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PREGLED NEDAVNIH DOSTIGNUĆA U DEČJOJ STOMATOLOGIJI

A REVIEW OF RECENT ADVANCES IN PAEDIATRIC DENTISTRY

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Sažetak

Uvod: *Do značajnih izmena u dečjoj stomatologiji došlo je usled razvoja tehnologije, materijala i znanja o bolestima. Kada se radi sa decom, najvažnijniji su prijatnost, brzina, bezbednost i primena konzervativne terapije. Iako se sve navedeno odnosi i na odrasle pacijente, od posebnog je značaja da se sa stomatološkim pregledima započne u detinjstvu, ali i da ovo iskustvo ne bude stresno ni za pacijente ni za roditelje. Uvođenje i korišćenje nove tehnologije izazvalo je promenu paradigme u stomatološkoj praksi, obeleženu razvojem novih i superiornih restaurativnih materijala koji omogućavaju da se ukloni manje zubnog tkiva. Sada smo postigli terapijske ciljeve otkrivene u pružanju minimalno invazivne stomatologije. Rana stomatološka dijagnoza postala je u poslednje vreme sve važnija. Poslednjih nekoliko godina, rano detektovanje karijesa dobilo je na značaju, budući da je konzervativna stomatologija i dalje u prvom planu. Stomatolog treba da naglasi važnost rane identifikacije karijesa i da ukaže na najmanje invazivne alternative lečenja, posebno u dečjem uzrastu. Tradicionalne metode otkrivanja karijesa često ne uočavaju rane lezije gleđi koje se nisu razvile u kavitaciju. Upravo zbog toga, razvijeno je nekoliko inovativnih strategija za rano otkrivanje karijesa.*
Cilj: *Cilj ovog rada bio je da pruži opširne informacije o novim restaurativnim materijalima i tehnologijama za otkrivanje karijesa i da sumira nedavna dostignuća u dečjoj stomatologiji.*
Zaključak: *U ovom preglednom radu predstavljena je oprema koja se trenutno koristi u stomatološkoj dijagnostici, kao i ona koja u te svrhe može biti korišćena u budućnosti. Razvoj tehnologije je toliko brz da je skoro nemoguće ostati u toku. Shodno tome, možda je za svakog pedodonta ili pedodontsku kliniku najbolje rešenje da odabere opremu koja se najviše isplati.*

Ključne reči: *materijali za restauraciju zuba, tehnologija snimanja, laser, fluorescencija, spektroskopija, zvučni talasi, Cone Beam kompjuterizovana tomografija*

Abstract

Introduction: *As a result of developments in technology, materials, and illness knowledge, paediatric dentistry has experienced major changes. When dealing with children, comfort, speed, safety, and conservative therapies are paramount. Of course, this also applies to adults, but getting youngsters started with dental appointments and making the experience stress-free for both patients and parents is extremely vital. The introduction and use of new technology caused a paradigm change in the practice of dentistry. This has been marked by the development of new and superior restorative materials that allow us to remove less tooth structure. We have now achieved the therapeutic goals discovered in giving more minimally invasive dentistry. Early dental diagnosis has become increasingly important in recent years. Early detection of dental caries has grown in relevance in recent years as conservative dentistry has remained at the forefront. The dentist should emphasize early identification of dental caries and the least invasive treatment alternatives, especially in paediatric patients. Traditional caries detection methods frequently miss early enamel lesions that have not developed into cavitation. As a result, several innovative strategies for detecting cavities early have been developed.*
Aim: *The purpose of the current literature is to provide broad information regarding new restorative materials and caries detection technologies and summarize recent advances in paediatric dentistry.*
Conclusion: *This overview highlighted a huge variety of current equipment that is either now used or can be utilized in dental diagnostics. Some of these devices are rather pricey and take up a lot of room. Technology evolves so quickly that it is impossible to stay up. As a result, possibly the best answer for each pedodontist or pedodontics clinic is to select the equipment with the greatest cost benefit.*

Key words: *tooth restorative materials, imaging technology, laser, fluorescence, spectroscopy, sound waves, Cone Beam Computed Tomography*

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Terapija karijesa od Black-a do danas

Prema rezultatima Nacionalne agencije o zdravlju i ishrani, karijes je najčešće hronično stanje kod dece. Pet puta je češći od astme i sedam puta češći od polenske groznice[1].

Prednosti restaurativne terapije čine: uklanjanje kavitacija ili defekata kako bi se eliminisala područja sklona karijesu, omogućilo zaustavljanje progresije demineralizacije zuba; obnavljanje strukture i funkcije zuba; sprečavanje širenja infekcije u zubnu pulpu i sprečavanje migracije zuba usled gubitka zubnih struktura. Restaurativna terapija može smanjiti životni vek zuba budući da ih čini sklonijim frakturama, ponavljajućim lezijama, neuspehu restauracije, izlaganju pulpe tokom ekskavacije karijesa i mogućim oboljenjima pulpe. Osim toga, postoji opasnost od jatrogenih povreda susednih zuba.

Konvencionalna metoda lečenja karijesa podrazumeva postavljanje materijala za restauraciju zuba. Koncept G. V. Blacka „ekstenzija u cilju prevencije", koji je bio standard duže od jednog veka, sada se može smatrati arhaičnim[2]. Ovaj pristup je podrazumevao uklanjanje zubnog tkiva proširenjem preparacije kaviteta u nekariozne žlebove. U Blackovo vreme nije bilo strategija, metoda i materijala za prevenciju karijesa, a ni validiranih alternativnih lekova. Karijes se obično lečio u kasnijoj fazi. Karijesni proces, uključujući cikluse demineralizacije i remineralizacije, pogrešno se tumačio. Tada je materijal najčešće korišćen za restauraciju zuba bio amalgam, a preparacija kaviteta uslovljavala je potrebu za retencijom. Prednosti amalgama ogledaju se u jednostavnosti primene i jakoj čvrstoći na pritisak. Amalgamske plombe imaju razne nedostatke, među kojima su slabljenje zuba, nemogućnost formiranja hemijske veze sa zubima i perkolacija, koja izaziva sekundarni karijes i promenu boje zuba.

Zahvaljujući Dawsonu i Makinsonu, koji su devedesetih godina prošlog veka prvi upotrebili izraz „minimalna interventna stomatologija" (sada se umesto toga koristi „minimalno invazivna stomatologija" ili MID), došlo je do pomaka u načinu preparacije kaviteta za primenu restaurativnih materijala[3]. Ovim konceptom naglašavaju se rana identifikacija i procena rizika od pojave karijesa, remineralizacija demineralizovane gleđi i dentina, prevencija karijesa, manje invazivne operativne procedure i mogućnost popravke umesto zamene restauracija. Sveobuhvatni cilj je da se omogući da zubi očuvaju svoju funkciju do kraja života.

Caries treatment from Black today

According to the National Health and Nutrition Examination Survey findings, caries is the most frequent chronic condition among children. It is five times as frequent as asthma and seven times as common as hay fever[1].

Restorative therapy benefits include removing cavitations or defects to eliminate caries-prone areas, halting the progression of tooth demineralization, restoring tooth structure and function, preventing the spread of infection into the dental pulp, and preventing tooth shifting due to tooth structure loss. Restorative therapy has the potential to shorten the lifespan of teeth by rendering them more prone to fracture, recurring lesions, restoration failure, pulp exposure during caries excavation, and future pulpal problems, in addition to the danger of iatrogenic injury to neighboring teeth.

The conventional method of treating caries is to put a dental restorative. G. V. Black's "extension for prevention" concept was the standard for more than a century and might be regarded archaic now[2]. This approach eliminated extra tooth structure by extending the cavity preparation into noncarious grooves. There was a paucity of strategies, methods, and materials for caries prevention at the time of Black, as well as a lack of validated alternative remedies. Caries was commonly treated at a later stage. There was a misunderstanding of the caries process, including the demineralization and remineralization cycles. At the time, the predominant dental restorative material was amalgam, and the preparation design mirrored the necessity to induce retention. Amalgam has advantages such as simplicity of application and strong compressive strength. Amalgam fillings have various disadvantages, including weakening the teeth, the inability to form a chemical bond with the teeth, filling leakage causing secondary caries, and tooth discoloration.

Thanks to Dawson and Makinson, who were the first to coin the phrase "minimal interventional dentistry" (now known as "minimally invasive dentistry" or MID) in the 1990s, there was a shift in the way cavities were prepared for the application of restorative materials[3]. Early caries identification and risk assessment, remineralization of demineralized enamel and dentin, caries prevention, less invasive operational procedures, and the ability to repair rather than replace restorations are all emphasized in this concept. The overarching objective is to keep the teeth functioning for the rest of one's life. This conservative approach decreases restorative time, pain, tension, and anxiety, all of which are critical factors for paediatric dentistry patients.

Ovaj konzervativni pristup smanjuje vreme restauracije, bol, napetost i anksioznost – kritične faktore za pacijente dečjih stomatologa. U MID-u se akcenat stavlja na upotrebu adhezivnih stomatoloških materijala i metoda. Ovi materijali omogućavaju uklanjanje karijesa sa minimalnom preparacijom kaviteta, što rezultira smanjenim gubitkom strukture zuba. Tako je zahvaljujući činjenici da nema potrebe za uključivanjem retencije u preparaciju[4].

Uzrok sve učestalije upotrebe kompozita leži u napretku tehnologije punila i potrebi javnosti da restauracije budu zadovoljavajuće u estetskom smislu[5]. Za razliku od amalgama, kompoziti imaju nekoliko prednosti. Prvo, mogu se napraviti manje preparacije kaviteta, što rezultira boljim očuvanjem zubnih struktura. Drugo, mehanička retenciija više nije potrebna[6]. Međutim, nije sve tako jednostavno. Kompozitnim smolama i zamenama od akrilne smole davala se prednost 1978. godine pošto su imale stabilniju boju, duže su se lepile za zub i češće odgovarale boji zubnog tkiva. Ipak, vremenom bi ove smole počele da se razgrađuju. Na sreću, kreativnost je trijumfovala i otkriveno je da u restauraciju treba uključiti i proceduru nagrizanja kada se koristi vezujuća supstanca. Stoga se restauracija i adhezija započinju unutar zuba češće nego sa spoljašnje strane. Hibridni kompoziti poboljšali su se devedesetih i dvehiljaditih godina, a razlike su postale toliko velike da se ova tehnologija počela efikasno koristiti na bočnim (zadnjim) zubima. Današnje kompozite koristi najveći deo stomatologa. Kao njihove prednosti možemo izdvojiti sledeće: prilagođavaju se nepravilnosti zuba; mogu se postaviti u sloju koji odgovara strukturi zuba; dostupna je široka paleta boja koja odgovara postojećim zubima; veoma su fleksibilni.

Premda je šezdesetih godina prošlog veka bilo dostupno nekoliko restaurativnih materijala, uključujući amalgam, kompozit, livene legure i dr., nijedan od njih nije se mogao odrediti kao optimalni restaurativni materijal. Idealan materijal za restauraciju jeste onaj koji je estetski prijatan, biokompatibilan, adhezivan, antikancerogen i dostupan po razumnoj ceni. Istraživači su tada počeli da rade na razvoju supstance koja ne bi samo delovala kao restaurativno sredstvo već bi i zamenila gleđ i dentin. Kao što su Vilson i Kent istakli sedamdesetih godina, ovo je 1969. godine dovelo do uvođenja glas-jonomer cementa (GJC). Stakleni polialkenoati su materijali koji se sastoje od kalcijum-aluminofluorosilikatnog ili stroncijum-aluminofluorosilikatnog staklenog praha (baze) i polimera rastvorljivog u vodi (kiseline).

The use of adhesive dental products and methods is emphasized in MID. These materials enable caries removal with a minimum cavity preparation design, resulting in reduced tooth structural loss. This is due to the fact that there is no need to include retention in the preparation[4].

Composites are being used more often. The cause for this is advancements in filler technology and public demand for more aesthetically pleasing restorations[5]. As opposed to amalgam, composites have several advantages. First, smaller cavity preparations can be made, resulting in more residual tooth structure. Second, mechanical retention is no longer required[6]. But it wasn't quite that straightforward. Composite resins and acrylic resin replacements were widely favored in 1978 because they had higher color stability, clung to the tooth longer, and were more likely to match the color of the tooth tissue. However, as time passed, these resins began to degrade more regularly as well. Fortunately, creativity triumphed, and it was discovered that restorations should incorporate an etching procedure when the bonding substance was used. As a result, the restoration and adhesion began within the tooth rather than only on the exterior. Hybrid composites improved in the 1990s and 2000s, and the differences grew so large that this technology began to be utilized effectively on posterior (back) teeth. Today's composites are utilized by the vast majority of dentists. They have the benefit of adjusting to a tooth's irregularity; their thickness may be stacked to conform to the tooth's structure; a wide color range is available to match existing teeth; and it is very flexible.

Back in the 1960s, there were several restorative materials available, including amalgam, composite, cast alloys, and so on, but none of them could be classified as optimal restorative materials. An ideal restorative material is one that is aesthetically pleasing, biocompatible, adhesive, anticarcinogenic, and reasonably priced. The researchers then started working on developing a substance that would not only operate as a restorative but also replace enamel and dentin. As Wilson and Kent described in the 1970s, this resulted in the introduction of *Glass Ionomer Cement (GIC)* in 1969. Glass polyalkenoates are materials composed of calcium or strontium aluminofluorosilicate glass powder (base) and a water-soluble polymer (acid). Kent referred to such materials as "glass ionomer" cements, and the term has become part of dental parlance. The benefits of glass ionomer cement include adhesion, good marginal seal, fluoride release, and biocompatibility.

Kent je takve materijale nazvao „glas-jonomernim" cementima, a termin je postao deo stomatološkog rečnika. Prednosti glas-jonomer cemenata jesu adhezija, dobro rubno zaptivanje, oslobađanje fluorida i bio-kompatibilnost. Međutim, imali su razočaravajuće kliničke učnike kod mlečnih molara budući da su osetljivi na dehidraciju u ranoj fazi procesa vezivanja i krti, što ih čini nepodesnim za upotrebu u područjima izloženim pritisku[7-9]. Stoga, pokušalo se da se svojstva GJC-a poboljšaju modifikovanjem hemijskog sastava originalnog praha. U skladu sa tim, napravljen je veći broj modifikacija.

Smolom modifikovani glas-jonomeri: Da bi se promenile fizičke karakteristike i translucencija standardnog GJC-a, u kiselu tečnu komponentu dodate su male količine grupa smole koje se polimerizuju svetlošću (često 2-hidroksietil metakrilat ili HEMA).

Metalom ojačani glas-jonomeri: Formiranje „kermeta" (keramika–metal) postiže se kombinovanjem praha amalgamske legure i sinterovanih čestica srebra sa staklenom komponentom. Bilo je dokaza o značajnom poboljšanju fizičkih kvaliteta GJC-a. Naknadno istraživanje o ovom materijalu otkrilo je da ima manju otpornost na karijes od običnih glas-jonomera.

Visokoviskozni autocare glas-jonomeri: Ovi cementi su dizajnirani da obezbede robusnu adhezivnu restauraciju, sa sposobnošću oslobađanja fluora. Pogodni su za lečenje pacijenata u udaljenim, nerazvijenim oblastima u kojima stomatološka nega nije dostupna.

Polikselinski modifikovane kompozitne smole (kompomeri): Rečju „kompomer" implicira se želja da se integrišu komponente i prednosti GJC-a i kompozita. Imali su estetiku kompozita i svojstvo oslobađanja fluora, karakteristično za GJC. Međutim, oslobađanje fluora bilo je manje nego kod klasičnog GJC-a; zidovi kaviteta malo su apsorbovali fluor zbog toga što sredstvo za vezivanje smole funkcioniše kao barijera.

Cirkonijumom ojačan GJC: Cirkonijumom prožet glas-jonomer cement (ZIRCONOMER) nov je dodatak porodici GJC-a, razvijen radi prevazilaženja svih poteškoća koje su dosad postojale kod tradicionalnih jonomera. Mehaničke osobine GJC praha poboljšane su kombinovanjem hidroksiapatita i cirkonijuma (HAp/ZrO2) pri 4% zapreminskoj koncentraciji.

GJC ojačan vlaknima: Kada su se aluminijumska vlakna iskombinovala sa staklenim prahom, poboljšala su dubinu očvršćavanja, otpornost na habanje i čvrstoću na savijanje, a smanjila polimerizaciju.

However, it had a disappointing clinical performance in primary molars because they are sensitive to dehydration early in the setting process and are brittle materials, making them unsuitable for use in stress-bearing areas[7-9]. Therefore, attempts have been made to improve the properties of GICs by modifying the chemical composition of the original powder. For these reasons, a vast number of modifications have been made to GIC.

Resin Modified Glass Ionomer: To change the physical characteristics and translucency of standard GIC, small amounts of light-polymerizable resin groups (often 2-hydroxyethyl methacrylate or HEMA) were added to the acidic liquid component.

Metal Reinforced Glass Ionomers: Forming a "Cermet" (ceramic-metal) by combining amalgam alloy powder and sintered silver particles with a glass component. There was evidence of a considerable improvement in the physical qualities of GICement. Further study on this material revealed that it had lower caries resistance than ordinary glass ionomers.

High-Viscosity Autocare Glass Ionomers: These cements were designed to provide a robust adhesive restoration with fluoride-releasing capabilities to treat patients in distant, underdeveloped areas where dental care is unavailable.

Polyacid Modified Composite Resins (Compomers): The word "Compomer" implies a desire to integrate the components and advantageous qualities of both GIC and composite. They had the aesthetics of composites as well as the fluoride-releasing attribute of GIC, albeit the fluoride release was minor when compared to normal GIC since there was little fluoride absorption by the cavity walls due to the resin bonding agent functioning as a barrier.

Zirconia Reinforced GIC: Zirconia-infused glass ionomer cement (ZIRCONOMER) is a new addition to the GIC family that has been developed to overcome all of the difficulties that have afflicted traditional ionomers up to this point. The mechanical properties of GIC powder were optimized by combining Hydroxyapatite and Zirconia (HAp/ZrO2) at 4% volume concentration.

GIC with Fibre Reinforcement: When alumina fibres were combined with glass powder, they improved curing depth, wear resistance, and flexural strength while decreasing polymerization. A continuous network/scaffold of alumina and silicon dioxide ceramic fibres is used in this polymeric stiff inorganic matrix technology.

Kontinuirana mreža/nosača od aluminijum-dioksid i silicijum-dioksid keramičkih vlakana koristi se u ovoj tehnologiji polimerne krute neorganske matrice.

GJC koji sadrži prolin: Posredi je GJC koji sadrži amino-kiseline, sa poboljšanom površinskom tvrdoćom, brzim vezivanjem i većom sposobnošću sorpcije vode bez uticaja na oslobađanje fluorida. Procenjena je i njegova upotreba u svojstvu koštanog cementa zbog niske citotoksičnosti i jake bio-kompatibilnosti.

Kalcijum-aluminat GJC: Ova svojstva GJC-a otkrivaju mešavinu kalcijum-aluminata i GJC-a za cementiranje. Prednosti su viši pH tokom očvršćavanja, manje marginalno curenje, poboljšana biokompatibilnost i povećana stabilnost i snaga.

Nanoglas-jonomeri sa modifikacijom praha: Kombinovanje standardnog glas-jonomera sa staklenim česticama nano veličine, kao što su nanoapatit i nanofluorapatit, smanjuje vreme vezivanja i povećava čvrstoću na pritisak i modul elastičnosti nakon sedam dana u destilovanoj vodi.

Smolom modifikovani GJC (SMGJC) sa nanopunjenjem: Da bi se unapredila mehanička svojstva, SMGJC-ima su dodati punioci nano veličine i biokeramičke čestice. Umesto mikromehaničke interakcije, otkrivena je povećana jonska veza sa zubom.

GJC impregnirani hlorheksidinom oslobodili su približno 10 ppm fluorida u toku prvih 48 sati nakon postavljanja u kavitet. Može im se dodati hlorheksidin-diglukonat kako bi se pojačala njihova antibakterijska svojstva[10-16].

Pored savremenih kompozitnih i glas-jonomer cemenata, postoji nekoliko materijala koje možemo prikazati kao stomatološke materijale koji se koriste odnosno kao materijale koji će se koristiti u dečjoj stomatologiji. U nastavku rada navode se neki od njih.

Srebro-diamin-fluorid (SDF) predstavlja fluoridnu tečnost na bazi srebra koja se koristi za sprečavanje širenja karijesa denaturacijom i razbijanjem mikroorganizama u zahvaćenom regionu. SDF se koristi kao dopuna restaurativnoj nezi zbog svoje sposobnosti da uđe u dentinske tubule i smanji bol u dubokim lezijama onda kada se primenjuje u indirektnom prekrivanju pulpe. Kada se uzima sam, SDF ima sposobnost da zaustavi početne lezije. Uklanjanje ovih lezija kod dece u ranom uzrastu, koja nisu u stanju da se pridržavaju pravila u konvencionalnom stomatološkom okruženju, može eliminisati potrebu za lečenjem pod opštom anestezijom ili za restaurativnim procedurama[17].

GIC-containing proline: An amino acid-containing GIC with improved surface hardness, rapid setting, and higher water sorption capabilities without impacting fluoride release. It was also evaluated for usage as a bone cement due to its low cytotoxicity and strong biocompatibility.

Calcium Aluminate GIC: This GIC's properties reveal a mixture of calcium aluminate and luting GIC. The benefits include a higher pH during curing, less marginal leakage, enhanced biocompatibility, and increased stability and strength.

Powder-Modified Nano Glass Ionomers: Combining standard glass ionomer with nano-sized glass particles such as nanoapatite and nano-fluorapatite reduced setting time and increased compressive strength and elastic modulus after 7 days in distilled water.

Nano-Filled Resin-Modified GIC: To increase mechanical qualities, nano-sized fillers, and bioceramic particles were added to RMGICs. Instead of micromechanical interaction, increased ionic bonding with a tooth was detected.

GICs impregnated with chlorhexidine released approximately 10 ppm of fluoride over the first 48 hours after being placed in the created cavity. Chlorhexidine digluconate can be added to it to boost its antibacterial properties[10-16].

Aside from contemporary composite and glass ionomer cements, there are several materials that we can fairly stately represent a future period of dental materials that are or will be employed in pediatric dentistry. Some of them are:

Silver Diamine Fluoride (SDF) is a fluoride liquid based on silver that is used to prevent caries from spreading by denaturing and breaking down microorganisms in the affected region. SDF is used as a complement to restorative care due to its ability to enter dentinal tubules and reduce pain in deep lesions when applied in indirect pulp therapy. When taken alone, SDF has the capacity to arrest incipient lesions. Arresting these lesions in young children who are unable to comply in a conventional dental setting has the potential to eliminate the need for treatment under general anaesthetic or restorative procedures[17].

Active bioactive restoratives: Bioactive materials that operate well in a moist oral environment, neutralize factors that cause tooth decay, provide preventive advantages, and maximize remineralization potential. ACTIVA™ the first dental resin containing a shock-absorbing rubberized resin component, reactive ionomer glass fillers, and a bioactive ionic resin matrix. Bioactive products imitate the physical and chemical qualities of real teeth.

Bioaktivni materijali: Bioaktivni materijali koji dobro funkcionišu u vlažnom oralnom okruženju neutrališu faktore koji uzrokuju karijes, pružaju preventivne prednosti i dovode do maksimuma potencijala remineralizacije. ACTIVA™ je prva stomatološka smola koja sadrži komponentu gumirane smole, punila od reaktivnog jonomernog stakla i bioaktivnu jonsku smolu. Bioaktivni proizvodi imitiraju fizičke i hemijske kvalitete pravih zuba. Uključujući se u cikluse jonske razmene, ovi materijali aktivno učestvuju u upravljanju prirodnom hemijom naših zuba i pljuvačke, čime pomažu u očuvanju oralnog zdravlja i strukture zuba[18].

Cention N: Tečnost *Cention N* sastoji se od četiri monomera koja se obično nalaze u smolastim kompozitima. S obzirom na to da mu nedostaju kiseli monomeri i voda, od samog početka izostaje sposobnost adhezije (proizvođač to signalizira lepkom u šupljinama koje se ne zadržavaju). Tečnost takođe sadrži aktivatore fotopolimerizacije i fotopolimerizatore, što je potencijalno čini pravim materijalom za punjenje. Njenu osobenost čini sastav praha ovog materijala, posebno reaktivna punila koja sadrži. Ovaj proizvod kombinacija je praha i tečnosti koja se mora ručno mešati spatulom. Poput giomera i kompomera, *Cention N* emituje jone, pre svega fluor, kada se unese u oralnu sredinu, naročito onu koja je kisela[19,20].

Surefil One prvenstveno se sastoji od poliakrilne kiseline visoke molekularne težine funkcionalizovane sa grupama koje mogu da se polimerizuju – kompanija ih naziva „modifikovani sistem polikiselina" (MOPOS). U pogledu strukture, ova poliakrilna kiselina slična je *Vitrebond* kopolimeru koji se nalazi u *Vitremeru* i *Ketac Nano*. Štaviše, tečnost sadrži monomere sa dva fotopolimerizujuća kraja koja deluju kao unakrsni vezivač između funkcionalizovanih lanaca poliakrilne kiseline. Naposletku, smesa uključuje hemikalije za fotopolimerizaciju i hemopolimerizaciju, kao i malo vode. U principu, ovaj materijal prava je supstanca za punjenje, budući da dolazi u obliku kapsule za jednokratnu upotrebu koja se mora mehanički protresti pre upotrebe. *Surefil One* je neobičan po tome što ga je proizvođač odobrio za upotrebu u svim vrstama restauracija[21].

Detection and diagnosis of dental caries

Ako se rano otkrije i dijagnostikuje, zubni karijes se lakše i jeftinije leči. Takođe, potrebno je manje vremena za obnovu zuba.

By engaging in ionic exchange cycles, these materials actively participate in the management of the natural chemistry of our teeth and saliva. As a result, they aid in the preservation of oral health and tooth structure[18].

Cention N: The liquid of *Cention N* is composed of four monomers that are commonly found in resin composites. It lacks acidic monomers and water; therefore, it lacks adhesive capability from the start (the maker signals this with an adhesive in non-retentive cavities). The liquid also contains photopolymerization and photopolymerization activators, making it potentially a true bulk-fill material. This material's powder composition, particularly the reactive fillers it includes, is its distinctive feature. This product is a powder-liquid combination that must be spatulated by hand. *Cention N*, like giomers and compomers, emits ions, most notably fluoride, when introduced into the oral environment, particularly in an acidic environment[19,20].

Surefil One is primarily composed of a high molecular weight polyacrylic acid that has been functionalized with polymerizable groups, which the company refers to as the Modified Polyacid System (MOPOS). In terms of structure, this polyacrylic acid is similar to the *Vitrebond* copolymer found in *Vitremer and Ketac Nano*. Furthermore, the liquid contains monomers with two photo-polymerizable ends that act as a cross-linker between functionalized polyacrylic acid chains. Finally, the mixture includes photopolymerization and chemopoly-merization chemicals, as well as some water. In principle, this material is a real bulk-fill substance because it comes in the shape of a single-use capsule that must be mechanically vibrated before use. *Surefil One* is unusual in that it is approved by the manufacturer for use in all types of restorations[21].

Detection and diagnosis of dental caries

Dental caries is easier to treat, less expensive to treat, and takes less time to rebuild teeth if discovered and diagnosed early. It typically originates in the cracks on the occlusal surface of the tooth. The major instruments utilized in traditional examination for caries detection are visual inspection, tactile sensation, and radiography. While these methods are useful for detecting cavitated lesions, they are typically insufficient for detecting early lesions. As a consequence of these deficiencies, new detection techniques have been developed to aid in improved

Obično nastaje u fisurama okluzalnih površina zuba. Glavne metode koje se koriste u tradicionalnoj dijagnostici karijesa jesu vizuelna inspekcija, taktilni osećaj i radiografija. Iako su ove metode korisne za otkrivanje kavitacija, obično nisu dovoljne za otkrivanje početnih lezija. S ciljem da se otklone ovi nedostaci, razvijene su nove tehnike detekcije koje olakšavaju dijagnozu. Bez obzira na savremene metode dijagnostikovanja karijesa, pregledi usne duplje i vizuelni pregledi najbolji su način da se identifikuju sumnjive lezije. Međutim, postoji niz dostupnih aktuelnih dijagnostičkih procedura i tehnika koje mogu otkriti čak i najsitnije promene u zubnom tkivu[22].

Radiografija

Radiografija je veoma korisna u detekciji karijesnih lezija, posebno onda kada one nisu klinički vidljive. Zbog upotrebe fluorida, ne dolazi do pucanja površine gleđi kod pacijenata sa malo karijesa, što otežava dijagnozu karijesa. Prevalencija takvih lezija naglo je porasla poslednjih godina[23]. Studije su pokazale da je radiografija sa nagriznim krilcem efikasan pristup za otkrivanje aproksimalnog i skrivenog karijesa[24].

Digitalna radiografija

Stomatolozi uveliko koriste digitalne stomatološke rendgenske snimke (digitalne rendgenske snimke) za identifikaciju i dijagnozu oralnih problema i bolesti, kao i tokom lečenja i praćenja bolesti. Digitalna radiografija predstavlja oblik rendgenskog snimanja koji zamenjuje standardni fotografski rendgenski film digitalnim rendgenskim senzorima s ciljem da se obezbede poboljšane kompjuterske slike zuba, desni i drugih oralnih struktura i bolesti. Digitalne dentalne slike dobijaju se pomoću jedne od triju metoda: direktne, indirektne ili poluindirektne. Direktna tehnika snima slike pomoću elektronskog senzora postavljenog u usta. Indirektni pristup koristi skener rendgenskog filma za generisanje digitalnih slika tipičnih rendgenskih snimaka zuba. Za pretvaranje zubnih rendgenskih zraka u digitalni film poluindirektni digitalni pristup upotrebljava senzor i skener. Tipovi ekstraoralnih rendgenskih zraka uključuju panoramske rendgenske snimke (Panorex), kompjutersku tomografiju sa više preseka (MCT), cefalometrijske projekcije i sijalografiju.

there is a pronounced disruption of the sutural articulation of the maxilla to the remaining nine bones of the craniofacial complex, enabling a reaction to the forces of protraction[22].

Radiography

Radiography is quite useful in finding caries lesions, especially when they are not clinically evident. Because of fluoride usage, the surface of enamel does not break down in low caries populations, making caries diagnosis more difficult. The prevalence of such lesions has skyrocketed in recent years[23]. Bitewing radiography has been shown in trials to be an efficient approach for detecting proximal and concealed caries[24].

Digital radiography

Digital dental radiographs (digital X-rays) are rapidly being used by dental practitioners to identify, diagnose, treat, and monitor oral problems and illnesses. Digital radiography is a form of X-ray imaging that replaces standard photographic X-ray film with digital X-ray sensors to provide improved computer pictures of teeth, gums, and other oral structures and diseases. Digital dental pictures are obtained using one of three methods: direct, indirect, or semi-indirect. The direct technique records pictures using an electronic sensor implanted in the mouth. The indirect approach uses an X-ray film scanner to generate digital pictures of typical dental X-rays. To convert dental X-rays into digital film, the semi-indirect digital approach includes a sensor and scanner. Types of extraoral X-rays include Panoramic (Panorex) X-rays, MCT (multi-slice computed tomography), Cephalometric projections, and Sialography.

Digital subtraction radiography (DSR)

Subtraction radiography improves the visibility of radiographic changes between two radiographs by removing unchanging backdrop disturbances. Subtraction was first accomplished in angiography by utilizing positive and negative prints. DSR has improved significantly in the identification of oral and maxillofacial lesions. This technology is employed in periodontal diagnostics because it has the capacity to identify bone alterations by as little as 1%. Another application of DSR is in the imaging of the temporomandibular joint (TMJ), particularly with panoramic. TMJ imaging programs permitted imaging of the

Digitalna suptrakciona radiografija

Suptrakciona radiografija poboljšava vidljivost radiografskih promena između dvaju radiografa tako što uklanja nepromenljive smetnje u pozadini. Suptrakcija je najpre postignuta u angiografiji korišćenjem pozitivnih i negativnih otisaka. Digitalna suptrakciona radiografija (DSR) značajno je poboljšana u identifikaciji oralnih i maksilofacijalnih lezija. Ova tehnologija koristi se u parodontološkoj dijagnostici pošto ima kapacitet da identifikuje koštane promene za samo 1%. DSR se primenjuje i u snimanju temporomandibularnog zgloba (TMZ), posebno sa panoramskim snimcima. Programi snimanja TMZ-a dozvoljavaju snimanje desnih i levih kondila donje vilice u otvorenim i zatvorenim pozicijama na jednom filmu. Međutim, glava kondila i intraartikularni prostor nisu jasno prikazani zbog superponiranja okolnih struktura i kosih projekcija zgloba. DSR se takođe koristi za procenu napredovanja, zaustavljanja ili regresije kaustičnih lezija. Čini se da kontrast između dveju fotografija predstavljaju tamni i svetli delovi. Ova metoda se u velikoj meri koristi i u parodontologiji za identifikaciju karijesa i za merenje gubitka koštane mase[25,26].

Transiluminacija

Transiluminacija u stomatologiji prvi put je sagledana u knjizi dr Williama Johna Camerona „Dijagnostika transiluminacijom: Traktat o upotrebi transiluminacije u dijagnozi infektivnih stanja zubnog procesa" 1922. godine[27]. Transiluminacija je prenos svetlosti kroz biološka tkiva. Odličan je način detekcije karijesa, fraktura, ograničenih otvora kanala korena i drugih kliničkih karakteristika. Deluje tako što ispušta jarku svetlost kroz bočnu stranu zuba. Može pozitivno uticati na dijagnostičke i terapijske sposobnosti kliničara. Indeks propuštanja svetlosti zdravih zubnih struktura veći je od onog kod zuba zahvaćenih karijesom ili kamencem. Linija preloma ili kalcifikovani otvor kanala korena takođe mogu ograničiti prenos svetlosti. Naime, ako se jako svetlo usmerava direktno na zub dok je druga strana svetlosti prigušena, ove kliničke pojave prikazaće se kao diskretne crne mrlje u inače briljantnoj strukturi. Vrh transiluminatora stavlja se na oralnu ili lingvalnu površinu zuba ili korena, a regija se može videti sa okluzalne površine ili površine koja se nalazi suprotno od transiluminatora.

right and left mandibular condyles in open and closed positions on a single film, however, the condylar head and intra-articular space were not clearly displayed due to the superimposition of surrounding structures and the joint's oblique projection. DSR has also been used to assess the advancement, stop, or regression of caustic lesions. The contrast between the two photographs appears to be dark and bright parts. This method is also widely used in periodontology for the identification of caries and the measurement of bone loss[25,26].

Transillumination

Transillumination in dentistry was first discussed in Dr. William John Cameron's book "Diagnosis by Transillumination: A Treatise on the Use of Transillumination in the Diagnosis of Infectious Conditions of the Dental Process" in 1922[27]. Transillumination is the transmission of light through biological tissues. Transillumination is a great way to see caries, fractures, restricted root canal orifices, and other clinical features. It works by shining a bright light through the side of the tooth and can significantly improve the clinician's diagnostic and treatment abilities. The index of light transmission of healthy dental structures is higher than that of caries or calculus. A fracture line or calcified root canal opening can also limit light transmission. As a result, if a strong light is shone directly on a tooth while other extraneous light is dimmed, these clinical entities will show as discrete black patches in an otherwise brilliant structure. The transilluminator tip is put on the tooth's or root's facial or lingual surface, and the region may be seen from the occlusal surface or the surface opposite the transilluminator. Depending on the region under inspection, direct eyesight or a dental mirror may be utilized for viewing. For cavities, endodontics, fractures, and so on, the exact positioning of the transilluminator varies. Transillumination's popularity as a diagnostic procedure has been considerably aided by the availability of sophisticated instruments designed specifically for this purpose. To provide the required bright white light, these transilluminators employ white light-emitting diode (LED) lamps. The light is then transferred without heat to the working area through a thin fibre-optic rod or fibre-optic wires. A crucial aspect is an ease with which a fibre-optic rod may be withdrawn and autoclaved to prevent cross-contamination between patients. The new gadgets' modest size and mobility make transillumination more practical to use.

U zavisnosti od regije koja se pregleda, promena se može posmatrati direktno ili stomatološkim ogledalom. Kada je reč o karijesu, endodonciji, frakturama i sl., tačno pozicioniranje transiluminatora varira. Popularnost transiluminacije kao dijagnostičke procedure umnogome je potpomognuta dostupnošću sofisticiranih instrumenata dizajniranih posebno u ove svrhe. Da bi obezbedili potrebno jarkobelo svetlo, ovi transiluminatori koriste bele svetleće diode (engl. *light-emitting diode* – LED). Svetlost se zatim bez toplote prenosi na radni prostor kroz tanku šipku od optičkih vlakana ili kroz optičke žice. Ključni faktor predstavlja lakoća sa kojom se fiberoptički štap može izvući i autoklavirati kako bi se sprečila kontaminacija među pacijentima. Skromna veličina i mobilnost novih uređaja čine transiluminaciju praktičnijom za upotrebu.

Fiberoptička detekcija

Svi oblici transiluminacije korišćenjem optičkih vlakana zasnivaju se na konceptu koji podrazumeva da se svetlost širi kroz optička vlakna od izvora svetlosti do zuba i da mora biti dovoljno svetla da pređe strukturu zuba. Transiluminacija optičkim vlaknima koristi se kao pomoćna dijagnostička procedura u dijagnostici prednjeg i zadnjeg inter-proksimalnog karijesa i okluzalnog karijesa, za otkrivanje kamenca, u proceni obojenih ivica kompozitnih smola, u proceni preloma kvržice i infrakcija zuba, kao alat za istraživanje za osvetljavanje endodontskog pristupa i otvora kanala korena u pulpnoj komori zuba u toku endodontskog tretmana, kao sredstvo poboljšanja procene otvora kanala korena u toku endodontskog lečenja, u proceni keramičkih restauracija kako bi se isključilo postojanje bilo kakvih preloma pre cementiranja, za kliničko ispitivanje linija loma i nabora na potpuno keramičkim restauracijama i prirodnim zubima, te za određivanje odgovarajućih preporuka za lečenje na osnovu nivoa spoljašnjeg bojenja. Metode koje koriste ovaj moćni izvor svetlosti poznate su kao FOTI (engl. *fiber-optic transillumination*) i digitalna slikovna optička transiluminacija (eng. *digital imaging fibre-optic transillumination*-DIFOTI). Putanja bliskog infracrvenog svetlosnog snopa u DIFOTI-ju razlikuje se između zvuka i povređenog tkiva. Nalazi se mogu sačuvati kao digitalne fotografije i prikazati na monitoru uz korišćenje DIFOTI-ja Vlakna usmeravaju svetlost na površinu zuba, a zub se sa obeju strana osvetljava vrhom ili senzorom koji se nalazi u plastičnom rukohvatu uređaja.

Fibre Optics Detection

Transillumination using fibre optics in all of its forms is based on the concept that light propagates through optical fibres from a light source to the tooth and must be bright enough to cross tooth structure. Fibre-optic transillumination is used as an adjunctive diagnostic aid for anterior and posterior interproximal caries and occlusal caries diagnosis; detection of calculus; evaluation of stained margins of composite resins; evaluation of cusp fractures and cracked teeth; as an exploration tool to illuminate endodontic access and root canal orifices within the pulp chamber of teeth during endodontic treatment; as a tool for improved evaluation of root canal orifices during endodontic treatment; for evaluating all-ceramic restorations to rule out any fractures before to cementation; for clinical examination of fracture and craze lines in all-ceramic restorations and natural teeth; and for determining suitable treatment recommendations based on the level of extrinsic staining. Methods utilizing this powerful light source are known as FOTI (fibre-optic transillumination) and digital imaging fibre-optic transillumination (DIFOTI). The path of the near-infrared light beam in DIFOTI differs between sound and injured tissue. The findings may be saved as digital photos and presented on a monitor using DIFOTI. Fibres guide the light onto the tooth surface, and the tooth is transilluminated from both sides by a tip or a sensor in the device's plastic handgrip. A small camera is built into the tip, and a digital image of the tooth is relayed to a monitor online. Images captured can be preserved in the database[28-32].

The Microlux Transilluminator® (Addent, Danbury, CT) detects anterior and posterior caries. It also aids in the visualization of crown fractures, root canal orifices, and root fractures without the requirement for X-rays. A simple push-button controls the dual-intensity operation and improves vision. The battery features a low-level indication, and the device contains a voltage regulator to provide consistent light output. It runs on two readily accessible AAA batteries. The Microlux 2 comes with a 2mm or 3mm light guide and accommodates all existing Microlux autoclavable accessories[33].

DEXIS CariVu™ is a small, portable caries diagnostic equipment that uses proprietary transillumination technology to help identify occlusal, interproximal, and recurring carious lesions and fractures. CariVu continues DEXIS' long legacy of offering straightforward, user-friendly diagnostic tools to the dentistry community[34].

Mala kamera ugrađena je u vrh, a digitalna slika zuba prenosi se na monitor na mreži. Snimljene slike mogu se sačuvati u bazi podataka[28-32].

The Microlux Transilluminator® (Addent, Danburi, CT) otkriva prednji i bočni karijes. Takođe pomaže u vizuelizaciji preloma krunice, otvora kanala korena i fraktura korena, i to bez potrebe za rendgenskim snimcima. Jednostavno dugme kontroliše rad dvostrukog intenziteta i poboljšava vid. Baterija ima indikaciju niskog nivoa, a uređaj sadrži regulator napona koji obezbeđuje konzistentan izlaz svetlosti. Koriste se dve lako dostupne AAA baterije. *Microlux 2* dolazi sa svetlosnim vodičem od 2 mm ili 3 mm i prihvata svu postojeću *Microlux* dodatnu opremu za autoklaviranje[33].

DEXIS CariVu™ je mala, prenosiva oprema za dijagnostiku karijesa koja koristi sopstvenu tehnologiju transiluminacije kako bi pomogla u identifikaciji okluzalnih, interproksimalnih i recidivirajućih karijesnih lezija i preloma. *CariVu* nastavlja dugu zaostavštinu *DEXIS* -a u ponudi jednostavnih dijagnostičkih alata lakih za upotrebu u stomatološkoj zajednici[34].

DIAGNOcam Vision Full HD® (KaVo, Biberach, Nemačka) pretvara zube u svetlosne provodioce korišćenjem bezbolnog lasera podešenog na određenu talasnu dužinu i uslovljava da bilo kakve lezije ili pukotine zaustave prirodni tok svetlosti, stvarajući senke na slici. Projektuje uživo zub na povezani monitor, pružajući stomatologu vođeni vizuelni pregled usne duplje. Ovaj proizvod prilično je delotvoran za otklanjanje problema kao što su rano otkrivanje karijesa okluzalnih, aproksimalnih i glatkih površina, sekundarnog karijesa i fraktura pre nego što se pojave komplikacije. *DIAGNOcam* pruža „tri u jedan” dijagnostiku pritiskom na dugme. Revolucionarna ideja „tri u jedan” proizvodi svetle, *Full HD* intraoralne, transiluminacione i fluorescentne slike. Dakle, tri klinički relevantne fotografije dobijaju se za manje od jedne sekunde i samo jednim klikom. Pored toga, korisnik može izabrati režim jedne fotografije ili kombinaciju dvaju ili triju režima za individualno optimizovani tok rada koji je idealan za proceduru tretmana[35].

Fluorescencija

Fluorescencija je vrsta foto-luminiscencije koju karakterišu apsorpcija objekta UV zračenja (od 1 nm do 400 nm nevidljive svetlosti) i spontana emisija dužih talasnih dužina (od 430 nm do 450 nm vidljive svetlosti).

DIAGNOcam Vision Full HD® (KaVo, Biberach, Germany) converts the teeth into a light conductor by using a painless laser tuned to a specific wavelength, causing any lesions or cracks to stop the natural flow of light, creating shadows in the imagery, and projects a live feed of teeth onto a connected monitor, providing the dentist with a guided visual tour of the mouth. This product is quite effective for catching problems like early detection of occlusal, approximal, smooth surfaces, secondary caries, and cracks before they grow too complicated. DIAGNOcam provides a three-in-one diagnostic with the stroke of a button. The revolutionary 3-in-1 idea produces bright, Full HD intraoral, transillumination, and fluorescence pictures. That is, three clinically relevant photos are created in less than a second and with only one click. In addition, the user can select a single photo mode or a combination of two or three modes for an individually optimized workflow that is ideal for the treatment procedure[35].

Fluorescence

Fluorescence is a type of photo-luminescence characterized by an object's absorption of UV radiation (1 nm to 400 nm invisible light) and spontaneous emission of longer wavelengths (430 nm to 450 nm visible light). Autofluorescence is the natural emission of light by biological structures when they absorb light, and it is used to differentiate light emission from fluorescent markers (fluorophores). The presence of endogenous fluorophores in the enamel and dentine accounts for tooth autofluorescence. Because of the energy difference, the colour of the emitted fluorescence light is always different from the colour of the excitation light, with a longer wavelength and lower photon energy. Thus, violet or blue excitation light will produce green, orange, or red emissions, all of which are longer wavelengths of visible light. It is generally known that the enamel and dentin both exhibit autofluorescence. Light absorption and reemission varies across enamel, dentin, and cementum, as well as between sound and carious tissues. As a result, fluorescence may be utilized to identify and further diagnose dental cavities. Fluorescent components can also be found in tooth plaque and oral bacteria. Aside from its use in caries detection and other tissue diagnostics, another important aspect of fluorescence revealed by the introduction of restorative materials into clinical dentistry is its relationship with the optical properties of teeth and the ability of said materials to reproduce it.

Autofluorescencija je prirodna emisija svetlosti bioloških struktura kada apsorbuju svetlost, a koristi se za razlikovanje emisije svetlosti od fluorescentnih markera (fluorofora). Prisustvo endogenih fluorofora u gleđi i dentinu objašnjava autofluorescenciju zuba. Zbog razlike u energiji, boja emitovane fluorescentne svetlosti uvek se razlikuje od boje ekscitacione svetlosti, sa dužom talasnom dužinom i manjom energijom fotona. Dakle, ljubičasta ili plava pobudna svetlost proizvešće zelenu, narandžastu ili crvenu emisiju, a sve su veće talasne dužine vidljive svetlosti. Opšte je poznato da i gleđ i dentin pokazuju autofluorescenciju. Apsorpcija i reemisija svetlosti variraju između gleđi, dentina i cementa, kao i između zdravih i karijesnih tkiva. Rezultat toga je da se fluorescencija može koristiti za identifikaciju i dalju dijagnozu kavitacija. Fluorescentne komponente takođe se mogu naći u zubnom plaku i oralnim bakterijama. Osim upotrebe u detekciji karijesa i dijagnostici oboljenja drugih tkiva, još jedan važan aspekt fluorescencije otkriven uvođenjem restaurativnih materijala u kliničku stomatološku praksu čini njen odnos sa optičkim svojstvima zuba i sposobnošću pomenutih materijala da je reprodukuju. U idealnoj situaciji, materijali za restauraciju treba da imaju nivo fluorescencije uporediv sa prirodnim zubima. To, nažalost, nije slučaj, čak ni kada je reč o savremenim stomatološkim materijalima koji pokazuju varijacije u emisiji fluorescencije. U stomatologiji se koristi laserska, ksenonska i LED oprema, koja emituje svetlost i radi na principima fluorescencije[30,36].

Uređaji koji emituju svetlost

Laser

Za otkrivanje karijesa mogu se koristiti različiti laserski zasnovani sistemi. Najčešći instrument za otkrivanje karijesa pomoću fluorescencije jeste laser. Fluorescencija normalne zdrave strukture zuba minimalna je ili nikakva. Karijesna struktura zuba fluorescira srazmerno obimu karijesa. Kada se primenjuje određena talasna dužina laserske svetlosti, nusprodukti bakterija poznati kao porfirini trepere crveno. Intenzitet fluorescencije stoga može biti određen kao direktna veza sa prisustvom i obimom aktivnosti karijesa. Dakle, što je veći atak kiseline na zub, to je veći broj na skali uređaja za detektovanje[37-40].

U ovoj oblasti dijagnostike pionir je bio *DIAGNOdent*® (KaVo, Biberach, Nemačka).

Restorative materials should ideally have fluorescence levels comparable to natural teeth; unfortunately, this is not the case, even with modern dental materials exhibiting variances in fluorescence emission. Laser, xenon, and LED light-emitting equipment is utilized in dentistry and works on the principles of fluorescence[30,36].

Light-emitting devices

Laser

There are a variety of laser-based systems available for detecting caries. The most often used instrument for detecting caries using fluorescence is a laser. Fluorescence from normal healthy tooth structure is minimal to non-existent. Carious tooth structure fluoresces in proportion to the extent of caries. When a certain wavelength of laser light is applied, bacterial byproducts known as porphyrins flash red. The fluorescence intensity may therefore be assessed as a direct link to the presence and extent of caries activity. As a result, the worse the acid assault on the tooth, the higher the number on the capture device's scale[37–40].

The DIAGNOdent® (KaVo, Biberach, Germany) was a pioneer in this diagnostic field. On a scale of 0 to 99, this portable gadget monitors fluorescence. Its effectiveness in assessing the presence and extent of the caries process is well documented, but there does not appear to be agreement on what number on the scale signals the point at which treatment should begin. Because the probe is so small, the DIAGNOdent can be technique-intensive. For large-coverage regions, such as a mandibular molar, several readings would have to be recorded by an assistant or the dentist for each pit or crack in the tooth[41].

The Canary System® (Quantum Dental Technologies Inc.)

The Canary System is a precise, low-powered laser-based instrument with an integrated intraoral camera that detects cracks and caries before they become large enough to show up on dental X-rays. Images from the intraoral camera can be shown for an instant chairside examination of the patient. A patient report is provided that includes an odontogram with color-coded Canary Numbers for the inspected teeth, as well as the dentist's treatment advice. The patient can also view this report on The Canary Cloud. During a three-second scan, a low-powered, pulsating laser light is shone on the tooth surface.

Ovaj prenosivi uređaj prati fluorescenciju na skali od 0 do 99. Njegova efikasnost u proceni prisustva i obima procesa karijesa dobro je dokumentovana, ali izgleda da nema saglasnosti u vezi sa tim koji broj na skali označava tačku kada treba započeti lečenje. Pošto je sonda vrlo mala, *DIAGNOdent* može zahtevati intenzivnu tehniku. Za regione sa velikom pokrivenošću, kao što je npr. mandibularni molar, asistent ili stomatolog morao bi snimiti nekoliko očitavanja za svako udubljenje ili svaku pukotinu na zubu[41].

The Canary System® (Quantum Dental Technologies Inc.)

The Canary System je precizan laserski instrument male snage sa integrisanom intraoralnom kamerom koja detektuje pukotine i karijes pre nego što postanu dovoljno veliki da se pojave na rendgenskim snimcima zuba. Slike sa intraoralne kamere mogu se u tom trenutku prikazati pacijentu. Obezbeđen je izveštaj pacijenta koji uključuje odontogram sa kodiranom bojom označenom *Canary* brojevima za pregledane zube, kao i savet stomatologa o mogućoj terapiji. Pacijent takođe može pogledati ovaj izveštaj na *Canary Cloudu*. Tokom skeniranja koje traje tri sekunde, pulsirajuća laserska svetlost male snage isijava na površinu zuba. Laserski svetlosni impulsi izazivaju fototermalne (PTR) i luminiscentne (LUM) reakcije. Korišćenjem laserskog impulsa na frekvenciji od 2 Hz lasersko svetlo može prodreti izvan površine zuba i identifikovati karijesne lezije koje imaju veličinu od čak 50 mikrona (što je dvadeset puta manje od milimetra) i koje se nalaze na čak 5 mm dubine od površine zuba. *Canary* broj generiše *Canary System* radi informisanja stomatologa o verovatnom zdravstvenom statusu određenog zuba. *Canary System* prevodi jedinstvene PTR/LUM potpise u *Canary* broj na skali od 0 do 100, koji se prikazuje na ekranu monitora, ali i čuje zahvaljujući komplikovanom algoritmu. Niže vrednosti ukazuju na dobru gleđ, a više vrednosti na postojanje pukotina i karijesa42.

LED fluorescentni uređaj

Tehnologija *Spectra Caries Detection®* (Air Techniques, Inc., Melville, N.I.) rešila je mnoge probleme izazvane upotrebom ranih tehnologija laserske fluorescencije. Pojavila se tehnologija koja je prenosiva, efikasna i ima značajan uticaj na pacijente, a pruža i odličnu dokumentaciju o stanju karijesa zuba.

Laser light pulses cause photothermal (PTR) and luminescence (LUM) reactions. The laser light can penetrate beyond the tooth surface and identify carious lesions as tiny as 50 microns (20 times smaller than a millimetre) and as deep as 5 mm from the tooth surface by utilizing a laser pulse at a frequency of 2Hz. A Canary Number is the output generated by The Canary System to inform an oral health care professional about the likely health status of a specific tooth. The Canary System translates the unique PTR/LUM signatures into a Canary Number on a scale of 0 to 100, which shows on a monitor screen and is also audible, using a complicated algorithm. Lower values indicate good enamel, whereas larger values indicate the existence of fissures and cavities[42].

LED fluorescence device

The Spectra Caries Detection technology® (Air Techniques, Inc., Melville, N.Y.) has addressed many of the concerns raised by early laser fluorescence technologies, resulting in a technology that is portable, efficient, and delivers considerable patient impact as well as great documentation of the tooth's caries condition. It comprises a wand that, through a TWAIN interface, smoothly connects with most digital imaging applications. This "plug-and-play" feature enables the user to rapidly unplug the device from one computer and attach it to another. The Spectra capture a single image of the tooth and map the fluorescence in various hues based on its intensity. Furthermore, a patented algorithm condenses the scale from 0 to 3, making analysis and decision-making easier. As a result, a value of 1 shows that acid has attacked the enamel. If one believes in early intervention, that region is in high danger of deeper degradation and should thus be examined and sealed. The inspection can be photographed against the same teeth as typical intraoral pictures and saved in the digital record for simple memory, or it can be printed for insurance companies and patients[43,44].

VistaProof® (Dürr Dental, Bietigheim-Bissingen, Germany)

The gadget works on the same premise of enhanced fluorescence in carious lesions as Diagnodent® but uses a different wavelength of excitation. It allows the practitioner to save and retain photographs of occlusal surfaces examined by the program, which indicates the regions of teeth that release a high amount of fluorescence.

Sastoji se od štapića koji se preko TVAIN interfejsa glatko povezuje sa većinom aplikacija za digitalno snimanje. Ova *plug-and-play* funkcija omogućava korisniku da brzo isključi uređaj sa jednog računara i priključi ga na drugi. *Spectra* snima jednu sliku zuba i mapira fluorescenciju u različitim nijansama na osnovu njenog intenziteta. Štaviše, patentirani algoritam sažima skalu od 0 do 3, što olakšava analizu i donošenje odluka. Vrednost 1 pokazuje da je reč o ataku kiseline na gleđ. Za one koji veruju u ranu intervenciju, ta regija je u velikoj opasnosti od dublje razgradnje i zato je treba ispitati i zaliti. Inspekcija se može fotografisati naspram istih zuba kao tipične intraoralne slike i sačuvati u digitalnom zapisu radi jednostavnog pamćenja ili se može odštampati za osiguravajuća društva i pacijente[43,44].

VistaProof® (Dürr Dental, Bietigheim-Bissingen, Germany)

Uređaj radi na istoj pretpostavci poboljšane fluorescencije karijesnih lezija kao *DIAGNOdent®,* ali koristi drugačiju talasnu dužinu ekscitacije. Omogućava lekaru da sačuva i zadrži fotografije okluzalnih površina koje su pregledane programom, što ukazuje na regione zuba koji oslobađaju veliku količinu fluorescencije. Ovom tehnikom snimaju se slike zuba, koje se zatim procenjuju softverom i čuvaju na računaru. *VistaProof®* koristi svetlo talasne dužine od 405 nm i softver koji pojačava fluorescenciju koju oslobađa tkivo. Softver za gledanje (*Dürr Dental*) koristi se za digitalizaciju video-toka, proizvodeći slike rezolucije 720 k 576 piksela, 3 k 8-bit RGB dubine boje i 72 piksela po inču (rezolucija ekrana računara). Program analizira fotografije i kvantifikuje crvene i zelene komponente fluorescencije. Program prikazuje intenzitet fluorescencije u veštačkim nijansama na osnovu tabele za traženje (LUT) u rasponu od zelene (*510 nm talasne dužine) do crvene (*680 nm talasne dužine). Vrednost rezultata, koja se kreće od 0 do 3, odnosi se na težinu lezije i ukazuje na odnos intenziteta crvene i zelene fluorescencije. Kada pređu vrednosti od 2,0, karijesne lezije dostižu dentin, što VistaProof na ekranu prikazuje kao narandžastu ili žutu oblast[45,46].

D-Carie mini™ (Neks Technologies Inc.)

Mini-D koristi LED tehnologiju i tehnologiju optičkih vlakana za identifikaciju okluzalnih i aproksimalnih karijesnih lezija.

Images of the teeth are captured using this technique, then evaluated by software and saved on the computer. VistaProof® employs a 405 nm wavelength light and software that amplifies the fluorescence released by the tissue. A viewer software (Durr Dental) is used to digitize the video stream, producing pictures with 720 x 576 pixels of resolution, 3 x 8-bit RGB colour depth, and 72 pixels per inch (computer screen resolution). The program analyzes the photos and quantifies the red and green components of fluorescence. The program displays the fluorescence intensity in artificial hues based on a look-up table (LUT) ranging from green (*510 nm wavelength) to red (*680 nm wavelength). The result value, which ranges from 0 to 3, refers to the severity of the lesion and indicates the intensity ratio of red and green fluorescence. When values exceed 2.0, carious lesions reach the dentin, which VistaProof depicts as an orange or yellow area on the screen[45,46].

D-Carie mini™ (Neks Technologies, Inc.)

Mini-D uses LED and fibre-optic technologies to identify occlusal and proximal caries lesions. This device creates 635−880 nm LED light, analyzes the light reflected off the surface of the tooth, and converts it into electrical impulses. It is simple to use because no calibration or difficult interpretation is required. Caries detection relies on structural changes in a tooth rather than the quantity of bacterial fluorescence present within pits and fissures. When used in combination with an X-ray, it enables the assessment of a third dimension—the volume of caries—prior to opening the tooth. The technology also enables the examination and diagnosis of children, pregnant women, and patients who choose to avoid or limit their exposure to X-rays for health or personal reasons[47,48].

Soprolife® (Acteon Imaging, La Ciotat, France) is a light-induced fluorescence intraoral camera system. Soprolife® uses two types of LEDs to illuminate the tooth and evaluate changes in mineral density. Images can be captured in three different modes: daylight, diagnosis, and treatment. The daylight mode uses a high-level magnification intraoral camera illuminated with white LEDs. The diagnosis and treatment modes use fluorescence via four blue LEDs at a 450 nm wavelength. The second light is directed at the tooth surface and produces a superimposed image over the white light image, a phenomenon known as autofluorescence. Soprolife uses a colour-coding system.

Ovaj uređaj stvara LED svetlo od 635 nm do 880 nm, analizira svetlost reflektovanu od površine zuba i pretvara je u električne impulse. Jednostavan je za upotrebu pošto nisu potrebni ni kalibracija ni teško tumačenje. Detekcija karijesa oslanja se na strukturne promene u zubu, a ne na količinu bakterijske fluorescencije prisutne u jamicama i fisurama. Kada se koristi u kombinaciji sa rendgenskim snimkom, omogućava procenu treće dimenzije – zapremine karijesa – pre otvaranja lezije. Ova tehnologija takođe omogućava pregled i dijagnostiku dece, trudnica i pacijenata koji iz zdravstvenih ili ličnih razloga odlučuju da izbegnu ili ograniče svoje izlaganje rendgenskim zracima[47,48].

Soprolife® (Acteon Imaging, La Ciotat, Francuska) predstavlja svetlo-indukovanu fluorescentnu intraoralnu kameru. *Soprolife®* koristi dve vrste LED dioda za osvetljavanje zuba i procenu promena u mineralnoj gustini. Slike se mogu snimiti u tri različita režima – jedan je dnevno svetlo, drugi dijagnoza, a treći lečenje. Režim dnevnog svetla koristi intraoralnu kameru visokog nivoa uvećanja osvetljenu belim LED diodama. Režimi dijagnoze i lečenja koriste fluorescenciju preko četiri plave LED diode na talasnoj dužini od 450 nm. Drugo svetlo je usmereno na površinu zuba i proizvodi sliku postavljenu iznad slike bele svetlosti, što je fenomen poznat kao autofluorescencija. *Soprolife* koristi sistem kodiranja boja. Zelena fluorescencija smatra se indikatorom zdravih tkiva, a crvena fluorescencija ukazuje na karijesnu leziju. Režim tretmana može se koristiti kao vodič u toku pripreme kaviteta. Slike se mogu sačuvati za buduća poređenja[26,49].

Kvantitativno svetlosno indukovana fluorescencija (engl. Quantitative light-induced fluorescence – QLF) prvi put je predstavljena 1995. godine. Ovo je optička metoda koja koristi prirodnu fluorescenciju zuba za razlikovanje karijesa od zdrave gleđi. Sjaj fluorescencije karijesnog tkiva koji se ispituje QLF-om niži je nego kod okolne zdrave gleđi. QLF određuje količinu minerala izgubljenu tokom demineralizacije izračunavanjem procentualne promene u osvetljenosti fluorescencije demineralizovane gleđi u poređenju sa okolnom zdravom gleđi. Svetlost se mnogo brže rasipa u karijesnim tkivima nego u zdravim zubnim tkivima, skraćujući put svetlosti u leziji i smanjujući apsorpciju i fluorescenciju u ovoj oblasti. To znači da se rasejanje svetlosti koristi za procenu gubitka minerala u vezi sa lezijom. QLF metoda takođe se može koristiti pri merenju crvene fluorescencije mikroorganizama u plaku.

Green fluorescence is considered an indicator of healthy tissues, and red fluorescence indicates a carious lesion. The treatment mode can be used as a guide during cavity preparation. Images can be saved for future comparisons[26,49].

Quantitative light-induced fluorescence (QLF) was first introduced in 1995. This is an optical method that leverages the natural fluorescence of teeth to distinguish between caries and sound enamel. The fluorescence radiance of a carious patch examined with QLF is lower than that of surrounding sound enamel. QLF calculates the quantity of mineral lost during demineralization by calculating the percentage change in fluorescence brightness of demineralized enamel compared to surrounding sound enamel. The light scatters much faster in carious tissues compared to sound dental tissues, shortening the pathway of the light in the lesion and decreasing the absorption and fluorescence in this area. This means that the scattering of the light is used for evaluating the mineral loss related to the lesion. The QLF method can also be used in measuring the red fluorescence from microorganisms in plaque. It works on the concept that distinct (organic) compounds in the mouth absorb light of a specific wavelength and then re-emit the absorbed energy at a different wavelength. A fluorescent or QLF picture is obtained by filtering the lighting light. Demineralized regions (e.g., white dots) appear as black patches in these pictures, and a decrease in fluorescence correlates with mineral loss. Porphyrin-covered areas, produced by (anaerobic) cariogenic bacterial activity, are bright red/orange. These impacts may be seen visually, analyzed and measured by proprietary software, and digitally documented[50,51].

Inspektor Pro™ (Inspektor™ Research, Amsterdam, Netherlands) was the first commercial QLF device marketed in 2004 which is a gadget for assessing oral cleanliness at home or at the dental clinic. The Inspektor Biluminator emits a harmless blue light that is used to detect porphyrins (byproducts of certain strains of anaerobic bacteria's metabolic process) in the oral cavity, especially inside or around tooth elements and the gingiva. These porphyrins cannot be seen with the naked eye. QLF has been utilized effectively for the past 12 years to identify and quantify demineralization and remineralization of tooth tissue and bacterial cavities. The Inspektor Biluminator improves the identification of white spot lesions, approximal caries, occlusal caries, margin leakage and secondary caries, sealant integrity, calculus, and gingivitis with

Bazira se na konceptu koji podrazumeva da različita (organska) jedinjenja u ustima apsorbuju svetlost određene talasne dužine, a zatim ponovo emituju apsorbovanu energiju na drugoj talasnoj dužini. Fluorescentna ili QLF slika dobija se filtriranjem svetla. Demineralizovani regioni (npr. bele tačke) pojavljuju se kao crne mrlje na ovim slikama, a smanjenje fluorescencije korelira sa gubitkom minerala. Područja pokrivena porfirinom, proizvedena (anaerobnom) kariogenom aktivnošću bakterija, svetlocrvene su ili narandžaste boje. Ovi uticaji mogu se prikazati vizuelno, analizirati i izmeriti vlasničkim softverom i digitalno dokumentovati[50,51].

Inspektor Pro™ (Inspektor™ Research, Amsterdam, Holandija) bio je prvi komercijalni QLF uređaj. Na tržištu je prisutan od 2004. godine, a služi za procenu oralne čistoće u kućnim uslovima ili u stomatološkoj klinici. *Inspektor Biluminator* emituje bezopasno plavo svetlo koje se koristi za otkrivanje porfirina (nusproizvoda određenih sojeva metaboličkog procesa anaerobnih bakterija) u usnoj duplji, posebno unutar zubnih tkiva i gingive ili oko njih. Ovi porfirini ne mogu se videti golim okom. QLF se poslednjih 12 godina efikasno koristi za identifikaciju i kvantifikaciju demineralizacije i remineralizacije zubnog tkiva i bakterijskih šupljina. *Inspektor Biluminator* olakšava identifikaciju početne lezije – bele mrlje, aproksimalnog karijesa, okluzalnog karijesa, curenja ruba i sekundarnog karijesa, integriteta zalivača, kamenca i gingivitisa. Za njegovu upotrebu nije potrebno ni mnogo finansijskih sredstava ni mnogo vremena. Koristi svetlosnu kutiju koja sadrži plavo-zelenu lampu sa talasnim dužinama od 290 nm do 450 nm, sa vršnim intenzitetom od 370 nm. Ekscitaciono svetlo putuje do intraoralnog štapića pomoću optičkog kabla. Štapić takođe sadrži kameru sa napunjenim uređajem (CCD) prekrivenu propusnim plavim filterom.

Ista kompanija predstavila je 2012. godine noviji QLF uređaj pod nazivom *QLF-D Biluminator 2* (Inspektor™ Research). Oba pomenuta uređaja osvetljavaju zube plavom svetlošću, što dovodi do toga da oni trepere zeleno (to je fenomen poznat kao autofluorescencija). Osim zelene autofluorescencije, plava svetlost može proizvesti i crvenu fluorescenciju. Smatra se da ovaj crveni sjaj stvaraju porfirini proizvedeni metaboličkim procesima određenih bakterijskih sojeva. Pokazalo se da je intenzitet crvene fluorescencije povezan sa aktivnošću bakterija.

little financial or time commitment. It utilizes a light box that contains a blue-green arc lamp with wavelengths of 290 nm to 450 nm with a peak intensity of 370 nm. The excitation light travels to an intraoral wand by fibre optic cable. The wand also contains a charged coupled device (CCD) camera covered with a bandpass blue filter.

In 2012, a newer QLF device was released by the same company under the name QLF-D Biluminator 2 (Inspektor™ Research). Both of these gadgets illuminate the teeth with blue light. This causes the teeth to flash green (a phenomenon known as autofluorescence). Aside from green autofluorescence, blue light can also produce red fluorescence. This red glow is thought to be created by porphyrins produced by particular bacterial strains' metabolic processes. It has been demonstrated that the intensity of the red fluorescence is connected to the activity of the bacteria. In addition to caries-related bacteria, several recent QLF research has revealed that red fluorescence may be linked to other oral health concerns such as gingivitis and halitosis. The capacity to track tooth surfaces over time (longitudinal monitoring) is a major feature of QLF. The program incorporates automated video repositioning, which allows for the capture of comparative QLF pictures of the same surfaces at various time intervals[52–55].

In addition to biluminators, the most recent capturing devices are available on the market.

For professionals and researchers, the *Q-Raycam*™ Pro is the gadget of choice. It is an intra-oral camera with the ability to zoom in on individual tooth surfaces. Offering an objective, longitudinal, quantitative oral health evaluation method, improving service quality, and helping the development of patient-centred preventative care programs are all advantages for dentists. Qraycam Pro is a high-resolution camera with an elegant and practical design that is lightweight, easy to use, and autofocus. Suitable for clinical and in vitro research. It contains an autosave function for white light and QLF™ photographs, full arch imaging, PMS compatibility, and a one-touch autofocus button. It also had anterior and occlusal modes, as well as PC or tablet apps, and the ergonomic grip design aided operation. *Qraypen C* is a portable intraoral diagnostic imaging gadget with autozoom capability. Quick capture of QLF™ and white light photos. Ideal for inspecting and diagnosing individual cracks, incipient and proximal caries, fissures, and plaque. It is compatible with PMS and has a one-touch imaging button.

Nekoliko nedavnih istraživanja QLF sistema otkrilo je da se crvena fluorescencija ne javlja samo kod bakterija povezanih sa karijesom već da može biti dovedena u vezu i sa drugim problemima oralnog zdravlja, kao što su npr. gingivitis i halitoza. Kapacitet praćenja površine zuba u toku vremena (longitudinalno praćenje) glavna je odlika QLF-a. Program uključuje automatizovano video-repozicioniranje, koje omogućava snimanje uporednih QLF slika istih površina u različitim vremenskim intervalima[52-55].

Pored biluminatora, na tržištu su dostupni i najnoviji uređaji za snimanje.

Q-Raycam™ Pro uređaj je koji uglavnom biraju profesionalci i istraživači. To je intraoralna kamera koja može zumirati pojedinačne površine zuba. Pružanje objektivne, longitudinalne, kvantitativne metode procene oralnog zdravlja, poboljšanje kvaliteta usluge i pomoć u razvoju programa preventivne nege usmerenih na pacijenta prednosti su za stomatologe. *Q-Raycam*™ Pro je kamera visoke rezolucije sa elegantnim i praktičnim dizajnom. Lagana je, jednostavna za upotrebu i ima autofokus. Pogodna je za klinička i *in vitro* istraživanja. Sadrži funkciju automatskog čuvanja za belo svetlo i QLF™ fotografije, snimanje punog luka, PMS kompatibilnost i dugme za automatsko fokusiranje jednim dodirom. Ima i prednji i okluzalni režim, kao i aplikacije za računar ili tablet. Ergonomski dizajn ručke pomaže u radu. *Qraypen C* je prenosivi uređaj za intraoralno dijagnostičko snimanje, sa mogućnošću automatskog zumiranja. Brzo snima QLF™ fotografije i fotografije belog svetla. Idealan je za pregled i dijagnostiku pojedinačnih fisura, početnih i aproksimalnih karijesa, fisura i plaka. Kompatibilan je sa PMS-om i ima dugme za snimanje jednim dodirom. *Qscan Plus* je jednostavan i siguran Biofilm samotester, kao i odličan asistent za praćenje oralne higijene. Štitnik od ambijentalnog svetla osigurava jasan i svetao vid. Zreli kariogeni zubni plak prikazuje se zahvaljujući revolucionarnoj kombinaciji četiri fluorescentne LED diode i Inspektor filtera[56].

Endoskopija

Ovaj pristup oslanja se na ideju merenja fluorescencije koja se dešava kada su tkiva izložena plavoj svetlosti od 400 nm do 500 nm. Lezije bele mrlje izgledaju tamnije od zdrave gleđi kada se fluorescentna struktura zuba pregleda korišćenjem određenog želatinskog filtera.

Qscan Plus is a simple and safe biofilm self-tester as well as an excellent oral hygiene monitoring assistant. The ambient light shield ensures that the vision is clear and bright. Mature cariogenic dental plaque is shown by a revolutionary combination of four fluorescent LEDs and the Inspektor filter[56].

Endoscopy

This approach relies on the idea of measuring the fluorescence that happens when tissues are exposed to 400–500 nm blue light. White spot lesions look darker than sound enamel when the fluoresced tooth structure is examined via a particular gelatin filter. Similarly, when a light source is linked via cable to an endoscope, the teeth may be examined without the use of a filter. This is known as white light endoscopy. It has been proven that this approach is effective in detecting early carious lesions. The endoscope is a revolutionary tool used to treat periodontal disease. The endoscope allows one to examine the contents of the periodontal pocket and analyze the root surface of the tooth for disease-causing bacterial accumulations (plaque and calculus) without the need for an incision or surgical therapy. It also aids in the removal of plaque and calculus from the root surface as part of periodontitis treatment. It also allows us to detect other problems (cracks, perforations, and other disease-causing flaws on the surface of the tooth root) that were previously buried behind the gum and required surgery to be detect[57].

Spectroscopy

Alternating current impedance spectroscopy (ACIST)

ACIST sends a low amplitude microamp current into the tooth structure from the sensor tip contact, penetrating the enamel, dentin, and pulp to record changes in mineral density throughout the tooth structure, not only at the surface.

CarieScan PRO® (CarieScan, LLC) is changing the way of detecting caries. It is one of the most dependable equipment in the dentistry business, with 94.8% accuracy in diagnosing caries and healthy tooth structures. The PRO not only identifies when a tooth has to be restored, but it also pinpoints the location of the lesion, allowing restorations (fillings) to be as minimal and cosmetically acceptable as feasible. This device produces minimal false positives, lowering the danger of drilling healthy teeth.

Slično tome, u slučajevima kada je izvor svetlosti povezan kablom sa endoskopom, zubi se mogu pregledati bez upotrebe filtera; ta pojava poznata je kao endoskopija bele svetlosti. Dokazano je da je ovaj pristup efikasan u otkrivanju ranih karijesnih lezija. Endoskop je revolucionarni alat koji se koristi za lečenje parodontalne bolesti. Endoskop omogućava pregled sadržaja parodontalnog džepa i pregled površine korena zuba na akumulacije bakterija koje izazivaju bolesti (plak i kamenac), bez potrebe za rezom ili hirurškom terapijom. Takođe, pomaže u uklanjanju plaka i kamenca sa površine korena u okviru lečenja parodontitisa. Omogućava i uočavanje drugih problema (pukotina, perforacija i drugih nedostataka koji izazivaju bolesti na površini korena zuba) koji su prethodno bili zariveni iza desni i za čije je otkrivanje bila potrebna operacija[57].

Spektroskopija

Spektroskopija otpora naizmenične struje (engl. Alternating current impedance spectroscopy – ACIST)

ACIST šalje struju male amplitude u strukturu zuba od kontakta vrha senzora, prodirući u gleđ, dentin i pulpu kako bi zabeležio promene u mineralnoj gustini u celoj strukturi zuba, a ne samo na površini.

Način otkrivanja karijesa promenio je *CarieScan PRO*® (CarieScan, LLC). To je jedan od najpouzdanijih alata u stomatološkoj praksi, sa 94,8% tačnosti u dijagnostici karijesa i zdravih zubnih struktura. Ne samo da ukazuje na vreme kada zub treba da se restaurira već precizno određuje i lokaciju lezije, omogućavajući pritom da nadoknade (plombe) budu minimalne i estetski prihvatljive onoliko koliko je to moguće. Ovaj uređaj proizvodi minimalne lažne pozitivne rezultate, smanjujući opasnost od bpreparacije zdravih zuba. Smanjuje potrebu za rendgenskim zracima i obezbeđuje merljiv i ponovljiv izlaz kako bi se omogućili kontinuirano praćenje pacijenata i povećanje broja ponovljenih preventivnih tretmana[58].

I zvučni talasi mogu biti korišćeni za otkrivanje karijesa. Ultrazvuk može lako otkriti lezije budući da se vreme putovanja ultrazvučnih impulsa razlikuje u zvučnim i demineralizovanim tkivima gleđi[59,60]. Ova metoda smatra se obećavajućom u otkrivanju ranih lezija gleđi pošto bele mrlje ograničene na gleđ ne proizvode uočljive ili slabe reakcije. S druge strane, dublje lezije proizvode znatno veće amplitude[61].

It reduces the need for X-rays and provides quantifiable and repeatable output to allow for ongoing patient monitoring and an increase in repeat preventive treatments[58].

Sound waves can be used for the detection of caries. Ultrasound can detect lesions easily because the travel time of ultrasonic pulses differs in sound and demineralized enamel tissues[59,60]. This method is considered promising in detecting early enamel lesions because the white spot lesions confined to enamel produce no detectable or weak echoes whereas deeper lesions produce substantially higher amplitudes[61].

Cone Beam Computed Tomography (CBCT)

Cone beam computed tomography (CBCT) systems are a type of computed tomography (CT) technology. Dental experts employ CBCT devices that circle around the patient, collecting data with a cone-shaped X-ray beam. These data are utilized to create a three-dimensional (3D) imaging of the patient's dental (teeth), oral and maxillofacial area (mouth, jaw, and neck), and ears, nose, and throat (ENT). Since the early 2000s, dental CBCT systems have been sold in the United States and are increasingly being used by radiologists and dental professionals for a variety of clinical applications such as dental implant planning, visualization of abnormal teeth, evaluation of the jaws and face, cleft palate assessment, diagnosis of dental caries (cavities), endodontic (root canal) diagnosis, and diagnosis of dental trauma[62–64].

Optic Coherence Tomography

This technique uses a high penetration near-infrared light at a wavelength of 780−1550 nm. No potential biological side effects have been reported on this system so far. Optic coherence tomography (OCT) generates high-resolution cross-sectional images of the oral structures. OCT is found to be more sensitive in the detection of recurrent caries and evaluation of the marginal adaptation of the restorations compared to other tools. Like ultrasonics, OCT uses near-infrared emissions to determine not only the presence of the caries lesions but also measure their depth. Another important advantage of this technique is that the patient is not exposed to X-rays[65].

Cone Beam kompjuterizovana tomografija (engl. Cone Beam computed tomography – CBCT)

Sistemi Cone Beam kompjuterizovane tomografije (engl. Cone Beam computed tomography – CBCT) predstavljaju vrstu tehnologije kompjuterske tomografije (CT). Stomatološki stručnjaci koriste CBCT uređaje koji kruže oko pacijenta i prikupljaju podatke pomoću rendgenskog zraka u obliku konusa. Ovi podaci potom se koriste za kreiranje trodimenzionalne (3D) slike pacijentovog zuba (pacijentovih zubi), oralne i maksilofacijalne oblasti (usta, vilica i vrat) i ušiju, nosa i grla (ENT). Od ranih dvehiljaditih godina, stomatološki CBCT sistemi prodaju se u Sjedinjenim Američkim Državama. Sve ih više koriste radiolozi i stomatolozi u različite kliničke svrhe, među kojima su i planiranje zubnih implantata, vizuelizacija abnormalnih zuba, procena vilica i lica, rascepa procena nepca, dijagnoza zubnog karijesa, endodontska dijagnoza (dijagnoza kanala korena) i dijagnoza stomatološke traume[62-64].

Optička koherentna tomografija

Ova tehnika koristi blisku infracrvenu svetlost visoke prodornosti na talasnoj dužini od 780 nm do 1550 nm. Dosad nisu prijavljeni potencijalni biološki neželjeni efekti na ovaj sistem. Optička koherentna tomografija (engl. Optical Coherence Tomography – OCT) generiše slike poprečnog preseka oralnih struktura visoke rezolucije. Utvrđeno je da je OCT osetljiviji u otkrivanju rekurentnog karijesa i proceni marginalne adaptacije restauracija od drugih alata. Poput ultrazvuka, OCT koristi bliske infracrvene emisije ne samo da bi odredio prisustvo karijesnih lezija već i da bi izmerio njihovu dubinu. Još jedna važna prednost ove tehnike ogleda se u tome što pacijent nije izložen rendgenskim zracima[65].

Terahertz Imaging (THz)

Stomatologija je takođe važan deo THz biomedicine. Karijesno tkivo često ima veće slabljenje transmisije THz od zdrave gleđi i možda neće apsorbovati THz vibracije pre nego da ih disperguju. Štaviše, THz indeks prelamanja gleđi veći je od indeksa dentina. Na osnovu ovih promena navedeno je da transmisija ili refleksija mogu razlikovati karijesnu gleđ od zdrave gleđi. THz impulsi upotrebljavaju se za pravilno i pouzdano otkrivanje debljine gleđi i za skeniranje trodimenzionalne strukture zuba. Pokazalo se i

Terahertz Imaging

Dentistry is also an important part of THz biomedicine. Carious tissue often has a higher THz transmission attenuation than healthy enamel and may not absorb THz vibrations rather than disperse them. Furthermore, the THz refractive index of enamel is greater than that of dentin. Based on these changes, it has been suggested that transmission or reflection imaging may discriminate between carious and healthy enamel. THz pulses were used to properly and reliably detect the enamel thickness and scan the three-dimensional structure of the tooth. THz pulse imaging was also shown to be capable of measuring the depth of artificial acid gel demineralization across a limited range. As a result, THz pulses have the potential to be utilized to detect the depth of a lesion. There is also a small optical fibre-coupled THz endoscope system for oral examination. Although THz technology has been explored in dentistry more extensively than in other medical applications, a more complete and systematic study on the mechanism of THz wave-tooth interaction is necessary[66].

Multiphoton Imaging

A carious lesion in the dentin is a dynamic process that involves demineralization and collagen denaturation. Collagen type I is the most abundant protein in dentin and its optical characteristics have been studied. Multiphoton microscopy (MPM) is a nonlinear imaging method that uses collagen two-photon excitation fluorescence (2PEF) and its second-harmonic generation (SHG) to expose the caries process. Multiphoton tomography (MPT) allows for an optical biopsy depth of up to 200 m with subcellular resolution, allowing for the visualization of cellular and extracellular features. Additional information regarding the microenvironment, energy status, and cellular metabolism may be gained when combined with fluorescent lifetime imaging. With a 700-nanometer excitation wavelength and a 1.3 numerical aperture objective, for example, the observed lateral resolution is roughly 0.2 micrometres, with a matching axial resolution of 0.6 micrometres[67].

da snimanje THz impulsa ima mogućnost da izmeri dubinu demineralizacije veštačkog kiselog gela u ograničenom opsegu, što znači da THz impulsi mogu da se koriste za otkrivanje dubine lezije. Postoji i mali THz endoskopski sistem spregnutih optičkih vlaknana za pregled usne duplje. Iako je primena THz tehnologije bolje istražena u stomatologiji nego u drugim granama medicine, neophodna je potpunija i sistematičnija studija o mehanizmu interakcije između THz talasa i zuba[66].

Multiphoton Imaging

Karijesna lezija u dentinu dinamičan je proces koji uključuje demineralizaciju i denaturaciju kolagena. Kolagen tipa I najzastupljeniji je protein u dentinu. Proučavale su se njegove optičke karakteristike. Multifotonska mikroskopija (engl. *multiphoton microscopy* – MFM) nelinearna je metoda snimanja koja koristi dvofotonsku ekscitaciju fluorescencije (engl. *two-photon excitation fluorescence* – 2PEF) kolagena i njegovu drugu harmoničnu generaciju (DHG) da otkrije proces karijesa. Multifotonska tomografija (engl. *multiphoton tomography* – MFT) omogućava dubinu optičke biopsije do 200 m, sa subcelularnom rezolucijom, dopuštajući tako vizuelizaciju ćelijskih i ekstracelularnih karakteristika. Dodatne informacije u vezi sa mikrookruženjem, energetskim statusom i ćelijskim metabolizmom mogu se dobiti kada se kombinuju sa fluorescentnim snimanjem tokom života. Sa talasnom dužinom pbudjivanje od 700 nm i objektivom sa numeričkim otvorom od 1,3, na primer, posmatrana lateralna rezolucija iznosi otprilike 0,2 mikrometra, sa odgovarajućom aksijalnom rezolucijom od 0,6 mikrometara[67]

Kompjuterska tomografija sa podešenim otvorom blende (engl. Tuned Aperture Computed Tomography – TACT)

Webber et al. razvili su kompjuterizovanu tomografiju sa podešenom blendom (engl. *Tuned Aperture Computed Tomography – TACT*), veoma jednostavan i brz pristup za rekonstrukciju tomografskih slika[68]. Zasnovan je na konceptima tomosinteze i teorije optičkog otvora. TACT počinje sa 2D periapikalnim radiografijama snimljenim iz različitih uglova projekcije, a zatim generiše uzdužne tomografske rezove (TACT-S) koji bivaju poređani u Z-osi oblasti od interesa.

Tuned Aperture Computed Tomo-graphy (TACT)

Webber and colleagues developed tuned aperture computed tomography (TACT), a very simple, quicker approach for reconstructing tomographic images[68]. It is based on the tomosynthesis and optical aperture theory concepts. TACT starts with 2-D periapical radiographs recorded from various projection angles and then generates longitudinal tomographic slices (TACT-S) that line up in the Z-axis of the area of interest. It generates real 3-D data from an arbitrary number of 2-D projections. TACT has proven to be a promising and successful alternative to other traditional modalities in a variety of therapeutic settings. TACT's total radiation exposure is no more than 1 to 2 times that of a standard periapical X-ray film. The resolution is said to be comparable to that of 2-D radiography. TACT does not have the artifacts associated with CT, such as starburst patterns found with metallic restorations[69].

This overview highlighted a huge variety of current equipment that is either now used or can be utilized in dental diagnostics. Some of these devices are rather pricey and take up a lot of room. Some are quite inexpensive and can be used in routine dental diagnostics. Technology evolves so quickly that it is impossible to stay up. As a result, possibly the best answer for each pedodontist or pedodontics clinic is to select the equipment with the greatest cost benefit.

Generiše stvarne 3D podatke iz proizvoljnog broja 2D projekcija. TACT se pokazao kao obećavajuća i uspešna alternativa drugim tradicionalnim modalitetima u različitim terapijskim okruženjima. Ukupna izloženost zračenju TACT-a nije više od jednog do dva puta veća od standardnog periapikalnog rendgenskog filma. Rezolucija se može uporediti sa rezolucijom 2D radiografije. TACT nema artefakte povezane sa CT-om, kao što su obrasci zvezdanog praska koji se nalaze kod metalnih restauracija[69].

U ovom preglednom radu predstavljena je oprema koja se trenutno koristi u stomatološkoj dijagnostici, kao i ona koja u te svrhe može biti korišćena u budućnosti. Pojedini od navedenih uređaja prilično su skupi i zauzimaju mnogo prostora. Ima i onih koji su jeftini i koji mogu biti korišćeni u rutinskoj stomatološkoj dijagnostici. Razvoj tehnologije je toliko brz da je skoro nemoguće ostati u toku. Shodno tome, možda je za svakog pedodonta ili pedodontsku kliniku najbolje rešenje da odabere opremu koja se najviše isplati.

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