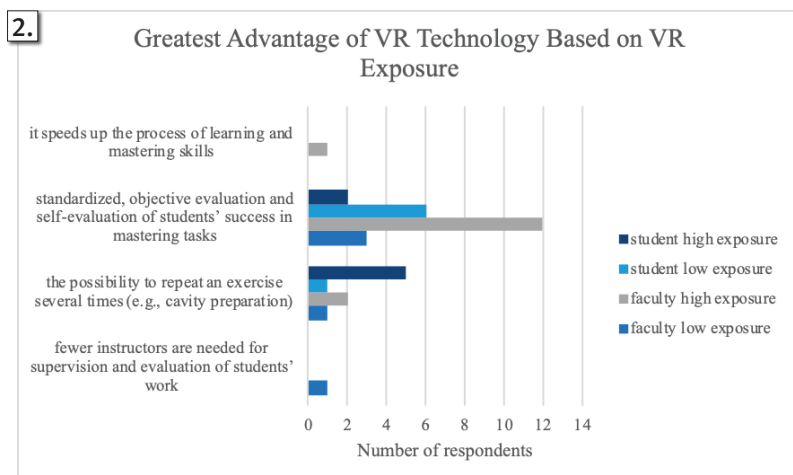
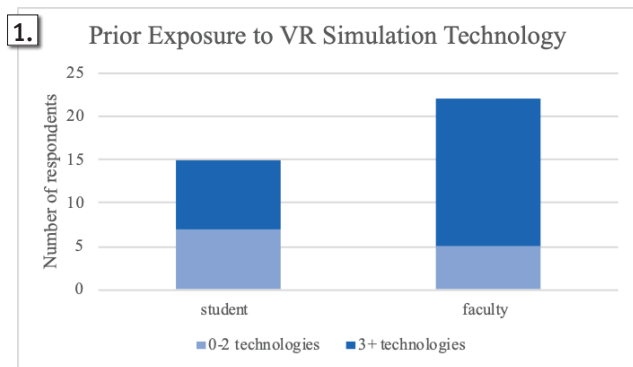
Na pitanje koji je najpouzdaniji način za praćenje napretka studenata i procjenu primjene u praktičnim zadacima tijekom pretkliničke nastave, najveći broj nastavnika naveo je VR tehnologiju i računalnu simulaciju (50 %, n = 11). Ostali ispitanici odabrali su akrilne ili izvađene zube montirane na fantomsku glavu (32 %, n = 7). Preostali su odgovorili da *ne znaju* (18 %, n = 4).

Iskustvo

Većina nastavnika (77 %, n = 17) izjavila je da obavlja taj posao 16 ili više godina te da su se u nastavi koristili barem trima tehnologijama ili s više njih. Gotovo četvrtina (23 %, n = 5) navela je minimalno iskustvo kad je riječ o tehnologiji (slika 1.).

Mišljenje/percepcija

Velika većina prodekana (95,45 %, n = 21) smatra da je ulaganje u VR tehnologiju važno. Zanimljivo je da je velik



A large portion of faculty participants (85%, $n=6$) who selected mannequin heads as the most reliable measure of student progress still found investing in VR technology worthwhile. All participants (100%, $n=11$) who selected VR technology as the most reliable measure held the same belief ($p=.50$). Almost all faculty respondents (95%, $n=21$) found it important for students to experience VR as a part of their graduate education. Of that fraction, fewer participants (32%, $n=8$) considered mannequin phantom heads to be the most reliable measure of clinical skill acquisition compared to VR technology (50%, $n=11$), with a few participants (14%, $n=3$) choosing the statement "do not know."

dio nastavnika (85 %, $n= 6$), koji su kao najpouzdaniji oblik procjene naveli rad na fantomskoj glavi, i dalje smatrao ulaganje u VR opravdanim. Svi ispitanici (100 %, $n = 11$) koji su odabrali VR kao najpouzdaniji način procjene dijelili su isto mišljenje ($p = .50$). Gotovo svi nastavnici (95 %, $n = 21$) smatraju kako je važno da studenti tijekom studija steknu iskustvo s VR-om. Među njima je manji broj (32 %, $n = 8$) ocijenio fantomsku glavu najpouzdanijim oblikom procjene u usporedbi s VR-om (50 %, $n = 11$), a nekoliko ispitanika (14%, $n=3$) odabralo je odgovor *ne znam*.

Figure 1 Prior exposure to VR simulation technology among students and faculty

Slika 1. Dosadašnja izloženost VR simulacijskoj tehnologiji među studentima i nastavnicima

Figure 2 Greatest advantage of virtual reality technology by respondents' role and VR technology exposure level

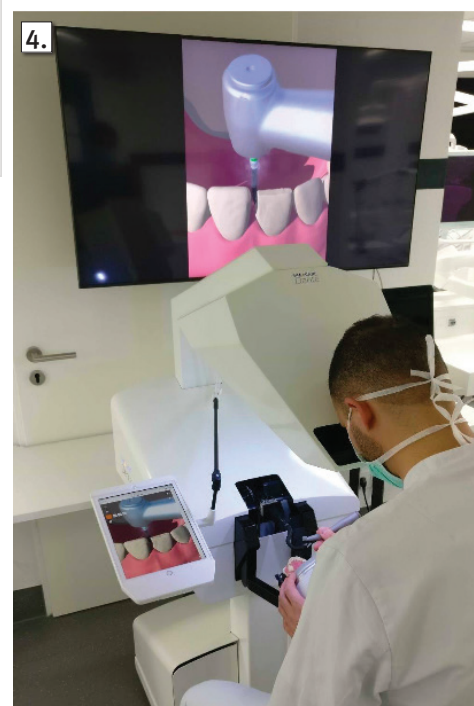
Slika 2. Najveća prednost tehnologije virtualne stvarnosti prema ulozi ispitanika i u odnosu prema razini izloženosti VR-u

Figure 3 Greatest disadvantage of virtual reality technology by respondents' role and VR technology exposure level

Slika 3. Najveći nedostatak tehnologije virtualne stvarnosti prema ulozi ispitanika i u odnosu prema razini izloženosti virtualnoj stvarnosti

Figure 4 Example of VR technologies, SIMtoCARE Dente Training Simulator

Slika 4. Primjer VR tehnologije: SIMtoCARE Dente – simulator za vježbu



Summary

Faculty participants mentioned key barriers to VR adoption in dental schools, including concerns that simulators could reduce faculty roles and weaken the human element of education. A significant barrier emerged around faculty preparedness and engagement. Participants reported that a great number of faculty members lack sufficient VR knowledge and demonstrate limited willingness to undergo the necessary training for effective implementation. This reluctance is particularly problematic given that faculty would bear responsibility for developing and building simulated clinical cases, a task requiring technical proficiency. Participants also stressed the need for stronger evidence of VR's educational benefits to justify institutional investment. Most critically, they highlighted CODA approval as a prerequisite for meaningful and widespread implementation of VR technology in U.S. dental schools.

Survey findings from students

Knowledge

When asked about the most reliable way to oversee a students' progress and evaluate their performance in practical tasks as part of preclinical training, the students' responses were split between either acrylic or extracted teeth mounted on mannequin (47%, n=7), VR simulation technology (33%, n=5), or "do not know" (20%, n=3).

Experience

The student responses comprised of predominantly fourth-year students (66%, n=10) and third-year students (33%, n= 5). When asked to select the VR technologies that participants have had prior experience with, there was an almost equal division between high exposure to VR, consisting of three or greater technologies (53%, n=8) and low exposure, consisting of two technologies or fewer (47%, n=7).

Opinion/Perception

All student respondents (100%, n=15) found it important for students to experience VR in their dental curriculum. All student participants (100%, n=15) believed that it is important to invest in VR technologies and to integrate them in their dental curriculum.

Summary

Some students reported on potential barriers to VR integration, such as "not all students can use VR at the same time." Another concern mentioned was the integration of VR into already established courses while respecting the course objectives. Other student participants questioned whether "[VR] can be used in the student's home". Students reported that with VR simulation, students might not be able to learn multiple approaches in the same way as they learn by receiving feedback from different faculty members. According to another survey participant, VR integration may create a gap in opportunity among U.S. dental students as some schools can invest in VR technologies while others lack the budget to invest in them.

Regardless of their views about VR versus conventional methods of dental education, students and faculty collective-

Sažetak (nastavnici)

Nastavnici su istaknuli ključne prepreke integraciji VR-a u dentalne škole, uključujući zabrinutost da bi simulacijski sustavi mogli smanjiti ulogu nastavnika i oslabiti ljudski element obrazovanja. Kao znatna prepreka navedena je i nedovoljna pripremljenost i angažman nastavnika. Mnogi nastavnici nemaju dovoljno znanja o VR-u niti pokazuju spremnost za dodatnu izobrazbu potrebnu za učinkovitu implementaciju. To je posebno problematično jer bi upravo nastavnici bili odgovorni za razvoj simuliranih kliničkih slučajeva. Nastavnici su također istaknuli da su potrebni detaljniji dokazi o obrazovnoj učinkovitosti VR-a kako bi se opravdalo institucionalno ulaganje. Kao najvažniji preduvjet naveli su odobrenje CODA-e (Commission of Dental Accreditation – nacionalna programska akreditacijska agencija koju priznaje Ministarstvo obrazovanja SAD-a) koje bi omogućilo značajniju i širu primjenu VR tehnologije na stomatološkim fakultetima u SAD-u.

Nalazi istraživanja — studenti

Znanje

Na pitanje koji je najpouzdaniji način procjene studentskoga napretka tijekom pretkliničke nastave, odgovori studenata bili su sljedeći: akrilni ili izvađeni zubi na fantomskoj glavi (47 %, n = 7), VR simulacija (33 %, n = 5) ili *ne znam* (20 %, n = 3).

Iskustvo

Odgovori su dobiveni uglavnom od studenata četvrte (66 %, n = 10) i treće godine (33 %, n = 5). Na pitanje o stečenom iskustvu s VR-om, studenti su bili gotovo jednako podijeljeni: velika izloženost (tri ili više tehnologija) – 53 % (n = 8), mala izloženost (dvije tehnologije ili manje) – 47 % (n = 7).

Mišljenje/percepcija

Svi studenti (100 %, n = 15) smatraju da bi VR trebao biti dio dentalnoga kurikula. Također su svi (100 %, n = 15) uvjereni da je važno ulagati u VR tehnologiju.

Sažetak (studenti)

Studenti su istaknuli nekoliko prepreka uvrštavanju VR-a, uključujući ograničenje da *se ne mogu svi studenti istodobno koristiti VR-om*. Također su izrazili zabrinutost zbog uvrštavanja VR-a u već postojeće kolegije bez narušavanja njihovih ciljeva. Neki su pitali mogu li se VR-om koristiti kod kuće. Studenti također smatraju da bi VR mogao smanjiti raznolikost pedagoških pristupa jer simulacija ne može zamijeniti učenje različitih načina primjene i savjeta više nastavnika. Drugi su naveli zabrinutost da bi VR tehnologija mogla povećati razliku u mogućnostima među studentima u SAD-u jer sve škole možda neće moći nabaviti takve sustave.

Bez obzira na stajališta o VR-u u odnosu prema tradicionalnoj metodi, obje su skupine zaključile da VR tehnologija treba biti uvrštena u kurikule ($p = .18$). Nastavnici i studenti istaknuli su mnoštvo prednosti (slika 2.) i nedostataka

ly established that VR technology should be experienced by students as a part of their dental curriculum ($p = .18$). Faculty and students alike selected a wide array of options for the greatest advantage (Figure 2) and disadvantage (Figure 3) of VR dental technology. Half of faculty (55%, $n=12$) with previous VR exposure (three or greater technologies) stated that standardization and objectivity ($p = .52$) are the greatest advantages of VR. Students with high exposure somewhat agreed, but over half of them also stated that repeatability is an advantage at an even higher rate (63%, $n=5$), ($p = .07$). The greatest limitation among faculty of either high (59%, $n=10$) or low (80%, $n=4$) exposure to VR technology was cost ($p = .76$). Students were less unanimous in their responses, stating other disadvantages such as haptic technology which is still not sufficiently sophisticated to achieve realistic tactile sensation (13%, $n=2$), limited types of dental procedures that can be practiced (7%, $n=1$), and most devices are still in experimental phase and do not entirely simulate real clinical situations (40%, $n=6$), ($p = .47$).

Discussion

The current study reported comparable findings to a European cross-sectional survey study (6), where 92% of students and faculty were in support of the need to invest in new and innovative technology and 88% of students supported VR exposure during their dental education. Survey participants found that cost was the largest obstacle for achieving VR integration in the curriculum. However, 67% of dentists believe that VR is more cost-effective than traditional techniques. In the next 20 years, most European students and faculty from the study project believe that virtual reality will be integrated into dentistry.

This study's motivation to determine how virtual reality dental technology can benefit students was also supported by a randomized controlled trial study based at Columbia University (14). This study, evaluating dental simulators, found that students were able to improve their operative skills with VR compared to conventional methods. This finding serves as concrete evidence that VR technology is the most reliable tool for measuring and improving preclinical skills acquisition.

In overall perception of students' competence with hand skills, another study surveying faculty found that there were benefits of VR based education compared to traditional methods (20). A noteworthy skill attained by students using simulation technology was positioning and finger rests. Additional advantages found included fewer faculty resources needed, ability to self-pace, ability to repeat preparation skills, and improved self-evaluation. This presents the idea that students may benefit from standardized and objective feedback, which is in line with our study findings. Moreover, the students may feel more comfortable when they receive feedback from a computerized system, especially at early stages of learning. Although there is no study assessing both students and faculty perceptions of VR in dentistry across U.S. institutions, the results of these published studies support the need for it.

(slika 3.) VR tehnologije. Polovina nastavnika (55 %, $n = 12$) s iskustvom o VR-u navela je standardizaciju i objektivnost kao najveću prednost ($p = .52$). Studenti s velikim iskustvom dijelom su se složili, ali je njih više istaknulo mogućnost ponavljanja kao ključnu prednost (63 %, $n = 5$) ($p = .07$). Najveće ograničenje za nastavnike, bez obzira na razinu iskustva, bio je trošak (visoka izloženost: 59 %, $n = 10$; niska izloženost: 80 %, $n = 4$) ($p = .76$). Studenti su bili manje usuglašeni u svojim odgovorima te su istaknuli razna druga ograničenja poput nedovoljno sofisticirane haptičke tehnologije (13 %, $n = 2$), ograničenog broja vrsta zahvata koji se mogu vježbati (7 %, $n = 1$) te činjenicu da su mnogi uređaji još u eksperimentalnoj fazi i ne simuliraju potpuno stvarne kliničke situacije (40 %, $n = 6$) ($p = .47$).

Rasprava

U ovom istraživanju izvještava se o nalazima usporedima s europskim presječnim istraživanjem (6) u kojemu je 92 % studenata i nastavnika poduprlo potrebu da se ulaže u nove i inovativne tehnologije, a 88 % studenata poduprlo je izloženost VR-u tijekom dentalnog obrazovanja. Sudionici ankete u objema studijama istaknuli su trošak kao najveću prepreku uvrštavanju te metode u kurikule. Međutim, 67 % europskih stomatologa smatra da je VR isplativiji od tradicionalnih tehnika. Tako većina europskih studenata i nastavnika pretpostavlja da će u sljedećih 20 godina VR biti integriran u dentalnu medicinu.

Motivaciju za istraživanje kako VR tehnologija može koristiti studentima podupire i randomizirano kontrolirano istraživanje provedeno na Sveučilištu Columbia (14). U toj studiji, u kojoj su procjenjivani dentalni simulatori, studenti su bili u mogućnosti poboljšati svoje operativne vještine koristeći se VR-om u usporedbi s konvencionalnim metodama. Ovaj nalaz konkretan je dokaz u prilog opažanjima iz aktualne studije prema kojima su studenti i nastavnici shvatili VR tehnologiju kao najpouzdaniju mjeru stjecanja pretkliničkih vještina.

Kad je riječ o procjeni ukupne kompetentnosti studenata u manualnim vještinama, u jednom drugom istraživanju među nastavnicima otkrivene su prednosti obrazovanja temeljenoga na VR-u u usporedbi s tradicionalnim metodama (20). Kao posebno značajnu vještinu stečenu korištenjem VR tehnologije istaknuli su pozicioniranje i uporište prsta. Dodatne prednosti obuhvaćale su manju potrebu za nastavnim resursima, samostalno napredovanje, mogućnost ponavljanja pripremnih vještina i poboljšanu samoevaluaciju. To pokazuje da studenti ne dobivaju samo standardiziranu i objektivnu povratnu informaciju – što je također potvrđeno u ovoj studiji – nego se mogu osjećati i ugodnije primajući povratne informacije od računalnog sustava, posebno u ranijim fazama svladavanja vještina. Iako ne postoji nacionalna studija u kojoj se istodobno procjenjuju percepcije studenata i nastav-

The position papers published by American Dental Education Association (ADEA) and Association for Dental Education in Europe (ADEE) place VR technology as a key tool to facilitate learning and assessment of the next generation of students (21, 22). These data are consistent with the current study where students and faculty collectively established that VR technology should be experienced by students as a part of their dental curriculum ($p = .18$).

The benefits regarding the use of VR as identified by both faculty and students in the current study are aligned with the findings of previous studies (6, 11-14, 23, 24). Some of the faculty members mentioned that the adoption of this technology in the curriculum can be facilitated if VR is included in the CODA standards. With some experience in using VR, certain CODA standards can be applied by integrating VR in the dental curriculum (Table 1). For example, for the "Comprehensive, Patient-Centered Care" standard, there are some VR systems (Figure 4) that allow for the day-to-day patient care data to be shared, and students can practice their respective preparation in the simulation center prior to performing a live procedure in a clinic. As mentioned by some of the faculty members that took part in this study, one of the benefits of integrating VR is faculty calibration.

nika o VR-u u dentalnoj medicini u SAD-u, rezultati dosadašnjih istraživanja podupiru potrebu za takvim radovima.

U dokumentima o stajalištima koje je objavilo Američko udruženje za stomatološko obrazovanje (ADEA) i Udruženje za stomatološko obrazovanje u Europi (ADEE), VR tehnologija smatra se ključnim sredstvom za olakšavanje učenja i ocjenjivanja sljedeće generacije studenata (21, 22). Ti podatci u skladu su s ovom studijom u kojoj su studenti i nastavnici zajednički istaknuli da bi studenti trebali steći iskustvo s VR tehnologijom u sklopu stomatoloških kurikula ($p = 0,18$). Prednosti korištenja VR-a, koje su identificirali i nastavnici i studenti u ovoj studiji, usklađene su s nalazima dosadašnjih studija (6, 11 – 14, 23, 24). Neki su nastavnici istaknuli da bi se uvođenje ove tehnologije u kurikule moglo olakšati ako se VR uključi u CODA standarde. Ako netko ima iskustva u korištenju VR-a, može izvijestiti da se određeni CODA standardi mogu primijeniti uvrštavanjem VR-a u stomatološki kurikulum (tablica 1.). Na primjer, za standard *sveobuhvatne skrbi usmjerene na pacijenta*, postoje neki VR sustavi (slika 4) koji omogućuju razmjenu podataka o svakodnevnoj skrbi za pacijente, a studenti mogu vježbati svoje preparacije u simulacijskom centru prije obavljanja postupka uživo u klinici. Kao što su naveli neki članovi fakulteta koji su sudjelovali

Table 1 Possible CODA standards that can be applied when integrating VR in the dental Curriculum (25).

Tablica 1. Mogući CODA standardi koje treba primijeniti pri uvrštavanju VR-a u stomatološke kurikule (23)

Standard Name • Standardni naziv	Further Details • Detalji
Comprehensive, Patient-Centered Care • Sveobuhvatna, na pacijenta usmjerena skrb	"Evaluations of practice patterns and the outcomes of care guide actions to improve both the quality and efficiency of care delivery" • Procjene obrazaca prakse i ishoda pružene skrbi usmjeravaju aktivnosti sa svrhom poboljšanja kvalitete i učinkovitosti pružanja zdravstvene skrbi.
Self-Directed Learning • Samousmjereno učenje	"Educational programs must depart from teacher-centered and discipline-focused pedagogy to enable and support the students' evolution as independent learners actively engaged in their curricula using strategies that foster integrated approaches to learning." • Obrazovni programi moraju se udaljiti od pedagogije usmjerene na nastavnika i pojedinu disciplinu kako bi omogućili i podržali razvoj studenata u neovisne učenike koji su aktivno uključeni u svoj kurikulum i koriste se strategijama koje potiču integrirane pristupe učenju.
Scientific Discovery and the Integration of Knowledge • Znanstveno otkriće i integracija znanja	"Learning must occur in the context of real health care problems rather than within singular content-specific disciplines. Learning objectives that cut across traditional disciplines and correlate with the expected competencies of graduates enhance curriculum design." • Učenje mora biti u kontekstu stvarnih zdravstvenih problema, a ne unutar pojedinačnih sadržajno specifičnih disciplina. Ishodi učenja koji povezuju tradicionalne discipline i usklađeni su s očekivanim kompetencijama diplomiranih studenata poboljšavaju dizajn kurikula.
Assessment • Vrijednovanje	"Dental education programs must conduct regular assessments of students' learning throughout their educational experiences." • Programi dentalnog obrazovanja moraju provoditi redovita vrijednovanja studentskog učenja tijekom cijeloga njihova procesa obrazovanja.
Application of Technology • Primjena tehnologije	"Technology enables dental education programs to improve patient care, and to revolutionize all aspects of the curriculum, from didactic courses to clinical instruction. Contemporary dental education programs regularly assess their use of technology and explore new applications of technological advances to enhance student learning and to assist faculty as facilitators of learning and designers of learning environments." "Use of technology in dental education programs can support learning in different ways, including self-directed, distance and asynchronous learning." • Tehnologija omogućuje programima dentalnog obrazovanja poboljšanje skrbi za pacijente te revolucioniranje svih aspekata kurikula – od teorijske nastave do kliničke poduke. Suvremeni programi dentalnog obrazovanja redovito procjenjuju svoju uporabu tehnologije i istražuju nove mogućnosti primjene tehnoloških dostignuća kako bi unaprijedili učenje studenata te pomogli nastavnicima kao posrednicima učenja i kreatorima obrazovnih okruženja. Uporaba tehnologije u programima dentalnog obrazovanja može podržati učenje na različite načine, uključujući samousmjereno, udaljeno i asinkrono učenje.
Faculty Development • Profesionalni razvoj nastavnika	"Dental education programs can re-examine the relationship between what faculty do and how students learn to change from the sage authority who imparts information to a facilitator of learning and designer of learning experiences that place students in positions to learn by doing." • Programi dentalnog obrazovanja mogu ponovno sagledati odnos između onoga što nastavnici rade i načina na koji studenti uče kako bi se prešlo s modela autoritativnog stručnjaka koji prenosi informacije na ulogu posrednika učenja i kreatora obrazovnih iskustava koja studente stavljaju u položaj da uče na temelju praktičnog djelovanja.

One of the challenges of integrating VR is faculty training. According to CODA "Faculty Development" standards, academic institutions are responsible to "re-examine the relationship between what faculty do and how students learn to change from the sage authority who imparts information to a facilitator of learning and designer of learning experiences that place students in positions to learn by doing" (25). Some of the limitations mentioned, especially by the students in this study, were previously reported by others such as realistic haptic feedback or accurate finger rest position (15, 23).

To our knowledge, the current study is the first national study that collected data from 30 dental schools regarding the perceptions of faculty and students on the integration of VR in the curriculum of dental schools. By achieving face and content validity of the surveys, the authors are confident that the instruments used for data collection are relevant to the field of dental education as assessed by both students and faculty. However, one limitation of this study is the relatively small number of academic institutions represented by both faculty and student participants. Furthermore, an overlap between faculty and student respondents was observed in only five dental schools, thus limiting the capacity to conduct institution-specific comparative analyses between two groups across all the participating institutions.

Conclusions

The current study highlighted the differences and similarities in the faculty and students' perspective on the use of VR in dentistry and identified barriers for VR adoption in dental education. The findings indicate that VR offers meaningful advantages, particularly by enabling standardized assessment of learner performance and repeatable skill practice under controlled conditions. To confirm these results and realize the full potential of technology, future studies should employ mixed methods designs combining quantitative and qualitative data. Such studies will guide effective implementation strategies, address barriers to adoption, and advance the evidence-based integration of VR in dental education.

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u ovoj studiji, jedna od prednosti uvrštavanja VR-a jest kalibracija nastavnika.

Jedan od izazova integracije VR-a jest osposobljavanje nastavnika. Prema standardu CODA-e *Razvoj nastavnika*, akademske institucije odgovorne su za ponovno ispitivanje odnosa između onoga što nastavnici rade i kako studenti uče kako bi se promijenile od mudroga autoriteta koji prenosi informacije do posrednika učenja i dizajnera iskustava učenja koja studente stavljaju u pozicije za učenje na temelju djelovanja (25). O nekim ograničenjima koja su posebno spomenuli studenti u ovoj studiji, poput realističnoga haptičkog doživljaja ili točnog uporišta za prste, već su izvijestili i drugi (15, 23).

Ovo je, koliko je autorima poznato, prvo nacionalno istraživanje u kojemu su prikupljeni podatci od 30 stomatoloških fakulteta o percepcijama studenata i nastavnika o integraciji VR-a u kurikulum. Budući da su ankete imale potvrđenu valjanost izgleda i sadržaja, autori smatraju da su instrumenti relevantni za područje dentalnog obrazovanja. Međutim, jedno od ograničenja studije jest razmjerno mali broj akademskih institucija zastupljenih objema skupinama ispitanika. Također, preklapanje odgovora studenata i nastavnika zabilježeno je na samo pet fakulteta, što ograničava mogućnost detaljne usporedbe na razini pojedinih institucija.

Zaključak

U ovoj studiji istaknute su razlike i sličnosti u perspektivama nastavnika i studenata o korištenju virtualne stvarnosti (VR) u stomatologiji te identificirane prepreke za prihvaćanje VR-a u stomatološkom obrazovanju. Nalazi upućuju na to da VR ima značajne prednosti, posebno zato što omogućuje standardiziranu ocjenu studenta i mogućnost vježbanja u kontroliranim uvjetima. Da bi se potvrdili ovi rezultati i ostvario puni potencijal tehnologije, u budućim studijama trebale bi se koristiti mješovite metode koje kombiniraju kvantitativne i kvalitativne podatke. U takvim će se studijama uvoditi učinkovite strategije implementacije, rješavati prepreke u prihvaćanju VR-a i poboljšati njegova integracija u stomatološko obrazovanje temeljeno na dokazima.

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Doprinosi autora

J. S. – metodologija, prikupljanje podataka, formalna i statistička analiza i interpretacija, odgovornost za vizualizaciju i pisanje izvornog teksta; K. D., M. S. S. – metodologija, pisanje i lektoriranje teksta; V. R., S. J. – pisanje i lektoriranje teksta; I. F. D. – konceptualizacija, metodologija, nadzor, pisanje i lektoriranje teksta. Svi autori pročitali su tekst i složili se s objavljenom verzijom.

Sažetak

Cilj: Cilj ovog istraživanja bio je razumjeti percepcije nastavnika i predstavnika studenata o postojećim tehnologijama virtualne stvarnosti (VR) koje se uvrštavaju u nastavne planove i programe stomatoloških fakulteta u SAD-u. **Metode:** Za ovo presječno istraživanje korištena su dva validirana instrumenta (valjanost izgleda i sadržaja). Nacionalni predstavnici (68 studenata i 68 prodekana) stomatoloških fakulteta u SAD-u pozvani su da sudjeluju u anketama Qualtricsa. Ankete su bile podijeljene u četiri dijela: opće informacije, znanje o VR-u, institucionalno iskustvo s VR-om te percepcija važnosti VR-a. **Rezultati:** U istraživanju su sudjelovali predstavnici nastavnika i studenata 30 stomatoloških fakulteta (44 %). Svi su se jednoglasno složili da bi VR tehnologija trebala biti u kurikulumima stomatoloških škola. Nastavnici s iskustvom, kad je riječ o VR-u, naveli su kao najveću prednost standardizaciju i objektivnost (55 %, n = 12). Studenti su se s njima složili u vezi s prednostima VR-a, ali su važnijom smatrali ponovljivost (63 %, n = 5). Najveće ograničenje koje su naveli nastavnici bio je trošak, a studenti su istaknuli različita ograničenja. **Zaključak:** U ovoj studiji istaknute su sličnosti i razlike u percepcijama nastavnika i studenata o trenutnoj uporabi VR-a u stomatologiji. Rezultati upućuju na to da VR ima značajne prednosti kad je riječ o uvrštavanju u kurikule, posebno zato što omogućuje standardiziranu, objektivnu procjenu studentskoga rada te ponavljanje vježbanja vještina u kontroliranim uvjetima. U budućnosti se preporučuje primjena mješovitih metodoloških pristupa kako bi se dodatno istražili i potvrdili ovi nalazi.

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