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Contents / Sadržaj

„Ne daj se zlu nadvladati,
nego nadvladaj zlo dobrim."
Biblija

U okeanu besmisla i ambijentu kiča naše svakodnevice, teško je naći izlaz iz „izvitoperene realnosti" i ostati samosvestan i svoj. Pandemiju laži o bajkovitom napretku i kodeks gde „preučeni" mogu sve nadvladava jedino „megafon zla" koji isključuje svaku normalnost. Pokušaj iskoraka iz neobuzdane fantazmagorije i aktuelne pseudonormalnosti je kao traženje igle u plastu sena.

Pravno, moralno i svekoliko beščašće „najboljih" i beskrajna praznina duha izvršioca „prljavih poslova" je paradigma našeg bitisanja. Vrednosni i intelektualni narativ našeg doba (čitaj zlatnog) identičan je „Šoićevom životnom konceptu", gde je odsustvo stida i destruktivni talenat „elite" sinonim ideologije propadanja, a bezočna arogancija i cinična empatija paradigma „kulture nasilja".

U takvoj imaginarnoj stvarnosti „etika i estetika zla" je fundamentalno opredeljenje neukih i bahatih sa kupljenim ili falsifikovanim diplomama. Istrajna dominacija laži i odsustvo srama kontaminiraju ambijent besmisla, dok se akteri „predstave" trude da „političkom narkozom" objasne neobjašnjivo.

U društvu poremećenih vrednosti „svekoliki napredak" se bazira na „trulim i lažnim" osnovama, i potpuno je eliminisan osećaj „transfera blama" kada se govori o uspesima koji ne postoje. Ovaj izum „nedostojnih" i onih koji su u „strašnom" sukobu sa istinom formira društvenu klimu gde su laž i primitivizam opšteprihvatljive „vrednosne i moralne mantre" koje demotivišu svaku izvesnost i društvenu stvarnost čvrsto pozicioniraju na „nultoj tački bezizlaza".

Kako dalje i da li je moguće iskoračiti iz „pandemije laži" i nadvladati hipokriziju aktuelnog trenutka?

Odgovor je vrlo jednostavan, a rešenje vrlo kompleksno. Naime, nije ni lako ni jednostavno promeniti sistem koji je iznedrio institucije za „nepoštovanje zakona" i bezočno „izopštavanje istine".

Zato je odgovornost slobodoumnih, učenih i nadasve moralnih članova zajednice na velikom „životnom" ispitu. Borba za sopstveno mišljenje i moralne ideale, vezana pre svega za istinu i dostojanstvo, mora znanjem i odgovornošću iskoreniti „pandemiju laži" i validnom „vakcinom" (čitaj znanjem, poštenjem, hrabrošću) zaustaviti „virus zabluda i laži" koji se brzo širi i još brže mutira, da bi se iskoračilo iz „šizofrenog vrednosnog sistema" i da bi se eliminisala „izopačena etika".

Neophodno je preskočiti paradokse koji „vređaju inteligenciju" i baziraju se na postulatima petogodišnjaka.

Elementarna svest svakog pojedinca odnosno osećaj sopstvenog morala i značajna želja da se napravi iskorak iz „kolektivne depresije" je neminovna za promenu „izvitoperene realnosti" i sumorne stvarnosti aktuelnog trenutka.

Urednički komentar ću završiti citatom Alfonsa de la Martina: „Ne može biti slave tamo gde nema vrline", jer apostrofira značaj lične odluke i odgovornosti u rešavanju svih izazova i eliminisanju „društvene matrice" koja nudi „svekoliki bezizlaz".

Prof. dr Slavoljub Živković

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Use of mineralized dentin graft in augmentation of different indication areas in the jaw bones

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SUMMARY

Introduction Extracted teeth are still considered clinical waste and therefore are being discarded. It is evident that obtained and prepared autogenous dentin graft (ADG) may be used for guided bone regeneration (GBR) due to its similar biochemical characteristics to human bone.

The aim was to present a novel procedure in a clinical setting that employs freshly extracted teeth that are processed into a bacteria-free particulate dentin, and then grafted immediately into the extraction sites or bone deffects. Monitoring the clinical and radiological parameters (vertical and horizontal dimensional changes on the alveolar ridge and vertical dimension of intrabony defects at the distal aspect of the second molar after extraction of third molar) for a period of 6 months, proved rapid healing capacity of ADG on the bone and soft tissue structures in the jawbones.

Material and methods Clinical measurements were performed using a questionnaire for monitoring the postoperative clinical manifestation, bone measuring calipers for measuring horizontal changes of the alveolar ridge and graduated probe for measuring vertical dimensional changes, also paraclinical-radiological examinations to follow-up bone density.

Results During the follow up period of six months, clinical measurements of post-extraction dimensional changes of the alveolar ridges showed minimal horizontal and vertical bone resorption with preserved alveolar ridge volume, with an accelerated bone regenerative process without special postoperative complications.

Conclusion Dentin particulate grafted immediately after extractions should be considered as gold standard due to its osteogenetic, osteoinductive and osteoconductive effects on bone tissue regeneration.With the use of mineralized dentin matrix we get maximum utilization of our own biological potential without the use of other artificial graft materials.

Keywords: autologous dentin graft; bone substitutes; socket preservation; Smart dentin grinder

INTRODUCTION

Different biomaterials (autograft, alograft, ksenograft or aloplastic) have been used to stimulate or improve bone gain in post-extraction sites. Autogenous bone continues to be considered as golden standard in bone augmentation, as it is the only option that fulfills the criteria of osteogenesis, osteoconduction and osteoinduction [1, 2]. Nevertheless, it suffers several disadvantages due to its limited availability, unpredictable early resorption and associated morbidity at the donor site. To avoid disadvantages of other graft materials, an alternative idea came to use their own extracted teeth to obtain a graft material that is completely identical to the bone autologous graft. Autogenous dentin graft (ADG) prepared chairside may be used for guided bone regeneration (GBR) because both alveolar bone in maxillofacial region and teeth embryologically are derived from the same neural crest cells and have similar biochemical contents and characteristics to human bone [3].

The tooth as a complex organ is rich source of stem progenitor cells, collagen fibers, metal ions, growth and development factors (BMPS, IGF, PDGF, TGF, etc). Dentin is present in 85% of the total tooth mass, in essence dentin is an acellular matrix unlike bone containing osteocytes. Although tissue structures of bone and dentin are different, the ratio of components is similar (mineral 70%, collagen 20%, body fluid 10% by weight) [4].

The first documented evidence of regenerative-osteoinductive potential of autologous dentin graft was provided by the study of Yeomans and Urist in 1967 who discovered that dentin contains BMP's and growth factors. This research was forgotten for nearly half a century until implant dentistry showed interest in optimal extraction site management. The first clinical case used in human body was sinus lifting – described in 2003 by Korean scientist Masaru Murata. From 2008 it has been used mainly for guided bone regeneration (GBR) in dental implants' osteointegration [4]. Recycled teeth "GREEN DENTISTRY" can make the best overall graft material with best economical, clinical and biological value that are shown in the Table 1.

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Table 1. Recycled teeth as graft material
Tabela 1. Reciklirani zubi kao graft materijal

ECONOMIC VALUE **Ekonomska vrednost**	**CLINICAL VALUE** **Klinička vrednost**	**BIOLOGICAL VALUE** **Biološka vrednost**
Low cost Jeftina opcija	No immune reaction Nema imunog odbacivanja	Low resorption Mala resorpcija
Reduce graft inventory Smanjuje potrebu za drugim materijalom	Painless procedure Bezbolna procedura	Excellent osseous ankyloses Izvanredna osteointegracija
Reduce number of visits Smanjuje broj poseta	Easy and simple process Jednostavan proces	Osteogenic Osteogenetski potencijal
Recycle teeth – Green Dentistry Reciklaža – zelena stomatologija	"doggy bag" graft for future use Graft koji se može i kasnije koristiti	Slow release of GF over a long time Otpušta faktore rasta produženo vreme
Graft volume / 3× more Količina grafta / 3× veća	bacteria free / no disease transmission Nema bakterija, nema prenošenja zaraznih bolesti	Hard "cortical like" graft quality Dobar kvalitet grafta
Easy to explain Jednostavna	Quicker prosthetic restoration Brža protestska rehabilitacija	Attract progenitor cells and contains stem cells Privlači progenitorske ćelije

MATERIALS AND METHODS

Protocol and procedure for obtaining and preparation of mineralized dentin matrix

The process from tooth extraction until grafting takes approximately 15 minutes. All needed equipement for this procedure is shown on Figure 1.Vital teeth without root canal fillings that are extracted due to advanced periodontal bone loss or other indications like wisdom teeth extraction or orthodontics indications, are prepared for immediate grafting. Immediately after extraction, any dental restorations or endodontic fillings should be removed. Also carious lesions, remnants of periodontal ligament (PDL) and calculus should be removed using low or high speed handpiece and a tungsten burs or manually with a curette. Clean teeth are dried by air syringe and sterile gauze, put into a grinding sterile chamber of a 'Smart Dentin Grinder'®. SDG is capable in 3 seconds to grind the roots and then by vibrating movements of the grinding chamber for 20 seconds the particles less than 1200 µm fall through a sieve to a lower chamber that keeps particles between 300-1200 µm. In the collecting drawer chamber dentin particles between 300-1200 µm are collected with various quantity of 1-2.5+ mg depending on which tooth serves as a source of receiving dentin graft material.

The particulate dentin from the drawer is immersed in basic alcohol for 5–10 minutes in a small sterile glass container. The basic alcohol cleanser consists of 0.5M of NaOH and 20% alcohol. This solution removes and dissolves all organic waste and eliminates all types of bacteria, viruses etc. At the end of procedure hydration and neutralization of pH value = 7.2 with PBS – sterile phosphate buffered saline (the same procedure repeated twice for 1 min) is performed.

Obtained and purified dentin particles are applied in the desired alveolar region with the help of a special instrument - a carrier or a plastic instrument, the graft material is gently pressed with a compressor to condense in the alveolar socket. Once this is done, a spongy fibrin-Gelatamp is placed on the top to protect applied graft material (ADG). This is followed by suturing with non-resorbable thread 4/0, that is removed after a period of 7–14 day [5]. After surgery, all patients undergo one-week antibiotic therapy Amoxicillin cum ac.clavullonic 1000 mg, 1 tablet every 12 hours as well as non-steroidal anti-inflammatory analgesics, or Clindamycin 300 mg, 1 capsule every 8 hours. Patients are advised to irrigate the surgical wound daily with 0.2% chlorhexidine solution for 15 days.

Figure 1. Required equipments and materials for obtaining autologous mineralized dentin graft
Slika 1. Potrebna oprema i materijal za pripremu autolognog mineralizovanog dentinskog grafta

Clinical parameters

Patients were evaluated at 1, 3, 7, 15 days and 3 months, postoperatively to assess wound healing. At these appointments, patients were given a questionnaire to evaluate postoperative pain, trismus, swelling and used of NSAID.

It was also important to describe possible postoperative complications: infection, swelling, paresthesia, hematoma, dehiscence, etc. Measurement of the horizontal dimensions of the alveolar ridge was performed with a special instrument-Bone measuring calipers at 2 and 4 mm below the limbus alveolaris. Measurement of the index of apical-epithelial migration – AEM, clinical loss of attachment (distance from the enamel-cement border to the bottom of the sulcus) in the adjacent tooth (distal surface of the second molar) was done with a periodontal probe. The depth of the formed intrabony defects was also measured during the extraction of the impacted wisdom tooth.



Figures 2, 3, 4. Clinical presentation of alveolar preservation with ADG
Slike 2, 3, 4. Klinički prikaz prezervacije alveolarnog grebena pomoću autolognog dentinskog grafta

These clinical measurements of dimensional changes in the alveolar ridge are performed intraoperatively and over a period of 3 and 6 months postoperatively.

Paraclinical-radiographic examination

Panoramic radiographs were performed 3 and 6 months postoperatively to evaluate bone regeneration and exclude pathologies that might have occurred from surgery. Software Image J (version 1.36b issued by the American National Institutes of Health) was used to analyze ROI (numerical area of interest) values from 0-250 in 1 pixel of the image. Also, with the help of digital panoramix, measurements of vertical bone defects were performed distally from second molar.

CASE PRESENTATIONS

Alveolar ridge preservation immediately after extraction of teeth 34, 35, 48

58-year old patient in good general health was interested in placement of dental implants. Multiple teeth were extracted with simultaneous immediate preservation of the post-extraction alveoli in order to preserve necessary dimensions of alveolar ridge. During this procedure, the alveolar socket of extracted teeth were filled with bone substitute – ADG (Figures 2, 3, 4). This allows primary stability of hard and soft tissues to the level of the limbus alveolaris, thus preventing buccal alveolar collapse of the preserved alveole. Clinical measurements were performed after 6 months with the help of a bone measuring instruments in position 1) 2mm below the limbus alveolaris (Table 2), and in position 2) 4 mm below the limbus alveolaris (Table 3). Both measurements showed a minimum of 1-2 mm of bone reduction of the alveolar ridge, while in the lower part of the alveolar ridge there was no visible dimensional change (Figure 5). Clinically, there was no significant postoperative symptomatology (pain, swelling, trismus) or any special complication.

After the tooth extraction, remodeling of bone and soft tissue structures is an inevitable physiological process that occurs in the residual alveolar ridge. Due to that fact, maintaining the volume of alveolar ridge by preserving socket immediately after tooth extraction plays an important role in implant therapy.

Table 2. Intraoperative measurements with Bone measuring calipers
Tabela 2. Intraoperativna merenja pomoću specijalnih kalipera

Tooth number **Broj zuba**	**#48**	**#34**	**#35**
In position 2 mm below limbus alveolaris *2 mm ispod limbus alveolarisa*	9 mm	8 mm	8 mm
4 mm below limbus alveolaris *4 mm ispod limbus alveolarisa*	10 mm	8 mm	9 mm

Table 3. Measurements 6 months postoperatively with Bone measuring calipers
Tabela 3. Merenja 6 meseci postoperativno pomoću specijalnih kalipera

Tooth number **Broj zuba**	**#48**	**#34**	**#35**
In position 2 mm below limbus alveolaris *2 mm ispod limbus alveolarisa*	9 mm	7 mm	6 mm
4 mm below limbus alveolaris *4 mm ispod limbus alveolarisa*	9 mm	8 mm	8 mm

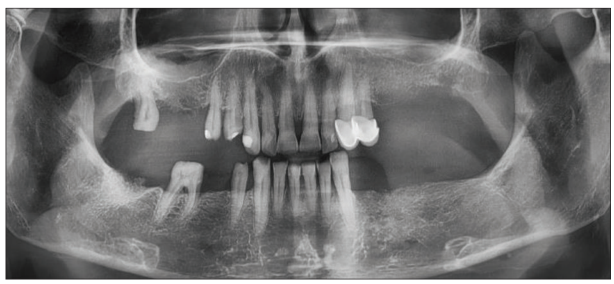


Figure 5. Panoramic imaging 3 months after pocket preservation with ADG
Slika 5. Ortopan tri meseca posle aplikacije autolognog dentinskog grafta

Autogenous dentin grafting of osseous defects distal to mandibular second molars after extraction of impacted mandibular molar – 38

Patient was willing to participate in the study, in good general health, without periodontal disease, and had at least one impacted molar tooth that was mesially inclined in relation to the second molar whereas the roots of the tooth 38 were in direct contact with mandibular canal (Figure 6, 7, 8).

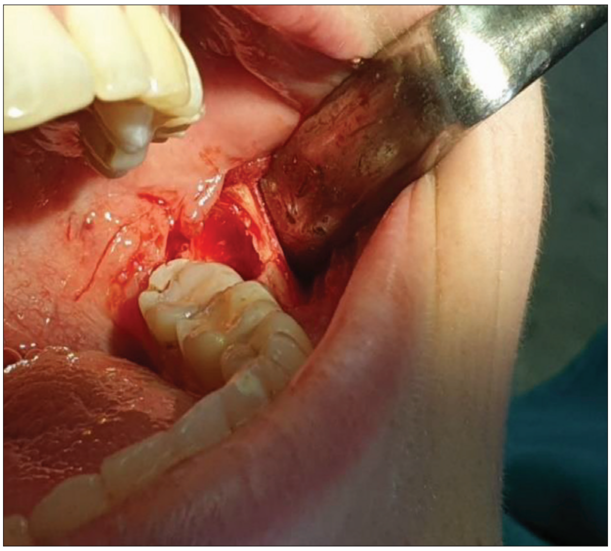
After a period of 6 months, the index of AEM-apical epithelial migration of the adjacent tooth distal to the second molar during preservation with ADG measured with a graduated probe showed a value of 1 mm, ie. there was

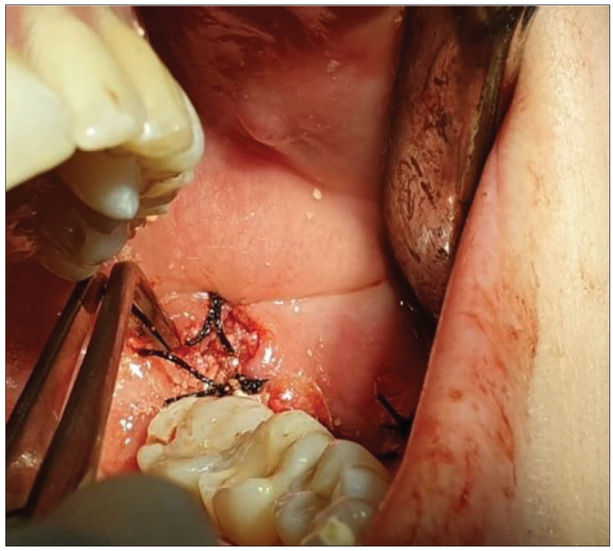
Figure 6. Pre-operative RTG imaging (mesially inclined 38)
Slika 6. Preoperativni ortopan (mezijalno impaktiran umnjak)

Temporary paraesthesia of the left lower lip was observed postoperatively for a period of 3 weeks. Kugelberg and colleagues found that 2 years after surgery, 43.3% of cases exhibited probing pocket depths exceeding 7 mm, and 32.1% showed IBDs (infrabone defects) of more than 4 mm [6].

Use of autologous dentin graft in augmentation of bone defects in jaw bone

50 years old patient admitted with insignificant swelling and pain in the left maxillary region complained of the same symptomatology for 2 years (associated with the teeth 22 and 23) with periodic exacerbations of the disease. He was treated many times symptomatically with antibiotics and drainage of swelling without removing the cause - radicular cyst. And the second cystic area was in position of tuberositas maxillaris lateralis sinistra that was asymptomatic.





Figures 7, 8. Intraoperative presentation of the preservation of osseous defect distal to the mandibular 2nd molar
Slike 7, 8. Intraoperativna prezentacija očuvanja koštanog defekta distalno od mandibularnog drugog kutnjaka

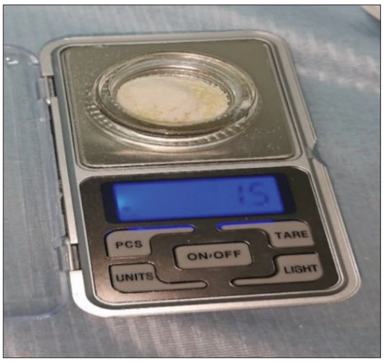
Figure 9. 6 months postoperatively, preservation of osseous defect distal to mandibular 2nd molar after extraction of impacted mandibular molar (#38)
Slika 9. Šest meseci postoperativno, prezervacija defekta kosti distalno od donjeg levog drugog kutnjaka posle ekstrakcije donjeg impaktiranog umnjaka (#38)

complete coverage of the defect created by osteotomy of the impacted mandibular molar. There was no damage to the periodontium of the adjacent tooth 37 or sensitivity. The roof of the mandibular canal was covered with autologous dentin graft (Figure 9).

Complete cyst enucleation was performed in the left frontal region (maxilla) and cystic membrane-method according to Partch II by completely filling the osseous defect with obtained mineralized dentin graft (1.5 mg) was performed. The cyst in the tuber maxillae was completely removed without being augmented with any graft material (Figures 10–13).

In the period after 3 months, a control digital panoramic X-ray was made, where with the help of a special Software – Image J (version 1.36b issued by the American National Institutes of Health) the density of newly formed bone with numerical values from 0-255 grey in 1 pixel of an image was measured. A value of 0 refered to the black color of the X-ray image (brightness), while 255 refers to the white color, complete x-ray absorption (shading) [7]. In our specific case, augmented osseous defect showed a solid bone density of 178 gray, which indicated faster process of osteointegration and regeneration of new

Figures 10, 11. Total enucleation of the radicular cyst and ADG augmentation
Slike 10, 11. Totalna enukleacija radikularne ciste i augmantacija kosti ADG-om



Figures 12, 13. Obtained mass of ADG from extracted teeth
Slike 12, 13. Dobijena masa ADG/a od izvađenih zuba

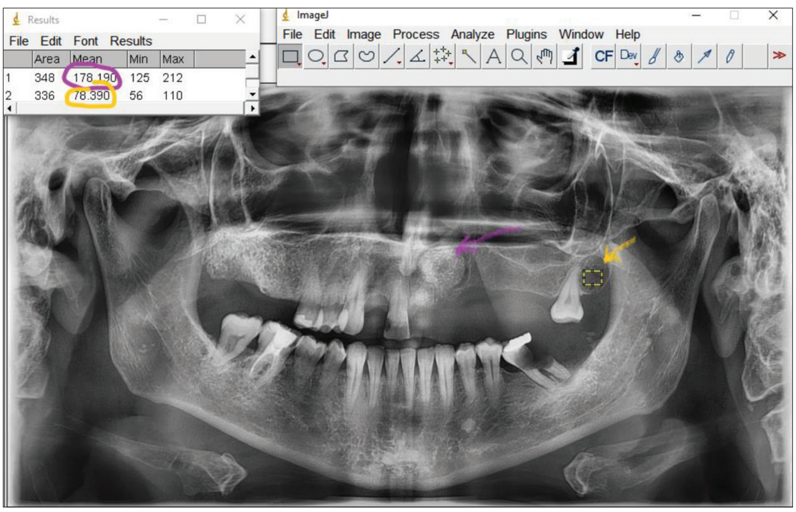


Figure 14. 3 months postoperatively RTG presentation of augmented osseous defect in the left maxillary region
Slika 14. Tri meseca postoperativno na ortopanu nadograđen koštani defekat u levoj maksilarnoj regiji

bone tissue, while the non-augmented osseous defect shows higher luminosity of 77 grey (Figure 14).

DISCUSSION

A treatment option to reduce the risk of future periodontal pathology mesial to the IMMT surgical site is the use of osseous grafting to preserve distal aspect of the second mandibular molar. Use of commercially available osseous grafting products, however, increases the cost of treatment for the patient, which may lead to their rejection. An ADG has been documented as a reliable graft source when socket preservation is being performed and for other osseous grafting applications, as it has been noted that large amounts of new woven bone formation were generated after 60 days of healing, and small amounts of lamellar bone were seen after 90 days.

Resorption of the ADG particles is slow (because of mineralized structure); therefore, lamellar bone is formed with stability of the resulting bone over time. Studies have supported that formed cortico-cancellous bone was maintained successfully with an implant after an average follow-up of 5 years.

The use of autologous dentin graft significantly minimizes the resorption of the residual alveolar ridge as seen in our cases. This is confirmed by the thesis of Vittorini et al. who concluded that preservation of alveolar ridge is significantly better treatment than without preservation, where there is minimal loss of vertical and horizontal bone. He specifically pointed out the need to preserve alveolar ridge in highly aesthetic zones where the thickness of the buccal lamina was less than 1.5 mm – 2 mm, and in cases where anatomical structures such as maxillary sinus and mandibular canal are in close proximity.

On the follow up, the bone ankylosed to dentin produced very stable alveolar ridge that otherwise would be resorbed during 3-6 months after extraction. This grafted site preserved the alveolar ridge both functionally and esthetically. It can be utilized for implant insertion after 3 months in the maxillary posterior region, changing it from D3 bone into D1 bone [7].

Impacted third molar extraction surgery is a very common procedure for prophylactic orthodontic or therapeutic oral surgery [8]. The frequency of impaction lies between 66% and 77% [9]. Statistically, it's estimated that 20 million teeth are extracted each year just in the USA, 30% of teeth are extracted because of periodontal support and mobility, and 10% of extracted teeth are wisdom teeth (impacted). In most instances these extracted teeth are discarded as biological waste instead to take advantage of the fantastic properties they possess. Standard surgical extraction of impacted third molar could lead to a compromised periodontal status of the adjacent second molar, which might necessitate additional future surgical treatment.

According to Schropp et al, about 50% of the overall reduction in horizontal and vertical dimensional changes occurs in the first 12 months after augmentation, of which the first 2/3 of resorption occurs in the first 3 months after extraction (3.8 mm) [10]. The reduction width of the alveolar ridge without bone augmentation during the process of natural healing of the extraction wound ranges between 2.6 - 4.6 mm while the height of the ridge decreases by 0.4 - 3.9 mm, while horizontal resorption shows average value of 3.87 mm with simultaneous reduction of vertical dimensions with an average value of 1.67 mm [11, 12].

Extracted teeth can no longer be considered as medical waste material due to the fact that in a short period of time graft material with great safety and significant biological importance can be obtained. With the use of mineralized dentin matrix we get maximum utilization of our own biological potential without the use of any other artificial graft materials.

CONCLUSION

The use of grafting at the time of surgical extraction of impacted third molars can aid in the prevention of site resorption during healing and has been documented to help formation of osseous tissues on the distal aspect of the adjacent second molar.

It is a cost-effective approach for the patient and allows the surgeon to employ autologous bone grafting material, which is often preferable, for GBR (guided bone regeneration).

Clinical process of bone and soft tissue healing is accelerated and with calm clinical flow without more pronounced oedema and pain with relatively preserved vertical and horizontal dimensions of alveolar ridge.

Postoperative X-ray shows early formation of the new bone (trabeculae) with excellent osteointegration of dentinal graft in the osseous defects in jawbones.

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Primena mineralizovanog dentinskog grafta indikovanog u različitim delovima vilične kosti

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KRATAK SADRŽAJ

Uvod Ekstrahovani zubi se još uvek smatraju kliničkim otpadnim materijalom i kao takvi neupotrebljivim. Međutim, jasno je da dobijeni i pripremljeni autogeni dentinski graft (ADG) može biti iskorišćen u vođenoj regeneraciji kosti zbog biohemijskih karakteristika sličnih ljudskoj kosti.

Ciljevi ovog rada su: prikaz novog postupka u kliničkim uslovima kojim se koriste sveže ekstrahovani zubi prerađeni u sterilne dentinske čestice i odmah zatim iskorišćeni kao graft na mestu ekstrakcije ili koštanog defekta; kontrola kliničkih i radioloških promena u periodu od šest meseci na postekstrakcionim defektima na alveolarnom grebenu; dokazati visok potencijal ADG-a u cilju regeneracije čvrstih i mekih tkivnih struktura u viličnim kostima; merenje vertikalnih i horizontalnih dimenzionih promena na alveolarnom grebenu, kao i merenje vertikalne dimenzije intrakoštanih defekta distalno od drugog kutnjaka nakon ekstrakcije trećeg kutnjaka.

Metode Klinička merenja su sprovedena uz pomoć upitnika za kontrolu postoperativnih kliničkih manifestacija, kalipera (osteometra) za merenje šupljine kosti i horizontalnih promena na alveolarnom grebenu, graduiranom sondom za merenje vertikalnih dimenzionih promena. Takođe, sprovedena su i paraklinička, odnosno radiološka ispitivanja da bi se pratio koštani denzitet.

Rezultati U periodu od šest meseci posle ekstrakcije, klinička merenja pokazuju minimalnu horizontalnu i vertikalnu resorpciju kosti uz očuvane dimenzije alveolarnog grebena i ubrzani proces koštane regeneracije bez značajnih postoperativnih komplikacija.

Zaključak Dentinske čestice iskorišćene kao graft odmah nakon ekstrakcije treba smatrati zlatnim standardom zahvaljujući njihovim osteogenetskim, osteoinduktivnim i osteokonduktivnim učincima na regeneraciji koštanih tkiva. Primenom mineralizovanog dentalnog matriksa maksimalno koristimo svoje sopstvene biološke potencijale bez upotrebe drugih arteficijalnih graft materijala.

Ključne reči: autologni dentinski graft; koštani supstituenti; prezervacija alveole; Smart dentin grinder

UVOD

Različiti biomaterijali (autograft, alograft, ksenograft ili aloplastični materijali) korišćeni su da bi stimulisali ili poboljšali koštanu regeneraciju posle ekstrakcije zuba. Autogena kost je i dalje zlatni standard kod koštane augmentacije, kao jedina opcija koja ispunjava kriterijume osteogeneze, osteokondukcije i osteoindukcije [1, 2]. I pored toga, treba pomenuti njene nedostatke zbog ograničene dostupnosti, nepredvidive rane resorpcije i postoperativnog morbiditeta. Da bi se izbegle slabosti drugih graft materijala, pojavila se alternativna ideja korišćenja sopstvenih ekstrahovanih zuba za dobijanje graft materijala, koji je u celosti identičan autolognom koštanom graftu. Autogeni dentinski graft (ADG) pripremljen za vreme tretmana može se koristiti pri vođenoj regeneraciji kosti jer embriološki obe alveolarne kosti u maksilofacijalnoj regiji i zubi potiču od istih ćelija nervne kreste i poseduju slične biohemijske sadržaje i karakteristike kao i ljudska kost [3].

Zubi kao kompleksni organ jesu bogat izvor matičnih progenitorskih ćelija, kolagenih vlakana, metalnih jona, faktora rasta i razvoja (BMPS, IGF, PDGF, TGF itd.). Dentin je prisutan u 85% totalne zubne mase i on je u osnovi acelularni matriks različit od osteocita sadržanih u kostima. Iako su tkivne strukture kosti i dentina različite, odnos komponenti je sličan (70% minerala, 20% kolagena, 10% telesne tečnosti) [4].

Prvi dokumentovani materijal o regenerativno-osteoinduktivnom potencijalu autolognog dentinskog grafta prikazan je u studiji koju su sproveli Yeomans i Urist 1967. g., kojom se u dentinu otkrivaju faktor razvoja BMP i faktori rasta. Ovo istraživanje je skoro pola veka bilo zaboravljeno sve do interesa dentalne implantologije za optimalno i dugotrajno očuvanje alveolarnog grebena. Prvi klinički slučaj upotrebe autolognog dentinskog grafta kod čoveka opisan je od strane korejskog naučnika Masaru Murata 2003. g. pri izvođenju sinus lift operacije. Od 2008. god. se uglavnom koristi za vođenu regeneraciju kosti u osteointegraciji dentalnih implantata [4].

Reciklirani zubi „Green dentistry" mogu ponuditi najbolji graft materijal sa stanovišta ekonomskih, kliničkih i bioloških vrednosti, što je prikazano u Tabeli 1.

MATERIJALI I METODE RADA

Protokol i procedura dobijanja i pripreme mineralizovanog dentinskog matriksa

Celokupni postupak od ekstrakcije zuba do postavljanja grafta traje oko 15 minuta. Sva potrebna aparatura prikazana je na Slici 1. Vitalni zubi ekstrahovani radi uznapredovalog periodontitisa ili ortodontskih indikacija pripremljeni su za imedijantni graft materijal. Neposredno posle ekstrakcije uklanjaju se zubne restauracije i endodontska punjenja, kao i ostaci karioznih lezija na periodontalnom ligamentu i zubnog kamenca pomoću ultrazvuka ili ručnim instrumentima. Očišćeni zubi se suše pusterom i sterilnom gazom i stavljaju se u sterilnu komoru za mlevenje zuba „Smart dentin grindera" (SDG-a). SDG može samleti korene za samo tri sekunde i zatim se vibrirajućim pokretima za 20 sekundi izbacuje kroz sito partikle manje od 1200 μm u donju komoru, koja čuva partikle između 300–1200 μm. U fioci za sakupljanje bile su dentinske partikle između 300–1200 μm sa različitim kvantitetom – od 1 do 2,5+ mg, u zavisnosti od toga koji zub služi kao izvor graft materijala.

Partikulirani dentin iz fioke se potopi u bazičnom alkoholu 5–10 minuta, u malom sterilnom i staklenom sudu. Ovaj rastvor sastoji se od 0,5M NaOH i 20% etanola i njime se obezmašćuje i rastvara sav organski otpad i eliminišu se svi tipovi bakterija, virusa itd. Na kraju postupka vrši se hidratacija i neutralizacija pH vrednosti do 7,2 uz pomoć PBS-a (fosfat-pufrani salin). Postupak se ponavlja dva puta u trajanju od jednog minuta.

Dobijene i očišćene dentinske čestice stavljaju se u željenu alveolarnu regiju uz pomoć specijalnog instrumenta-nosača ili plastičnim instrumentom. Graft materijal se nežno pritisne nabijačem kako bi se zgusnuo u alveolarnoj čašici. Nakon toga, da bi se zaštitio aplicirani graft materijal (ADG), odozgo se postavlja spongiozni fibrin-Gelatamp, i na kraju uširva se neresorptivnim koncem 4/0, koji se uklanja nakon 7–14 dana [5]. Posle intervencije, svi pacijenti se podvrgnu jednonedeljnoj antibiotskoj terapiji, koja podrazumeva Amoxicillin cum ac.clavullonic 1000 mg, jedna tableta svakih 12 sati, kao i nesteroidne antiinflamatorne analgetike, ili Clindamycin 300 mg, jedna kapsula svakih osam sati. Pacijenti se savetuju da 15 dana svakodnevno ispiraju hiruršku ranu 0,2% rastvorom hlorheksidina.

Klinički parametri

Klinička merenja se izvode postoperativno prvog, trećeg, sedmog, petnaestog dana i nakon tri meseca da bi se utvrdilo zarastanje rane. Na ovim pregledima pacijenti dobijaju upitnik da ocene prisustvo bola, trizmusa, otoka i upotrebu analgetika, a od važnosti je i da daju opis mogućih postoperativnih komplikacija: infekciju, otok, paresteziju, hematom, dehiscenciju itd. Merenje horizontalnih dimenzija alveolarnog grebena izvodi se specijalnim instrumentom – Bone measuring calipers (osteometar) na 2. i 4. mm ispod limbusa alveolarisa.

Merenje indeksa apikalno-epitelne migracije – AEM, tj. klinički gubitak pripoja (razdaljina između gleđno-cementne granice i dna sulkusa) kod susednog zuba (distalno od drugog kutnjaka). Drugim rečima, meri se dubina formiranog intrakoštanog defekta posle ekstrakcije impaktiranog umnjaka i istovremeno prati se koštani defekt nakon augmentacije autogenim dentinskim graftom. Merenje periodontalnog džepa izvodi se pomoću graduirane periodontalne sonde. Ova klinička merenja dimenzionih promena alveolarnog grebena izvode se intraoperativno i u periodu od 3 i 6 meseci postoperativno.

Parakliniča ispitivanja – radiografija

Panoramska radiografija uradi se trećeg meseca posle operacije da bi se ocenila regeneracija kosti i da bi se isključile moguće komplikacije uzrokovane hirurškim postupkom. Ortopantomogram se uradi postoperativno 3. i 6. meseca zbog merenja denziteta kosti uz pomoć softvera ImageJ (verzija 1,36b, izdata od strane Američkog nacionalnog instituta za zdravlje), koji se koristi za analizu ROI (regija od interesa) sa vrednostima od 0 do 255 greja u jednom pikselu slike. Takođe, pomoću digitalnog panoramiksa izvode se i vertikalna merenja vertikalnih koštanih defekta distalno od drugog kutnjaka.

PRIKAZ SLUČAJA

Imedijantna zaštita alveolarnog grebena posle ekstrakcije zuba (34, 35, 48)

Pacijent, 58 godina, dobrog opšteg zdravlja, zainteresovan je za ugradnju implantata. Iz tog razloga izvedena je multipna ekstrakcija, a istovremeno i imedijantna prezervacija alveola sa ciljem zaštite neophodnih dimenzija alveolarnog grebena. Za vreme ovog postupka, alveolarna čašica ekstrahovanog zuba popunjava se koštanim supstitutom – ADG-om (slike 2, 3, 4). Ovo omogućava primarnu stabilnost čvrstih i mekih tkiva do nivoa limbusa alveolarisa i sprečava bukalni kolaps zaštićene alveole. Klinička merenja su vršena nakon šest meseci pomoću instrumenta za merenje kosti (Bone measuring instrument) u poziciji 1 tj. 2 mm ispod limbusa alveolarisa (Tabela 2), i u poziciji 2 tj. 4 mm ispod limbusa alveolarisa (Tabela 3). Obe merne tačke pokazuju minimalnu koštanu redukciju alveolarnog grebena od 1 do 2 mm, dok u donjim delovima alveolarnog grebena nema vidljivih dimenzionih promena (Slika 5). Klinički nema naglašene postoperativne simptomatologije (bolovi, otok, trizmus), kao ni posebnih komplikacija.

Promene na koštanim i mekim tkivnim strukturama posle ekstrakcije zuba su neizbežan fiziološki proces koji se javlja na rezidualnom alveolarnom grebenu. Upravo zbog te činjenice održavanje volumena alveolarnog grebena pomoću imedijantne prezervacije alveole igra važnu ulogu u terapiji implantatima.

Postavljanje autogenog dentinskog grafta u koštanim defektima distalno od drugog donjeg kutnjaka posle ekstrakcije impaktiranog donjeg umnjaka – 38

Kod pacijenta u dobrom opštem zdravstvenom stanju, saglasnih da učestvuju u studiji, bez periodontalnih oboljenja, postoji najmanje jedan impaktirani umnjak mezijalno inklinirani, a koreni zuba 38 su u direktnom kontaktu sa mandibularnim kanalom (slike 6, 7, 8).

Indeks apikalno-epitelne migracije – AEM susednog zuba distalno od drugog kutnjaka, meren graduiranom sondom šest meseci posle prezervacije ADG-om iznosi 1 mm, što znači da postoji potpuno pokrivanje infrakoštanog defekta nastalog posle osteotomije impaktiranog donjeg umnjaka. Nema oštećenja na periodoncijumu susednog zuba 37, kao ni povećane osetljivosti na njemu. Mandibularni kanal je pokriven sa imedijatno pripremljenim autolognim dentinskim graftom (Slika 9). Temporarna parestezija donje leve usne praćena je postoperativno u periodu od tri nedelje. Kugelberg i saradnici su otkrili da dve godine posle operacije kod 43,3% slučaja dubina džepa premašuje 7 mm, dok je IBDs (infrakoštani defekt) kod 32,1% veći od 4 mm [6].

Primena autolognog dentinskog grafta za augmentaciju koštanog defekta u viličnoj kosti

Pacijent, 50 godina, žali se na neznatni bol i otok u levoj maksilarnoj regiji. Na iste simptome ukazuje dve godine (udruženo sa zubima 22, 23) sa periodičnim egzacerbacijama bolesti, usled kojih je tretiran simptomatskom i antibiotskom terapijom. Vršena je i drenaža otoka. Pritom uzrok ovog stanja – radikularna cista, nije bio uklonjen. Druga cista u delu *tuberositas maxillaris lateralis sinistra* je asimptomatska.

Urađena je kompletna enukleacija ciste i cistične membrane u levoj frontalnoj regiji maksile metodom Partch ll uz kompletno popunjavanje koštanog defekta dobijenim mineralizovanim dentinskim graftom (1,5 mg). Cista u tuberu maxillae je kompletno uklonjena bez augmentiranja bilo kojim graft materijalom (slike 10–13).

Kontrolni digitalni panoramski snimak urađen je posle tri meseca i uz pomoć specijalnog softvera – Image J (verzija 1,36b, izdata od strane Američkog nacionalnog instituta za zdravlje) sa numeričkim vrednostima 0–255 greja u jednom pikselu slike meri se denzitet novoformirane kosti. 0-vrednost odgovara crnoj boji na RTG snimku (prosvetljenje), dok 255 odgovara beloj boji, potpuna x-ray apsorpcija (senke) [7].

U našem konkretnom slučaju, augmentirani koštani defekat pokazuje solidan koštani denzitet od 178 greja, što ukazuje na brži proces osteointegracije i regeneracije novog koštanog tkiva, dok neaugmentirani koštani defekat pokazuje viši luminozitet od 77 greja (Slika 14).

DISKUSIJA

Mogućnost smanjenja rizika od buduće periodontalne patologije mezijalno od hirurške regije IMMT jeste primena koštanog grafta sa ciljem zaštite distalne strane drugog mandibularnog kutnjaka. Upotreba komercijalno raspoloživih koštanih graftova podiže cenu tretmana, što za pacijenta može biti razlog za odbijanje dodatnog postupka. ADG predstavlja pouzdan izvor grafta za prezervaciju alveola i za ostale koštane graft aplikacije, jer se nakon 60 dana zapaža stvaranje velike količine novog koštanog tkiva, a nakon 90 dana i male količine lamelarne kosti.

Resorpcija ADG čestica je spora (zbog mineralizovane strukture), što omogućava dugoročno i postepeno stvaranje lamelarne kosti. Studije su pokazale da se formirana kortikospongiozna kost uspešno održava implantatom u proseku u narednih pet godina.

Kao što su pokazali naši slučajevi, primena autolognog dentinskog grafta značajno minimizira resorpciju rezidualnog alveolarnog grebena. Ovo potvrđuje i teza Vitorinija i saradnika, koji zaključuju da je prezervacija alveolarnog grebena značajno bolji tretman od slučajeva bez prezervacije, gde postoji manji gubitak vertikalne i horizontalne dimenzije kosti. On naročito ističe potrebu zaštite alveolarnog grebena u visoko estetskim zonama, gde je debljina bukalne lamine manja, od 1,5 mm do 2 mm, i u slučajevima gde su u neposrednoj blizini anatomske strukture kao što su maksilarni sinus i mandibularni kanal.

Zapaža se da ankilotična kost stvorena u kontaktu sa dentinom proizvodi veoma stabilan alveolarni greben, koji bi se inače resorbirao 3–6 meseci nakon ekstrakcije. Ovaj graft štiti alveolarni greben kako u funkcionalnom tako i u estetskom smislu. Može se koristiti posle tri meseca za inserciju implantata u posteriornoj maksilarnoj regiji, menjajući D3 kost u D1 [7].

Hirurška ekstrakcija trećeg impaktiranog umnjaka izvodi se često u ortodonciji iz profilaktičkih razloga ili u oralnoj hirurgiji iz terapeutskih razloga [8]. Učestalost impakcije kreće se između 66% i 77% [9]. Statistički, procenjuje se da samo u SAD od 20 miliona ekstrahovanih zuba godišnje 30% su izvađeni zbog periodontalne pokretljivosti, a 10% izvađenih zuba su impaktirani zubi. Uglavnom ove zube smatramo biološkim otpadom umesto da iskoristimo prednosti njihovih fantastičnih karakteristika. Standardna hirurška ekstrakcija impaktiranog trećeg kutnjaka može kompromitovati periodontalni status susednog drugog kutnjaka i tako ubuduće iziskivati dodatnu hiruršku intervenciju.

Schropp i saradnici smatraju da se 50% svih redukcija horizontalnih i vertikalnih dimenzija dešava prvih 12 meseci posle augmentacije, od kojih 2/3 resorpcije u prva tri meseca posle ekstrakcije (3,8 mm) [10]. Redukcija širine alveolarnog grebena bez koštane augmentacije posle prirodnog zarastanja ekstrakcione rane kreće se između 2,6 mm i 4,6 mm, visina grebena opada od 0,4 mm do 0,9 mm, horizontalna resorpcija ima srednju vrednost od 3,87 mm sa istovremenom redukcijom vertikalne dimenzije sa srednjom vrednošću od 1,67 mm [11, 12].

Ekstrahovani zubi ne mogu se i dalje smatrati medicinskim otpadom upravo zbog činjenice da u kratkom periodu mogu poslužiti za dobijanje izuzetno bezbednog graft materijala sa visokom biološkom važnošću. Primenom mineralizovanog dentinskog matriksa maksimalno iskorišćavamo naš sopstveni biološki potencijal bez upotrebe drugih arteficijalnih graft materijala.

ZAKLJUČAK

Upotreba grafta odmah posle hirurške ekstrakcije impaktiranog umnjaka može pomoći u prevenciji resorpcije za vreme zarastanja rane i to je dokazano stvaranjem koštanih tkiva na distalnoj strani susednog drugog kutnjaka.

Finansijski je dostupna pacijentu i to omogućava hirurgu da primeni autologni koštani graft materijal kao najbolji izbor za vođenu regeneraciju kosti.

Klinički proces zarastanja koštanih i mekih tkiva je ubrzan sa mirnim tokom bez naglašenog otoka i bolovima, sa relativno sačuvanim vertikalnim i horizontalnim dimenzijama alveolarnog grebena.

Na postooperativnom RTG snimku vidi se rano stvaranje nove kosti – trabekule uz odličnu osteointegraciju dentinskog grafta u koštanim defektima viličnih kosti.

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CBCT analysis of apical distance between second lower premolars, first and second lower molars and mandibular canal

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SUMMARY

Introduction Mandibular canal with the associated neurovascular bundle may be closely related to the apices of mandibular teeth. In order to avoid injuries and damages to the inferior alveolar nerve during invasive dental procedures, it is important to know its localization.

The aim of this study was to determine the average vertical distances of the root apices of second premolars, first molars and second molars mesially and distally from the upper projection of the mandibular canal on the sagittal section of CBCT images, and determine if there were statistically significant differences between the age and gender groups.

Material and methods The research was conducted at the Faculty of Medicine of the University of Banja Luka, and the sample consisted of 146 CBCT images of patients. CBCT images were obtained using Planmeca ProMax 3D Mid instrument (Planmeca, Helsinki, Finland) and analyzed using Planmeca Romexis Viewer software. In the sagittal section, the vertical distance from the root apex to the upper projection of the mandibular canal was measured for each examined tooth.

Results The distal root of the first molar (4.88 mm) had the greatest average vertical distance of the root apex from the mandibular canal, and the distal root of the second molar had the smallest average vertical distance (2.76 mm). There was statistically significant difference between certain age groups in the values of individual roots, for the second molar mesially and distally ($p < 0.05$), while for the first molar mesially the value of p was at the limit of significance ($p = 0.05$).

Conclusion The results of this study showed that distal root of the mandibular second molar had the smallest vertical distance from mandibular canal, therefore an extra caution during a root canal treatment and careful planning of oral surgery in this region is recommended.

Keywords: CBCT; mandibular canal; vertical distance of tooth apex; lower premolars; lower molars

INTRODUCTION

Cone-beam computerized tomography (CBCT) is a modern radiological imaging system, designed specifically for use in the maxillofacial region. The system overcomes many limitations of conventional radiography, creating a non-distorted, three-dimensional image of the examined area. It is used in endodontics to determine the morphology and dimensions of root canals, periapical lesions, detection and localization of resorptions, postoperative control and monitoring of treatment outcomes. It is also used in orthodontic treatment, as well as implant prosthodontics, facilitating prosthetic planning, selection of implants and the place of its installation [1, 2, 3]. Also, successful endodontic treatment largely depends on an adequate radiographic method, which should provide critical information about examined teeth and their surrounding anatomy. Since its beginning, conventional radiography has remained the mainstay of auxiliary diagnostic methods in endodontics.

Data from the literature indicate that there are differences when comparing the distances of the tips of mandibular teeth from mandibular canal in relation to gender and age. However, numerous individual variations of the position of the canal in the mandible can occur, as well as the position of teeth and their mutual relationship [4]. Mandibular canal extends through the lower jaw from the mandibular opening (foramen mandibulae). In most cases, it is bilaterally symmetrical and in the form of one main canal on each side of the mandible, but variations are also possible. The contents of the mandibular canal are inferior alveolar nerve (nervus alveolaris inferior) and blood vessels of the same name. Inferior alveolar nerve is mixed and its terminal branch with its sensitive part

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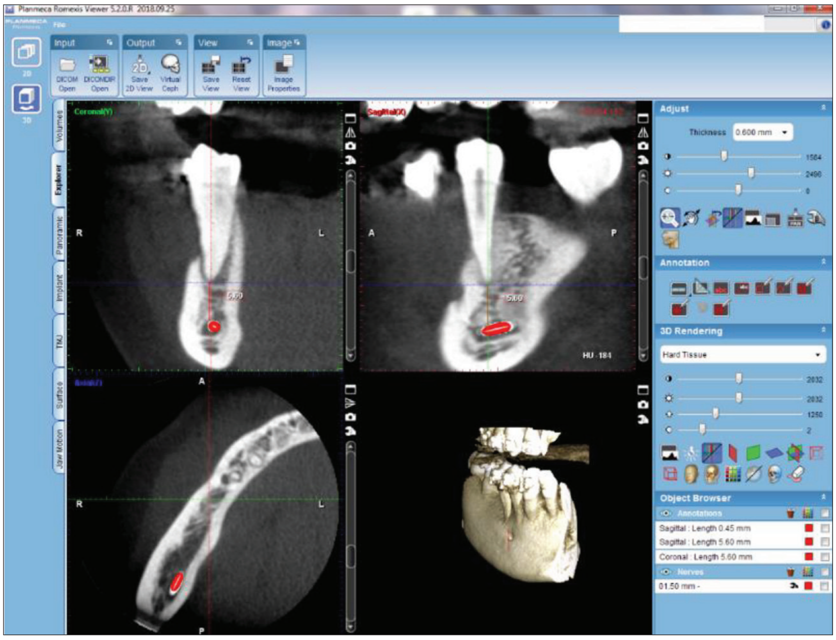

Figure 1. Planmeca Romexis Viewer software
Slika 1. Softver Planmeca Romexis Viewer

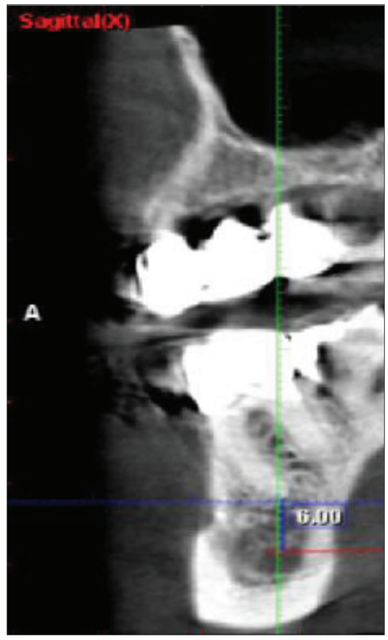

Figure 2. Measuring the distance between canal and a tooth; sagittal 3D image
Slika 2. Merenje udaljenosti kanala od zuba; sagitalni 3D snimka

innervates teeth and gums of the lower jaw, while motor part controls mylohyoid muscle and anterior belly of digastric muscle [5, 6].

Many authors have confirmed that iatrogenic injuries of the inferior alveolar nerve are common (64.4%). Therefore, it is necessary to know the exact location of the mandibular canal and its contents for adequate endodontic treatment of lower posterior teeth as well as adequate resection of their root tips. Endodontic treatment includes mechanical use of instruments combined with chemical irrigation, medication agents and materials for final obturation of the canal system. During all these phases, the occurrence of unwanted complications is possible - mechanical, chemical or thermal injury to the nerve that can cause neuropathic pain or anesthesia in its innervation zone. During endodontic treatment of 1% of lower premolars and even 10% of the lower second molars there is possibility of an injury to lower alveolar nerve. Injury to the content of the mandibular canal is also possible during oral surgery. Such injuries sometimes require treatment in the form of microsurgical decompression of the inferior alveolar nerve [7–10].

The aim of this retrospective study was to determine the average vertical distances of the root apices of second premolars, first molars and second molars mesially and distally from the upper projection of the mandibular canal on the sagittal section of the CBCT, and determine whether there were statistically significant differences between the age and gender groups.

MATERIAL AND METHODS

The research was approved by the Ethics Committee of the Faculty of Medicine at the University of Banja Luka (18/4.141/21). The sample included 146 CBCT images of patients where the vertical canal distance of the second premolar, first molar and second molar was measured distally and mesially and statistical significance of the difference in relation to gender and age was examined. The initial database included 174 images, of which 146 met the criteria for sample selection: the presence of at least one tooth of importance for research (second mandibular premolar, first mandibular molar and second mandibular molar) and visibility of the mandibular canal on the image. Teeth with internal and external root resorption and endodontically treated teeth were not included in the study. The research included images made in the period from January 1st 2018 until December 31st 2018.

The imaging process was performed using Planmeca ProMax 3D Mid camera (Planmeca, Helsinki, Finland), and CBCT images were analyzed using Planmeca Romexis Viewer software (Figure 1). On the sagittal section, for each tooth (second mandibular premolar, first mandibular molar, second mandibular molar), vertical distance of the root apex to the upper projection of the mandibular canal was measured (Figure 2). For teeth with two roots, the distance was measured for each root separately (Figure 3).

Mandibular canal on sagittal section shows variability in appearance and usually appears as a radiolucent circle, which can be up to 4 mm in diameter. To facilitate the identification of mandibular canal, mental opening was identified on sagittal section, and the canal was followed to the level of the apex of the corresponding tooth [11].

A total of 406 measurements were performed, of which 146 for the second premolar, 42 for the first molar mesially, 42 for the first molar distally, 88 for the second molar mesially, and 88 for the second molar distally (Table 1). After the measurements, obtained values were divided according to the gender and age of the patients (Table 2). Based on age, the sample was divided into the three groups: group

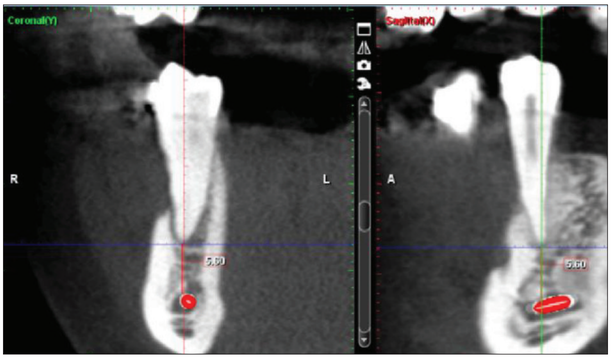

Figure 3. Distance of the mandibular canal from the apex of the mesial root of the tooth
Slika 3. Udaljenost mandibularnog kanala od vrha mezijalnog korena zuba

Table 1. Total number of measurements by gender and age groups for each root
Tabela 1. Ukupan broj merenja po polnim i starosnim grupama za svaki koren

GENDER POL	GROUP GRUPA	FMD PMD	FMM PMM	SMD DMD	SMM DMM	SP DP	TOTAL UKUPNO
FEMALE ŽENE	A	2	2	2	2	2	**10**
	B	9	9	22	22	29	**91**
	C	3	3	12	12	24	**54**
MALE MUŠKARCI	A	3	3	2	2	3	**13**
	B	18	18	30	30	48	**144**
	C	7	7	20	20	40	**94**
TOTAL UKUPNO		**42**	**42**	**88**	**88**	**146**	**406**

A – ≤17 years; B – 18–49 years; C – ≥50 years; FMD – first molar distally; FMM – first molar mesially; SMD – second molar distally; SMM – second molar mesially; SP – second premolar
A – ≤17 godina; B – 18–49 godina; C – ≥50 godina; PMD – prvi molar distalno; PMM – prvi molar mezijalno; DMD – drugi molar distalno; DMM – drugi molar mezijalno; DP – drugi premolar

Table 2. Average vertical distance by age groups
Tabela 2. Prosečna vertikalna udaljenost po starosnim grupama

AVERAGE VERTICAL DISTANCE BY AGE GROUPS PROSEČNA VERTIKALNA UDALJENOST PO STAROSNIM GRUPAMA					
GROUP GRUPA	FMD PMD	FMM PMM	SMD DMD	SMM DMM	SP DP
A	4.48	4.62	4.63	4.69	3.20
B	4.39	4.40	2.20	2.56	4.17
C	6.40	6.22	3.44	3.54	4.39

A – ≤17 years; B – 18–49 years; C – ≥50 years; FMD – first molar distally; FMM – first molar mesially; SMD – second molar distally; SMM – second molar mesially; SP – second premolar
A – ≤17 godina; B – 18–49 godina; C – ≥50 godina; PMD – prvi molar distalno; PMM – prvi molar mezijalno; DMD – drugi molar distalno; DMM – drugi molar mezijalno; DP – drugi premolar

A, which included CBCT images of patients younger than 17, group B, which included CBCT images of patients aged 18 to 49, and group C, which included CBCT images of patients older than 50.

STATISTICAL ANALYSIS

All data were presented in tables and figures. R Studio Version 3.6.2 was used to analyze the obtained data. Data were processed with a 95% significance level using The Kruskal-Wallis and The Mann-Whitney U test. Based on the measured values, the average vertical distances for each root were determined, as well as average vertical distances for each root by age groups. It was also examined what this statistical significance is reflected in, by comparing individual groups separated by gender. In groups of teeth where significant statistical deviation was observed, CBCT images of persons of one gender, from one age group, were compared with CBCT images of persons of the same gender from another age group.

RESULTS

Analysis of the results of the average vertical distance for each root from the upper projection of mandibular canal showed that distal root of first molar (4.88 mm) had the highest average vertical distance and distal root of second molar (2.76 mm) the smallest. The average distance for first molar mesially was 4.86 mm, for second molar mesially 3.01 mm, and for second premolar 4.23 mm (Figure 4).

Observed by age groups, in the group A, second molar had the greatest distance from the mandibular canal mesially (4.69 mm), and second premolar had the smallest distance (3.2 mm).

In the group B, the greatest average vertical distance of the root apex from mandibular canal was shown in first molar mesially (4.4 mm) and the smallest in second molar distally (2.2 mm). In the group C, first molar distally had the highest average vertical distance (6.4 mm), and second molar distally had the smallest distance (3.44 mm). With statistical significance of 95% and using The Kruskal-Wallis test, the average vertical distance by types of premolars and molars in relation to age groups was observed (Table 2) but there was no statistically significant difference, $p > 0.05$. With statistical significance of 95% and using The Mann-Whitney U test, it was observed whether there was a statistically significant difference between age groups for each individual root and found that in the first molar mesially there was a statistically significant difference between groups B and C, with note that the value of p was at the significance limit ($p = 0.05$). In the second molar distally, statistically significant difference was observed between groups A and B, as well as between B and C ($p < 0.05$), and in second molar mesially between groups B and C ($p < 0.05$). No statistically significant difference was observed in other groups.

Previously mentioned groups, where statistically significant difference was found were further divided by gender in the analysis, after which persons of one gender from one age group were compared with persons of the same gender from another age group.

Comparing the vertical distance between CBCT images of females by age groups B and C for the first molar mesially, it was found that the difference was not statistically significant ($p>0.05$), while in males there was significant difference ($p<0.05$) (Figure 5).

Comparing the vertical distance between females by age groups B and C for the second molar distally, it was found that the difference was not statistically significant

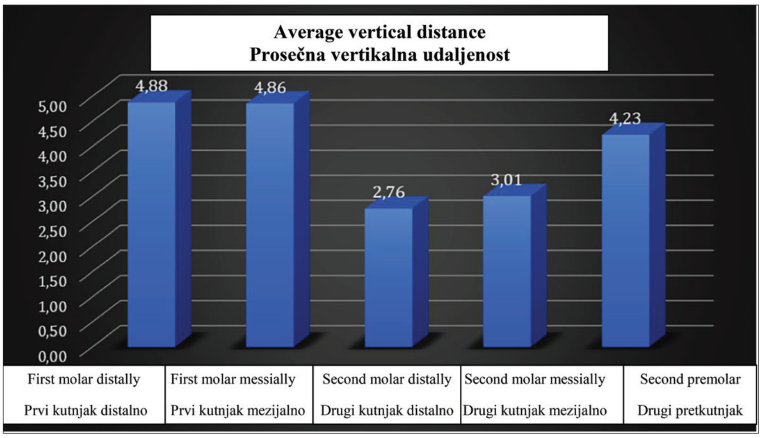

Figure 4. Average vertical distance for each root from the upper projection of the mandibular canal
Slika 4. Prosečna vertikalna udaljenost za svaki koren od gornje projekcije mandibularnog kanala

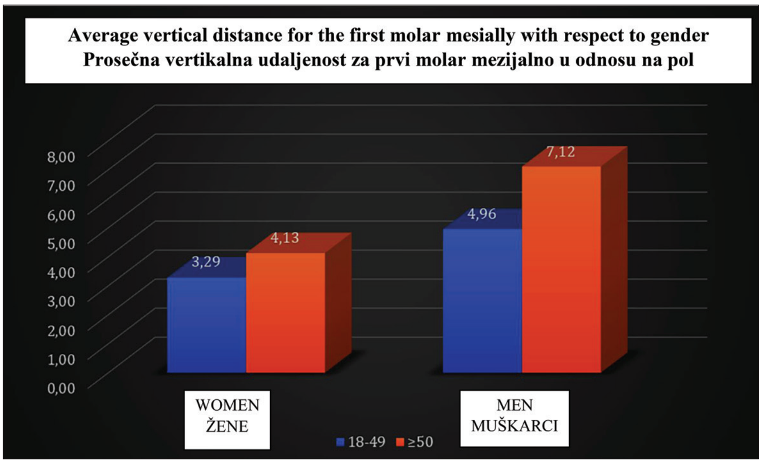

Figure 5. Average vertical distance for the first molar mesially with respect to gender
Slika 5. Prosečna vertikalna udaljenost za prvi molar mezijalno u odnosu na pol

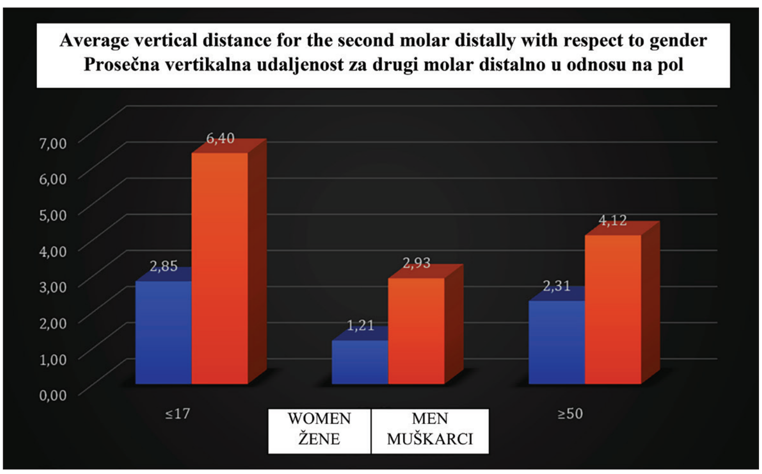

Figure 6. Average vertical distance for the second molar distally with respect to gender
Slika 6. Prosečna vertikalna udaljenost za drugi molar distalno u odnosu na pol

(p>0.05), while for the same groups in males statistically significant difference was found (p<0.05) (Figure 6).

Although there is a statistically significant difference for the whole age groups B and C in the second molar mesially, observing the same by gender, and from different age groups no statistically significant difference was found (p > 0.05) (Figure 7).

No statistically significant difference between different age groups in women was found, while in men it was observed only in the first molar mesially and the second molar distally, between groups A and B.

Comparing the average vertical distances for each root by gender, it was observed that all average values were higher in males. For men, the greatest average vertical distance was present in the root of first molar distally (5.57 mm) and the smallest in second molar distally (3.52 mm). In women, also, first molar distally had the greatest average vertical distance (3.50 mm), and second molar mesially had the smallest (1.64 mm) (Figure 8).

DISCUSSION

Development of modern radiological imaging system and CBCT, designed specifically for use in maxillofacial region, allowed obtaining timely information relevant to endodontic, surgical or endodontic-surgical treatment [12, 13, 14]. CBCT overcomes many of the limitations of conventional radiography, creating a non-distorted, three-dimensional image of the examined area and allowing visualization of the images by layers and sections in all three dimensions [15].

The results of our study showed that distal root of the first molar (4.88 mm) had the greatest average vertical distance of the apex from mandibular canal. Distal root of second molar (2.76 mm) had the smallest average vertical distance, it is more gracile than the mesial and slightly distally oriented, and its close relationship with the mandibular canal can be attributed to the trajectory and its position in the mandible. Uğur Aydın et al. obtained partially similar results in Turkish population, where they found, based on CBCT images, that distal root of second molar (2.75 mm) had the smallest average distance from mandibular canal, while the greatest average distance was registered in the mesial root of the first molar (4.98 mm) [16].

In their study on CBCT images, Lvovsky et al. concluded that mesial root of the first molar (6.18 mm) had the greatest average distance, and distal root of the second molar (3.42 mm) had the smallest distance to mandibular canal [17]. The mean value for the mesial root of the first molar in our study was 4.86 mm.

Aksoy et al., by measuring the shortest distance from the mandibular canal, also found that the roots of the

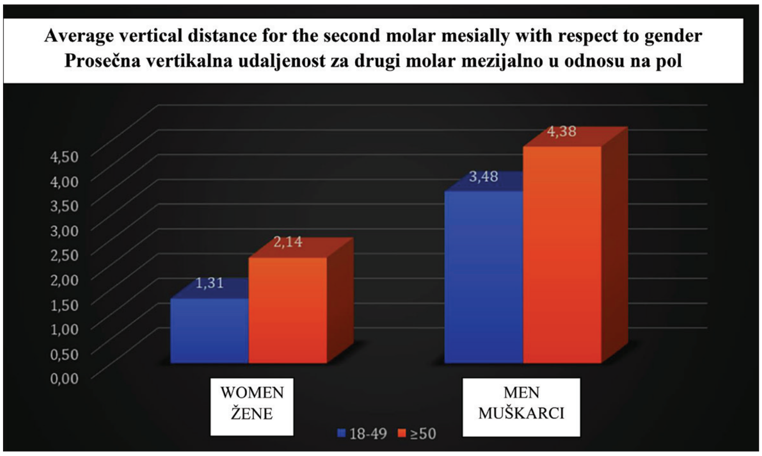

Figure 7. Average vertical distance for the second molar mesially with respect to gender
Slika 7. Prosečna vertikalna udaljenost za drugi molar mezijalno u odnosu na pol

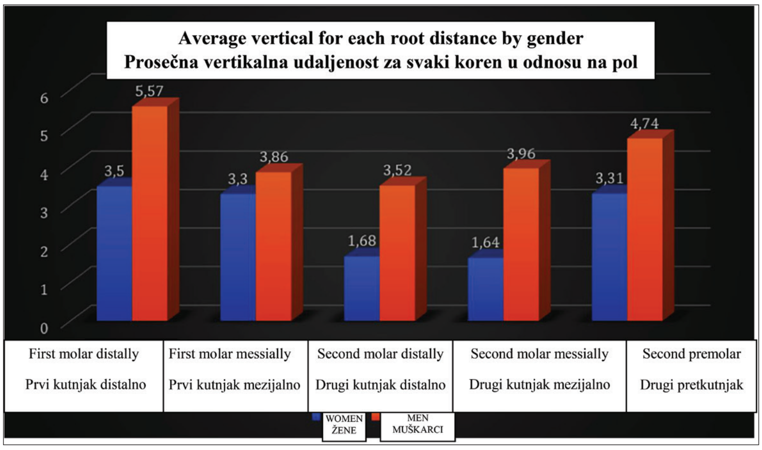

Figure 8. Average vertical distances for each root by gender
Slika 8. Prosečna vertikalna udaljenost za svaki koren u odnosu na pol

second molar were significantly closer to mandibular canal than the roots of the first molars, first, and second premolars [18]. In the study of Denio et al. that analyzed anatomical relationships of the mandibular canal and lateral teeth by dissecting 22 mandibles, it was concluded that second mandibular premolar and second mandibular molar had the smallest distance from mandibular canal [19].

Using CBCT images, Kosumarl et al. found that mesial root of the first molar had the greatest average distance from mandibular canal, while the shortest was in distal root of second molar, both in persons with normal skeletal jaw ratio or skeletal open bite [20]. With the exception of the third molar, Pucilo et al. concluded in a systematic review that distal root of the second molar was closest to the mandibular canal, which coincided with the results of our study [21]. Littner et al. measured the average values of the distance from the apex of first and second molars from the canal on radiographic images of the cadaver and they were between 3.50 and 5.40 mm, and according to a study conducted by Kovisto et al. on CBCT images, these average values were between 1.51 and 3.43 mm [22, 23]. In our study, the average values of the distance of the apices in lower lateral teeth from the mandibular canal ranged between 2.76 and 4.88 mm.

Observing the average vertical distances for each root by gender, it was noticed that all average values were higher in males, which could be related to more gracile constitution of women and smaller dimensions of the lower jaw. Similar findings were reported by other researchers (Aksoy et al. 2017; Simonton et al. 2009), who found that distances between the apices of the lower premolars and lower molars and mandibular canal were smaller in female population [18, 24].

Sato et al. performed research on cadavers, and with the help of CT images and panoramic radiography measured the distances from the root apex to the upper projection of the mandibular canal. Data were grouped by gender and side of mouth. They recorded slightly lower values of the distance in first and second molars from the mandibular canal in women, compared to men [25].

It has been shown that there is four times higher possibility of developing chronic pain after endodontic treatment, if the patient is a female person, as the incidence of postoperative pain in women is also higher [26].

For a definitive conclusion on the reliability of such measurements of the distance of the tooth apices from the mandibular canal, verification in a larger group of teeth is necessary. The deviations in the measurements can be explained by the fact that they were obtained through different sagittal sections of the CBCT, which could affect the repeatability of these measurements.

CONCLUSION

Measurements obtained in our study and statistical analyses showed that distal root of mandibular second molars had the smallest vertical distance from the mandibular canal, so careful canal instrumentation and careful planning of oral surgery in this region is recommended.

Interventions in the lateral region of the mandible can lead to damage of the neurovascular bundle of the canal, and unwanted complications, such as paresthesia or neuropathic pain. Therefore, it is important that the therapist is familiar with these relations and performs treatment in compliance with biological principles.

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Primena CBCT analize u proceni udaljenosti korenova drugih donjih premolara, prvih i drugih donjih molara od mandibularnog kanala

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KRATAK SADRŽAJ

Uvod Mandibularni kanal sa pripadajućim neurovaskularnim snopom može biti u bliskom odnosu sa vrhovima mandibularnih zuba. Da bi se izbegle povrede i oštećenja donjeg zubnog živca tokom invazivnih dentalnih procedura, važno je poznavati njegovu lokalizaciju.

Cilj ovog istraživanja je bio da se na osnovu sagitalnog preseka CBCT snimka odrede prosečne vrednosti udaljenosti korenova drugih donjih premolara, prvih i drugih donjih molara mezijalno i distalno od gornje projekcije mandibularnog kanala, te utvrdi da li postoji statistička značajnost u odnosu na pol i starosnu dob.

Materijal i metode Istraživanje je sprovedeno na Medicinskom fakultetu Univerziteta u Banjoj Luci, a uzorak je činilo 146 CBCT snimaka pacijenata. CBCT snimci su dobijeni sa aparatom Planmeca ProMax 3D Mid (Planmeca, Helsinki, Finska) i analizirani pomoću softvera Planmeca Romexis Viewer. Na sagitalnom preseku je za svaki zub izmerena vertikalna udaljenost vrha korena do gornje projekcije mandibularnog kanala.

Rezultati Najveću prosečnu vertikalnu udaljenost apeksa korena zuba od mandibularnog kanala imao je distalni koren prvog molara (4,88 mm), a najmanju distalni koren drugog molara (2,76 mm). Statistički značajna razlika postoji između određenih starosnih grupa kod vrednosti pojedinačnih korenova i to za drugi molar mezijalno i drugi molar distalno ($p < 0,05$), za prvi molar mezijalno vrednost r je na granici značajnosti ($p = 0,05$).

Zaključak Rezultati ovog istraživanja pokazuju da najmanju vertikalnu udaljenost od mandibularnog kanala ima distalni koren mandibularnih drugih molara, pa se preporučuje pažljiva obrada kanala ovog korena i pažljivo planiranje oralnohirurških zahvata u ovoj regiji.

Ključne reči: CBCT; mandibularni kanal; vertikalna udaljenost apeksa zuba; donji premolari; donji molari

UVOD

Kompjuterizovana tomografija Cone-beam (CBCT) savremeni je radiološki sistem za snimanje, dizajniran posebno za upotrebu u maksilofacijalnoj regiji. Sistem prevazilazi mnoga ograničenja konvencionalne radiografije, stvaranjem neiskrivljenje, trodimenzionalne slike područja koje se ispituje. Koristi se u endodonciji za određivanje morfologije i dimenzija kanala korena, periapikalnih lezija, otkrivanje i lokalizaciju resorpcija, za postoperativnu kontrolu i praćenje ishoda terapije. Primenu je našao i u ortodontskoj terapiji, kao i u implantoprotetici, budući da olakšava protetsko planiranje, izbor implantata i mesta njegove ugradnje [1, 2, 3].

Uspešan endodontski tretman uveliko zavisi od adekvatne rendgenografske metode, koja bi trebalo da pruži kritične informacije o ispitivanim zubima i njihovoj okolnoj anatomiji. Od svog osnivanja, konvencionalna radiografija je ostala glavni oslonac pomoćnim dijagnostičkim metodama u endodonciji.

Podaci iz literature ukazuju da postoje razlike kada se uporede udaljenosti vrhova mandibularnih zuba od mandibularnog kanala u odnosu na pol i godine pacijenta. Međutim, mogu se javiti brojne individualne varijacije položaja kanala u mandibuli, kao i položaja zuba i njihovog međusobnog odnosa [4].

Mandibularni kanal se pruža kroz donju vilicu od donjoviličnog otvora (*foramen mandibulae*). On je u najvećem broju slučajeva bilateralno simetričan i u vidu jednog glavnog kanala sa svake strane mandibule, ali su moguće i varijacije. Sadržaj mandibularnog kanala čine donjovilični živac (*nervus alveolaris inferior*) i istoimeni krvni sudovi. Donji zubni živac je mešovita i završna grana mandibularnog živca, svojim senzitivnim delom inerviše zube i desni donje vilice, a motornim delom milohioidni mišić i prednji trbuh digastričnog mišića [5, 6].

S obzirom na to da su mnogi autori potvrdili da su jatrogene povrede donjoviličnog živca najčešće (64,4%), neophodno je poznavanje tačne lokalizacije mandibularnog kanala i njegovog sadržaja radi adekvatne endodontske terapije donjih bočnih zuba, kao i adekvatne resekcije vrhova korena donjih bočnih zuba. U okviru protokola endodontske terapije koriste se instrumenti za mehaničku obradu kanala, kombinovani sa hemijskim sredstvima za irigaciju, medikamentozna sredstva i materijali za definitivnu opturaciju kanalnog sistema. U toku svih ovih faza moguć je nastanak neželjenih komplikacija – mehanička, hemijska ili termalna povreda nerva, što može izazvati neuropatski bol ili anesteziju u njegovoj inervacionoj zoni. Kod endodontske terapije 1% donjih premolara i čak kod 10% donjih drugih molara zabeležena je mogućnost povrede donjoviličnog živca. Povreda sadržaja mandibularnog kanala rotirajućim i hirurškim instrumentima moguća je u toku oralnohirurških zahvata. Takve povrede nekada zahtevaju terapiju u vidu mikrohirurške dekompresije donjoviličnog živca [7–10].

Cilj ovog retrospektivnog istraživanja je bio da se na sagitalnom preseku CBCT-a odrede prosečne vertikalne udaljenosti vrhova korenova drugih premolara, prvih molara i drugih molara mezijalno i distalno od gornje projekcije mandibularnog kanala, te utvrdi da li postoji statistička značajnost u odnosu na pol i starosnu dob.

MATERIJAL I METODE

Istraživanje je odobreno od strane Etičkog komiteta Medicinskog fakulteta Univerziteta u Banjoj Luci (18/4.141/21).

Uzorak je obuhvatao 146 CBCT snimaka pacijenata pomoću kojih je merena vertikalna udaljenost kanala drugog premolara, prvog molara i drugog molara distalno i mezijalno i ispitivana statistička značajnost razlike u odnosu na pol i starosnu dob. Početna baza podataka obuhvatala je 174 snimka, od kojih je 146 ispunilo kriterijume za izbor uzorka: prisustvo minimum jednog zuba od značaja za istraživanje (drugi mandibularni premolar, prvi mandibularni molar i drugi mandibularni molar) i vidljivost mandibularnog kanala na snimku. Zubi sa internom i eksternom resorpcijom korena i enodontski lečeni zubi nisu bili uključeni u istraživanje. Istraživanje je obuhvatilo snimke urađene u periodu od 1. 1. 2018. do 31. 12. 2018. godine.

Proces snimanja je obavljen sa aparatom Planmeca ProMax 3D Mid (Planmeca, Helsinki, Finska), a CBCT snimci su analizirani pomoću softvera Planmeca Romexis Viewer (Slika 1). Na sagitalnom preseku je za svaki zub (drugi mandibularni premolar, prvi mandibularni molar, drugi mandibularni molar) izmerena vertikalna udaljenost vrha korena do gornje projekcije mandibularnog kanala (Slika 2). Za zube sa dva korena merena je udaljenost za svaki koren posebno (Slika 3).

Mandibularni kanal na sagitalnom preseku pokazuje varijabilnost u izgledu i obično se pojavljuje kao radiolucentni krug, koji može biti do 4 mm u prečniku. Za lakše identifikovanje mandibularnog kanala, na sagitalnom preseku je identifikovan mentalni otvor, te je kanal praćen do nivoa apeksa odgovarajućeg zuba [11].

Ukupno je izvršeno 406 merenja, od toga 146 za drugi premolar, 42 za prvi molar mezijalno, 42 za prvi molar distalno, 88 za drugi molar mezijalno i 88 za drugi molar distalno (Tabela 1). Nakon izvršenih merenja sve dobijene vrednosti su podeljene prema polu i starosnoj dobi pacijenata (Tabela 2). Na osnovu starosne dobi, uzorak je podeljen u tri grupe: grupa A, koja je obuhvatala CBCT snimke pacijenata mlađih od 17 godina, grupa B, koja je obuhvatala CBCT snimke pacijenata starosti od 18 do 49 godina i grupa C, koja je obuhvatala CBCT snimke pacijenata starijih od 50 godina.

Statistička analiza

Svi podaci su prikazani tabelarno i grafički. Za analizu dobijenih podataka korišćen je program R Studio Version 3.6.2. Podaci su obrađeni uz stepen značajnosti od 95% korišćenjem testova Kruskal –Wallis i Mann–Whitney U. Na osnovu izmerenih vrednosti određene su prosečne vertikalne udaljenosti za svaki koren, kao i za svaki koren po starosnim grupama. Takođe je ispitivano u čemu se ogledaju ove statističke značajnosti, poredeći pojedine grupe razdvojene po polu. Kod grupa zuba gde je uočeno značajno statističko odstupanje, CBCT snimci osoba jednog pola iz jedne starosne grupe poređene su sa CBCT snimcima osoba istog pola iz druge starosne grupe.

REZULTATI

Analiza rezultata prosečne vertikalne udaljenosti za svaki koren od gornje projekcije mandibularnog kanala je pokazala da najveću prosečnu vertikalnu udaljenost ima distalni koren prvog molara (4,88 mm), a najmanju distalni koren drugog molara (2,76 mm). Prosečna udaljenost za prvi molar mezijalno je 4,86 mm, za drugi molar mezijalno 3,01 mm, a za drugi premolar 4,23 mm (Slika 4).

Posmatrano po starosnim grupama, u grupi A najveću udaljenost od mandibularnog kanala imao je drugi molar mezijalno (4,69 mm), a najmanju drugi premolar (3,2 mm).

U grupi B najveću prosečnu vertikalnu udaljenost apeksa korena od mandibularnog kanala pokazao je prvi molar mezijalno (4,4 mm), a najmanju drugi molar distalno (2,2 mm).

U grupi C je najveću prosečnu vertikalnu udaljenost imao prvi molar distalno (6,4 mm), a najmanju drugi molar distalno (3,44 mm).

Sa statističkom značajnosti od 95% i koristeći Kruskal–Wallis test, posmatrana je prosečna vertikalna udaljenost po vrstama premolara i molara u odnosu na starosne grupe (Tabela 2) i utvrđeno je da ne postoji statistički značajna razlika, $p > 0,05$.

Sa statističkom značajnosti od 95% i koristeći Mann–Whitney U test, posmatrali smo da li postoji statistički značajna razlika između pojedinih starosnih grupa za svaki pojedinačni koren i utvrđeno je da kod prvog molara mezijalno postoji statistički značajna razlika između grupa B i C, uz napomenu da je vrednost p na granici značajnosti ($p = 0,05$). Kod drugog molara distalno uočena je statistički značajna razlika između grupa A i B, kao i između B i C ($p < 0,05$), a kod drugog molara mezijalno između grupa B i C ($p < 0,05$). Kod ostalih grupa nije uočena statistički značajna razlika.

Prethodno pomenute grupe, kod kojih je uočena statistički značajna razlika, u daljoj analizi su razdvojene prema polu, nakon čega su osobe jednog pola iz jedne starosne grupe poređene sa osobama istog pola iz druge starosne grupe.

Poredeći vertikalnu udaljenost između CBCT snimaka osoba ženskog pola po starosnim grupama B i C za prvi molar mezijalno, utvrđeno je da razlika nije statistički značajna ($p > 0,05$), dok kod osoba muškog pola postoji značajna statistička razlika ($p < 0,05$) (Slika 5).

Poredeći vertikalnu udaljenost između osoba ženskog pola po starosnim grupama B i C za drugi molar distalno, utvrđeno je da razlika nije statistički značajna ($p > 0,05$), dok je za iste grupe kod osoba muškog pola utvrđeno da postoji značajna statistička razlika ($p < 0,05$) (Slika 6).

Iako postoji statistički značajna razlika za cele starosne grupe B i C kod drugog molara mezijalno, posmatrajući iste po polu, a iz različitih starosnih grupa, utvrđeno je da razlika nije statistički značajna ($p > 0,05$) (Slika 7).

Utvrđeno je da ne postoji statistički značajna razlika između različitih starosnih grupa kod žena, dok je kod muškaraca ona uočena samo kod prvog molara mezijalno i drugog molara distalno, između grupe A i B.

Posmatrajući prosečne vertikalne udaljenosti za svaki koren po polu, uočeno je da su sve prosečne vrednosti veće kod osoba muškog pola. Za muškarce je najveća prosečna vertikalna udaljenost prisutna kod korena prvog molara distalno (5,57 mm), a najmanja kod drugog molara distalno (3,52 mm). Kod žena je najveću prosečnu vertikalnu udaljenost takođe imao prvi molar distalno (3,50 mm), a najmanju drugi molar mezijalno (1,64 mm) (Slika 8).

DISKUSIJA

Zahvaljujući savremenom radiološkom sistemu za snimanje, CBCT-u, koji je dizajniran posebno za upotrebu u maksilofacijalnoj regiji, moguće je pravovremeno dobiti informacije od značaja za endodontsku, hiruršku ili endodontsko-hiruršku terapiju [12, 13, 14].

CBCT prevazilazi mnoga ograničenja konvencionalne radiografije stvaranjem neiskrivljenje, trodimenzionalne slike područja koje se ispituje i omogućava vizuelizaciju snimaka po slojevima i presek u sve tri dimenzije [15].

Rezulatati ove studije su pokazali da je najveću prosečnu vertikalnu udaljenost apeksa od mandibularnog kanala imao distalni koren prvog molara (4,88 mm). Najmanju prosečnu vertikalnu udaljenost imao je distalni koren drugog molara (2,76 mm), koji je gracilniji u odnosu na mezijalni i blago distalno usmeren, a njegov blizak odnos sa mandibularnim kanalom može se pripisati putanji kanala i njegovom položaju u mandibuli. Do delimično sličnih rezultata merenjem na CBCT snimcima su došli Uğur Aydın i saradnici koji su, na uzorku iz turske populacije, ustanovili da je najmanju prosečnu udaljenost od mandibularnog kanala takođe imao distalni koren drugog molara (2,75 mm), dok je najveća prosečna udaljenost registrovana kod mezijalnog korena prvog molara (4,98 mm) [16].

Lvovsky i saradnici su u svom istraživanju na CBCT snimcima zaključili da je najveću prosečnu udaljenost imao mezijalni koren prvog molara (6,18 mm), a najmanju distalni koren drugog molara (3,42 mm) [17].

Prosečna vrednost za mezijalni koren prvog molara u našem istraživanju bila je 4,86 mm.

Aksoy je sa saradnicima merenjem najkraće udaljenosti od mandibularnog kanala takođe ustanovio da su korenovi drugog molara značajno bliži mandibularnom kanalu u odnosu na korenove prvih molara, prvih i drugih premolara [18].

Denio i saradnici su u svojoj studiji, u kojoj su proučavali anatomske odnose mandibularnog kanala i bočnih zuba seciranjem 22 mandibule, zaključili da najmanju udaljenost od mandibulrnog kanala pokazuju drugi mandibularni premolar i drugi mandibularni molar [19].

Kosumarl i saradnici su merenjem na CBCT snimcima ustanovili da je najveću prosečnu udaljenost od mandibularnog kanala imao mezijalni koren prvog molara, a najkraću distalni koren drugog molara, bilo da se radi o osobama sa normalnim skeletnim odnosom vilica ili skeletno otvorenim zagrižajem [20].

Izuzimajući treći molar, Pucilo je sa saradnicima u sistematskom pregledu zaključio da je distalni koren drugog molara najbliži mandibularnom kanalu, što se podudara sa rezultatima ove studije [21].

Littner i saradnici su na radiografskim snimcima kadavera izmerili prosečne vrednosti udaljenosti apeksa prvih i drugih molara od kanala, koje su iznosile između 3,50 i 5,40 mm, a prema istraživanju koje su sproveli Kovisto i saradnici na CBCT snimcima te prosečne vrednosti su iznosile između 1,51 i 3,43 mm [22, 23].

U ovom istraživanju prosečne vrednosti udaljenosti vrhova donjih bočnih zuba od mandibularnog kanala se kreću između 2,76 i 4,88 mm.

Posmatrajući prosečne vertikalne udaljenosti za svaki koren po polu, uočeno je da su sve prosečne vrednosti veće kod osoba muškog pola, što se može dovesti u vezu sa gracilnijom konstitucijom žena i manjim dimenzijama donje vilice. Do sličnog zaključka došli su i drugi istraživači (Aksoy et al. 2017; Simonton et al. 2009), koji su ustanovili da su rastojanja između vrhova donjih premolara, odnosno donjih molara i mandibularnog kanala bila kraća u ženskoj populaciji [18, 24].

Sato i saradnici su vršili istraživanje na kadaverima, te uz pomoć CT snimaka i panoramske radiografije merili udaljenosti od apeksa korena do gornje projekcije mandibularnog kanala. Podaci su grupisani po polu i strani usta. Zabeležili su nešto manje vrednosti udaljenosti prvih i drugih molara od mandibularnog kanala kod žena, u odnosu na vrednosti kod muškaraca [25].

Pokazalo se da postoji četiri puta veća mogućnost nastanka hroničnog bola nakon endodontske terapije ako je pacijent ženska osoba, a takođe je veća i incidenca postoperativnog bola kod žena [26].

Za definitivan zaključak o pouzdanosti ovakvih merenja udaljenosti vrhova zuba od mandibularnog kanala neophodna je provera kod veće grupe zuba nego u ovoj studiji. Odstupanja u merenjima se mogu objasniti činjenicom da su dobijena kroz različite sagitalne preseke CBCT-a, što može uticati na ponovljivost ovih merenja.

ZAKLJUČAK

Merenja u okviru ovog istraživanja i statistički podaci pokazuju da najmanju vertikalnu udaljenost od mandibularnog kanala ima distalni koren mandibularnih drugih molara, pa se preporučuje pažljiva obrada kanala ovog korena i pažljivo planiranje oralnohirurških zahvata u ovoj regiji.

Prilikom intervencija u bočnoj regiji mandibule može doći do oštećenja neurovaskularnog snopa kanala, te pojave neželjenih komplikacija, poput parestezija ili neuropatskih bolova. Zbog toga je važno da se terapeut, uz pridržavanje bioloških principa terapije i adekvatno urađene odontometrije, prethodno informiše o odnosu zuba i mandibularnog kanala.

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SEM analysis of Mtwo instruments after instrumentation of root canals with different curvatures

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SUMMARY

Introduction Deformations and fractures of Ni-Ti instruments during chemomechanical instrumentation of root canals occur due to the action of cyclic and torsional forces. The aim of this research was to analyze the surfaces of the working parts of Mtwo instruments after preparation of root canals with different curvatures using SEM and determine possible changes and deformations after instrumentation.

Materials and methods The study included 3 sets of Mtwo (VDW, Munich, Germany) instruments. Each set was used to instrument 10 canals in three experimental groups (straight, slightly curved, and highly curved canals). Instrumentation was carried out using crown-down technique with the following irrigation solutions, 2% NaOCl (CHLORAXID 2%, Cerkamed, Polska) and Distilled water (Iva, Serbia) in the amount of 5 cm^3. The apical and middle third of the instruments were scanned in two directions using SEM at different magnifications (150-2000X). The SEM images were analyzed using qualitative analysis for the presence of different irregularities according to Eggert et al. Statistical analysis of obtained data was performed using Fisher test at a confidence level of 5% ($\alpha = 0.05$).

Results Most defects (37.3%) were observed in instruments used in highly curved canals, followed by the instruments of the second group (35.6%), and the least defects were (27.1%) observed in the group with straight canals. Higher prevalence of defects was observed in the apical thirds of instruments (54.2%), especially in the experimental group of curved canals where the highest presence was observed (20.3%). The presence of production grooves was observed in all instruments, and the most common types of defects after instrumentation were the appearance of corrosion and changes in the cutting edges. In the group with extremely curved canals fractures were observed in two instruments (10/0.04 and 15/0.05).

Conclusion Root canal curvature significantly affects the occurrence of deformations and fractures of Ni-Ti rotating instruments. The most common types of defects were grooves, corrosion and changes in the blade edges. Mtwo instruments showed deformations in terms of thread changes, microfractures and two complete fractures.

Keywords: Mtwo; Ni-Ti instruments; deformation; curved canals

INTRODUCTION

Rotary instruments are more efficient than manual ones in almost all aspects (speed, simplicity, uniformity and efficiency of instrumentation), but more often they lead to complications in the form of unexpected fractures [1]. There are number of factors influencing the occurrence of defects in Ni-Ti instruments which can be classified into four basic categories: operator related factors (skills, expertise and assessment of therapy protocols), anatomical factors (preparation of the access cavity and root canal anatomy), factors related to instruments (material, design, production process and errors in instrument fabrication) and technical instrumentation factors (instrumentation techniques, instrument reuse, sterilization and irrigation during root canal instrumentation) [2].

During the endodontic procedure, an operator has the most dominant role, who, with good clinical training and adequate manual skills, must make the right choice of instruments and instrumentation techniques, but also recognize the complex morphology of the endodontic space. Complex morphological endodontic systems (double curves, pronounced curvatures of the apical segment, intercanal communications and ramification, apical deltas) significantly complicate biomechanical processing [1, 3]. The degree and level of curvature of the root canal can also significantly affect the occurrence of instrument deformations, especially during instrumentation of the most complex, apical segment [1, 3].

Although the use of nickel-titanium instruments is the standard in the endodontic procedure today, knowledge of the design and their characteristics is basic prerequisite for planning and implementation of the endodontic procedure in each individual case. To prevent deformation and breakage of Ni-Ti instruments, scientists and manufacturers find new design solutions, with different cones, angle inclination, cross section and blade design, different alloy and finished instrument treatments and different ways of activating instruments in root canals [1, 2, 4].

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A lot of different Ni-Ti systems are currently on the market and new ones are appearing every day with numerous innovations and improved features. The Mtwo system (VDW, Munich, Germany) was created by Dr. Malagnino in 2003. Although this system was created two decades ago, due to its specific design and technique of use, it is still widely used and analyzed today [5]. These files are made of conventional alloy (austenitic at room temperature), have a passive tip and a cross section in the shape of the letter S. The instruments have positive inclination angles of the blade from the tip to its handle, without radial curves which provide space for evacuation of dentinal detritus [6]. Two almost vertical blades with aggressive cutting edges require less cutting force compared to instruments with a neutral or negative cutting angle. The greater thread depth from the tip to the handle of these instruments allows for more delicate cutting at the tip and more aggressive in the coronal segment (this design reduces the core diameter and thus increases flexibility) [7].

The specific design and variable length of the sequences along the working part of the Mtwo instruments eliminates the possibility of screwing during continuous rotation and reduces the possibility of apical detritus transportation [5, 8, 9]. The handle of 11mm Mtwo instruments is shorter than other rotary instruments and therefore extremely suitable for work in the molar region.

The aim of this research was to analyze surfaces of the working parts of Mtwo instruments after the preparation of canals with different curvature using SEM and determine their possible changes and deformations after instrumentation.

MATERIAL AND METHOD

The study included 3 sets of Mtwo (VDW, Munich, Germany) instruments. Each set contained four instruments: 10/.04; 15/.05; 20/.06 and with 25/.06. (Figure 1).

Figure 1. Set of Mtwo instruments
Slika 1. Set Mtwo instrumenata
(Figure taken from: https://www.vdw-dental.com/en/products/detail/Mtwo/)
(Slika preuzeta sa: https://www.vdw-dental.com/en/products/detail/Mtwo/)

The study was performed *in vitro* on human premolars, extracted for various reasons after obtaining the consent of the Ethics Committee of the Faculty of Dentistry in Belgrade (No. 36/6). Immediately after extraction, the teeth were stored in 4% sodium hypochlorite solution for two hours, and until the beginning of the preparation in physiological solution with 0.2% thymol in order to prevent the growth of bacteria. The crowns of the teeth were shortened to the level of 2 mm coronally from the enamel-cement junction using a diamond disk. After the access cavity preparation, the initial patency of canals were determined with K-files of size #15 (Dentsply / Maillefer) and the working length was determined for each canal. Xray of the canals with instrument placed inside the canal (#10) and an on-line protractor was taken enabling determination of the curvature degree (Schneider's X-ray technique) [10]. Based on this, the teeth were divided into the three categories:

I group - 10 straight canals - low degree of curvature (less than 10 °),

II group - 10 slightly curved canals - moderate degree of curvature (from 10 ° to 25 °) and

III group - 10 extremely curved canals - with a high degree of curvature (over 25 °).

In order to achieve uniform experimental conditions, each instrument was used in ten canals or until the moment of its fracture (one set was applied in preparation of 10 canals in each experimental group).

Experimental protocol

Preoperative preparation involved cleaning in an ultrasonic tub using a mild disinfectant Orocid Multisept plus ("OCC", Switzerland) for 15 minutes. After additional checking of the obligatory straight line and patency of the canal with K-files of sizes 10 and 15 (MicroMega, France), abundant (5 ml) irrigation with 2% NaOCl solution followed. The canal instrumentation was performed in accordance with the manufacturer's instructions involving the X-Smart Endodontic Rotary Motor (Dentsply, Sirona, Maillefer, Ballaigues Salzburg, Austria) using crown-down technique. Ni-Ti files were regularly cleaned in a sterile sponge to remove dentin residues, and after each rotary instrument, the working length was recapitulated with a hand instrument (#10). After each instrument, 2% NaOCl solution (CHLORAXID 2%, Cerkamed, Polska) and then Distilled water (Iva, Serbia) were used as irrigants in the amount of 5 ml^3, using a plastic syringe and an endodontic irrigation needle with a closed tip and side openings (Side-vented needle, SmearClear, SybronEndo). Ethylenediamine tetra-acetic acid gel, applied to the working part of the instrument, was used as a lubricant (Glyde-Dentsply, Maillefer, Switzerland). During the instrumentation of the canal, each used instrument was carefully inspected with a magnifying glass, in order to detect any changes (possible cracks, fractures, unwinding of threads or other deformations).

One operator conducted all instrumentations.

Table 1. Defects and impurities on the working part of Mtwo instruments after instrumentation
Tabela 1. Deformacije i nečistoće na površini radnog dela Mtwo instrumenata posle instrumentacije

Defects and impurities on Mtwo instruments Zatečene deformacije i nečistoće Mtwo instrumenata		I group I grupa		II group II grupa		III group III grupa	
		Apical third % apikalna trećina %	Middle third % srednja trećina %	Apical third % apikalna trećina %	Middle third % srednja trećina %	Apical third % apikalna trećina %	Middle third % srednja trećina %
1.	No Bez vidljivih defekata	0	0	0	0	0	0
2.	Pitting Jamičasta udubljenja	0	0	0	0	0	0
3.	Fretting Žljebovi	100	100	100	100	100	100
4.	Microfractures Mikrofrakture	25	0	0	0	50	0
5.	Complete fractures Kompletne frakture	0	0	0	0	50	0
6.	Metal flash Metalna uglačanost	0	0	0	0	0	0
7.	Metal strips Metalni opiljci	0	0	0	0	0	0
8.	Blunt cutting edge Zatupljene sečivne ivice	25	0	25	0	0	25
9.	Disruption of cutting edges Prekid sečivne ivice	0	0	25	0	0	25
10.	Corrosion Korozija	25	25	50	75	0	25
11.	Debris Debris	0	0	0	0	0	0
12.	Thread change Promena navoja	0	0	25	25	50	25

Table 2. Distribution of defects on Mtwo instruments in different experimental groups
Tabela 2. Distribucija defekata na Mtwo instrumentima u funkciji eksperimentalnih grupa

Experimental group Eksperimentalna grupa	I group I grupa		II group II grupa		III group III grupa	
Working part of instruments Radna površina instrumenta	Apical third % Apikalna trećina %	Middle third % Srednja trećina %	Apical third % Apikalna trećina %	Middle third % Srednja trećina %	Apical third % Apikalna trećina %	Middle third % Srednja trećina %
Deffects % Defekti %	15.2	11.9	18.6	16.9	20.3	16.9
Σ	27.1		35.6		37.3	

After instrumentation, the instruments were cleaned in an ultrasonic bath using a mild disinfectant Orocid Multisept plus ("OCC", Switzerland) for 15 minutes. SEM analysis of used instruments was performed in the laboratory of the Faculty of Mining and Geology, University of Belgrade, at SEM type JEOL JSM-6610LV, Japan. Images were made using a secondary electron detector (SE images - second electron) (150-2000x). The apical and middle thirds of instruments were analyzed from two different directions, and three images were taken for each surface of the instrument. The apical third included the apical 5mm, the middle third - the next 5 mm coronally. After canal preparation, 250 recordings of instruments were examined and the results of the two researchers were reconciled by Cohen Kappa analysis.

Qualitative analysis of the presence of various irregularities was applied as per Kristina Egert at al.: Grade 1 – No visible defect, Grade 2 – pitting, Grade 3 – grooves (Fretting), Grade 4 – microfractures, Grade 5 – complete fractures (Complete fracture), Grade 6 – metal flash, Grade 7 – metal strips, Grade 8 – Blunt cutting edge, Grade 9 – Disruption of cutting edge, Grade 10 – Corrosion, Grade 11 – presence of debris [11]. A qualitative analysis was performed, but without quantifying the obtained results.

Statistical analysis of the obtained data was performed using Fisher test at a confidence level of 5% ($\alpha = 0.05$).

RESULTS

The results of SEM analysis of Mtwo instruments after instrumentation of canals with different curvatures are presented in Tables 1, 2, 3 and Figures 2–7.

The results of the study indicated that, following instrumentation there was no instrument without deformation. The analysis of the images showed the presence of defects in the form of grooves on all instruments created as a result of instrumentation process (Table 1). Most defects (37.3%) were observed on instruments used for instrumenting extremely curved canals, followed by instruments of the second group (35.6%), and the least defects were observed in the group of straight canals (27.1%). 2). Higher

Table 3. Deformations on the surface of the working part of Mtwo instruments after instrumentation
Tabela 3. Deformacije na površini radnog dela Mtwo instrumenata posle instrumentacije

	I group I grupa		II group II grupa		III group III grupa	
Instrument Instrument	**Apical third apikalna trećina**	**Middle third srednja trećina**	**Apical third apikalna trećina**	**Middle third srednja trećina**	**Apical third apikalna trećina**	**Middle third srednja trećina**
10-0.04	Blunt cutting edge Zatuplena sečivna ivica Corossion Korozija	Corossion Korozija	Disruption of cutting edges Prekid sečivne ivice Corossion Korozija Thread change Promene navoja	Corossion Korozija	Microfractur Mikrofrakture Complete fractures Kompletne frakture Thread change Promene navoja	
15-0.05					Microfracture Mikrofraktura Complete fractures Kompletne frakture	Blunt cutting edge Zatupljena sečivna ivica Corossion Korozija Thread change Promene navoja
20-0.06				Corossion Korozija Thread change Promene navoja		
25-0.06	Microfractur Mikrofraktura		Blunt cutting edge Zatupljena sečivna ivica Corossion Korozija	Corossion Korozija	Thread change Promene navoja	Disruption of cutting edges Prekid sečivne ivice

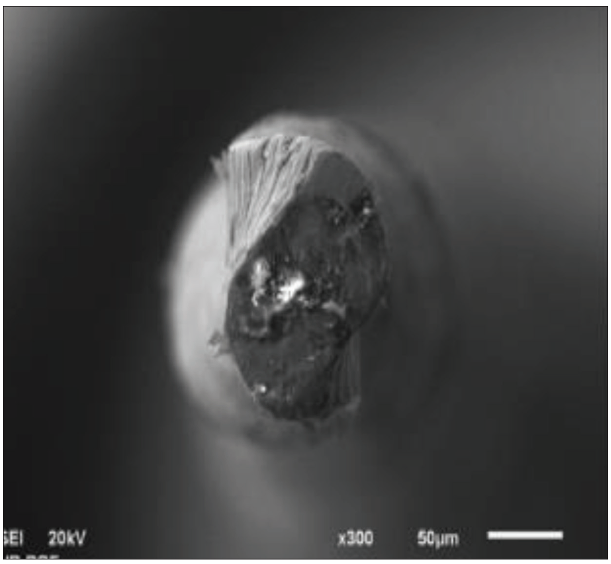

Figure 2. SE image of Mtwo 10/.04 instrument with complete fracture (fractographic image at magnification ×300) which shows the difference in the appearance of the fracture surface in the central and peripheral area.
Slika 2. SE snimak MTwo 10/0,04 instrumenta sa kompletnom frakturom (fraktografski snimak na uvećanju ×300), na kojoj se uočava razlika u izgledu frakturne površine centralne i površinske zone frakturne površine.

prevalence of defects was observed in the apical surface of instruments (54.2%), especially in the third experimental group (20.3%) (Table 2).

Defects were observed on the thinnest (10/.04) and most conical instrument (25/.06) in all three experimental groups. For the instrument 15/.05, changes were recorded only in the third group and for instrument 20/.06 only in the second group (Table 3). The most common type of defect after instrumentation was corrosion. It was observed on one instrument in the first group (10/.04) (apical and middle third); two instruments in the second group (10/.04 and 25/.60) (apical and middle third) and one instrument in the middle third (20/.06); while in the third group the defect was registered in the middle third of one instrument (15/.05) (Table 3). Along with corrosion, dullness, rupture of the cutting edges, the appearance of microfractures was also observed. Blunted blade edge was observed in the apical third of the thinnest (10/.04) instrument in the first group (the same instrument which showed corrosion), in the apical third (25/.06) of the instrument in the second group and in the middle third of the instrument (25/.06) of the third group. The interrupted cutting edge was noted in the apical third of the smallest instrument (10/.04) in the second group and in the middle third of one instrument (25/.06) in the third group. Microfracture was observed in the apical third of the instrument (15/.05) in the first group and in the apical third of two instruments in the third group, (10/.04 and 15/.05). Complete fractures were recorded on the same instruments in the third group (10/.04 and 15/.05). The fracture of instrument 10/.04 occurred after nine uses (length of the fractured fragment 1.5 mm) and after the eighth use of instrument 15/.05 (fragment of 0.8 mm) (Table 3, Figure 2, 3).

Fractographic micrographs (Figure 3) under 1500× and 2000× magnifications showed the central zones of the fracture surface with microscopic holes (which is an indicator of torsional changes) and clear traces of circular abrasion on its outer parts. Another defect was the appearance of a thread change and twisting (present only after preparation of curved (25% apical and middle third) and extremely curved canals (50% apical and 25% middle third) (Table 1). This change was observed in the second experimental group on two instruments (in the apical third of the instrument (10/.04) and in the middle third of the instrument (20/.06)), and on three instruments in the third group, (in the apical third of the instruments

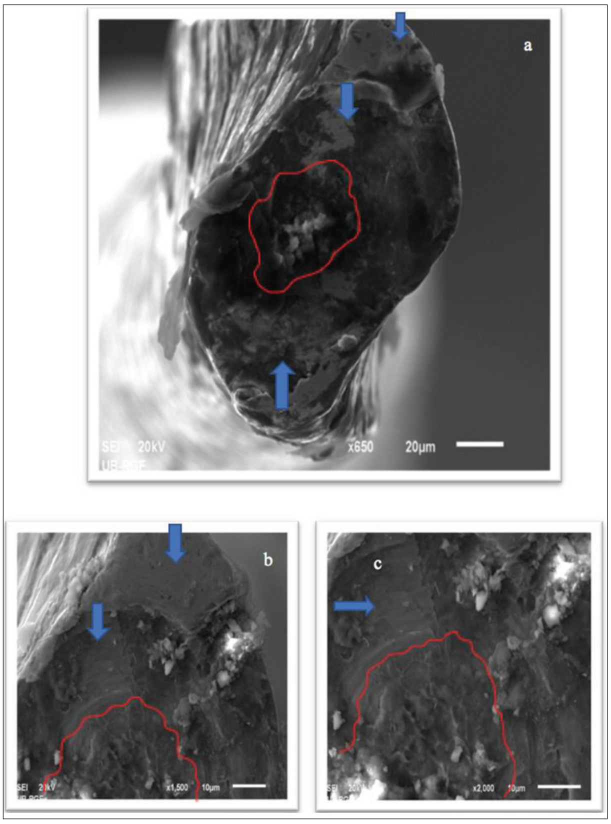

Figure 3. SE images of Mtwo 10/.04 instrument with complete fracture:
a) fracture surface (×650) on which central zones with microscopic holes (marked with a red field) and circular traces of abrasion on the outer parts of the fracture surface (marked with blue arrows) are clearly visible; b) detail from Figure 3a at higher magnification (×1500) and c) detail from Figure 3a at higher magnification (×2000)
Slika 3. SE snimci MTwo 10/0,04 instrumenta sa kompletnom frakturom:
a) frakturna površina (×650) na kojoj se jasno uočavaju centralne zone sa mikroskopskim rupicama (označene crvenim poljem) i kružni tragovi abrazije na spoljašnjim delovima frakturne površine (označene plavim strelicama);
b) detalj sa slike 3a na većem uvećanju (×1500) i c) detalj sa slike 3a na većem uvećanju (×2000)

10/.04 and 20/.06) and in the middle third of one instrument (15/.05) (Figure 4, 5, 6).

SEM images (Figure 4) showed longitudinal image of a fractured Mtwo instrument (15/.05), thread changes (thread straightening and unwinding) with an abundance of microfractures on the surface of the fractured instrument, especially in the immediate vicinity of the fracture. The same finding was observed on the fracture surface of the Mtwo 15/.05 instrument (Figure 7). The occurrence of thread change deformation in bent and exteremly bent canals shows a statistically significant difference in relation to the group with straight canals ($p < 0{,}05$).

DISCUSSION

The experimental protocol applied in this paper was developed in accordance with the previously used models for testing changes on Ni-Ti rotating instruments. This research represents an *in vitro* study on extracted teeth

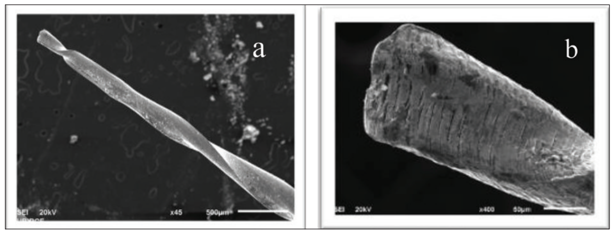

Figure 4. SE recordings of Mtwo instrument 15/.05 (longitudinal recording):
a) ×45 magnification showing thread changes (thread straightening and unwinding) and complete apical segment fracture;
b) longitudinal SE image of the apical fracture (×400) on which a multitude of microfractures were observed on the surface of the fractured instrument.
Slika 4. SE snimci MTwo instrumenta 15/0,05 (uzdužni snimak):
a) uvećanje ×45 na kome se uočavaju promene navoja (ispravljanje i odmotavanje navoja) i kompletna fraktura apikalnog segmenta;
b) uzdužni SE snimak apikalne frakture (×400) na kom se primećuje mnoštvo mikrofraktura na površini zalomljenog instrumenta.

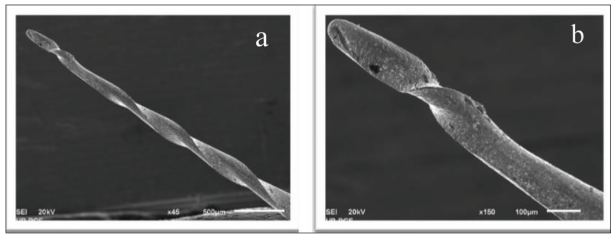

Figure 5. SE images: a) Mtwo instrument (10/.04 of the second group at magnification ×45) on which changes in the thread (unscrewing, straightening) are observed; b) the apical segment of the Mtwo instrument (10/.04 of the second group at magnification ×150) on which changes in the thread (unscrewing, straightening) are observed;
Slika 5. SE snimci: a) MTwo instrumenta (10/0,04 druge grupe na uvećanju ×45) na kome se uočavaju promene navoja (odvijanje, ispravljanje); b) apikalnog segmenta MTwo instrumenta (10/0,04 druge grupe na uvećanju ×150) na kome se uočavaju promene navoja (odvijanje, ispravljanje);

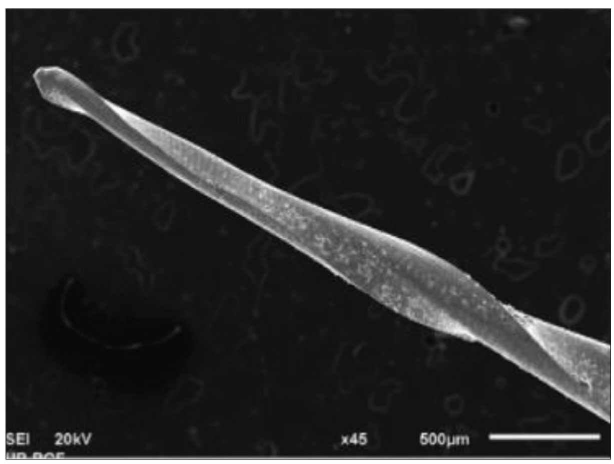

Figure 6. SE image of the apcal segment of the Mtwo instrument (20/.06 of the third group at magnification ×45) on which the straightening of the thread is observed
Slika 6. SE snimak apikalnog segmenta MTwo instrumenta (20/0,06 treće grupe na uvećanju ×45) na kome se uočava ispravljanje navoja

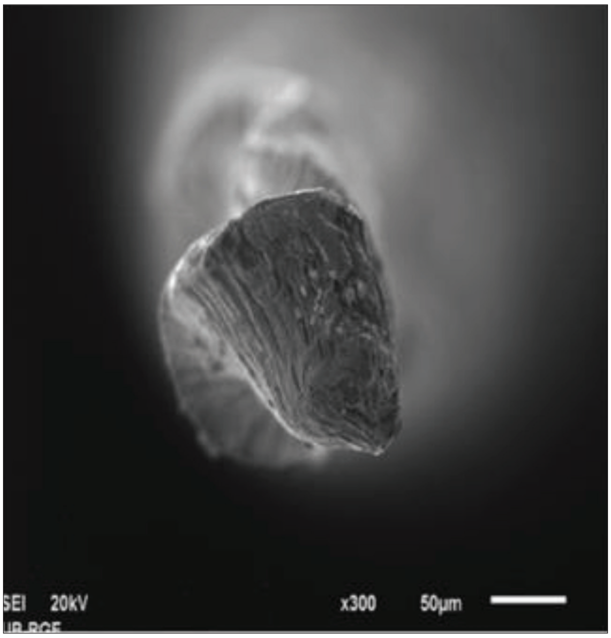

Figure 7. SE image of the fracture surface of the Mtwo instrument 15/.05 at magnification ×300, which shows a multitude of microfractures
Slika 7. SE snimak frakturne površine MTwo instrumenta 15/0,05 na uvećanju ×300, na kojoj se uočava mnoštvo mikrofraktura

which was conducted in laboratory conditions, in order to provide conditions close to the clinical situation.

The results of this study confirmed the views that the most frequent occurrence of defects is in the apical segment of the instrument, especially after the instrumentation of complicated endodontic systems [7, 8, 9, 12, 13, 14]. It is stated in the literature that deformations and fractures of instruments most often occur in complex molar systems (more often than in the anterior and premolar teeth) [7, 9, 14]. The most common occurrence of fractures was observed in the mesiobuccal canals of the molars of the upper and lower jaw, due to their complex curvature [12]. Mesial roots of the lower molars are curved not only distally, but very often mesiobuccal canal is additionally curved lingually and mesiolingual buccally. Analyzing the incidence of fracture of Ni-Ti instruments in different groups of Di Fiore teeth, the refractive rate in anterior teeth was 0.28%, premolar 1.56% and molar 2.74% [15].

Mtwo is the only system that has instruments of small dimensions (10/.04 and 15/.05) and all instruments in the set are used for instrumentation up to full working length [16]. The specific size and design of the instrument 10/.04 is used to establish the initial passability and formation of the instrumentation path (glide path) [16]. Blunted cutting edge and blade edge breakage, corrosion, thread changes, microfractures and complete fractures of the instrument 10/.04, indicate vulnerability of the Mtwo instrument of the smallest dimensions during instrumentation of exteremly curved canals. The results of this study are in agreement with the results of studies where the thinnest instruments showed most fractures and most deformations [17–19]. It has been confirmed that the shape and size of the cross section of instruments can affect their fatigue resistance, where thinner instruments are more resistant to cyclic fatigue and more sensitive to torsional loads, while thicker instruments can withstand higher torque and are more sensitive to cyclic fatigue [17]. In the study of Inan and Ganulol, authors observed a refraction in the apical third (fragments of 1 mm and less) in smaller instruments (10/.04 and 15/.05) [14]. Due to the small size and localization of fractured instrument tips (in isthmus or apical delta), clinicians are often unaware of their occurrence [18]. With the Mtwo system, all instruments are used for instrumentation up to full working length, so the stress is much higher on thinner and less conical instruments. Therefore, Shen at al. in their study suggested a single use of thinner instruments, in order to avoid deformations and fractures [19].

Ni-Ti instrument fracture is the most complex error during rotary instrumentation. Unlike stainless steel instruments that are visibly deformed before fracture (bending, unwinding of threads), rotating NiTi instruments very often break without warning and visible signs of deformation [1, 2]. Fracture of rotary NiTi instruments can occur as a result of torsional stress, cyclic fatigue, or a combination of these two factors. When passing through curved canal, rotary instrument is exposed to the action of tensile (tension) forces on the outer side of the curve, and on the inner side to the action of compressive forces. These forces alternately act on the rotating instrument during instrumentation, which often leads to breakage [2]. It has been observed that duration of use and increase in torque significantly reduce the resistance of the instrument to cyclic fatigue [4].

Fractures due to torsional stress occur when there is a large contact area between the instrument and dentinal wall and if the apical pressure is too strong during instrumentation [1, 2]. Accumulation of torsional stress of the instrument and exceeding the elastic limit of Ni-Ti alloy leads to its plastic deformation and fracture [1, 2]. Zones of microscopic holes are most often observed on the fractured surface, which indicate a torsion change without concentric signs characteristic of fractures caused by cyclic fatigue [20]. Torsional changes are characterized by unwinding, straightening and twisting of the thread and fractures are directly dependent on the anatomy of the canal, the characteristics of Ni-Ti alloy, instrument design, applied speed, and experience and skill of therapist [18]. Reduction of torsional load and possible screwing of instruments in the canal is achieved by mandatory use of endomotors with torque control. In full rotation systems, due to repeated torsional stresses of instruments, this is the most common cause of deformations and fractures [21].

Two fractures of Mtwo instruments in the third experimental group confirmed torsional stress as the cause. On the SEM images of the cross section of the fractured instrument (10/.04), the central zones with microscopic holes that indicate torsional changes are clearly visible. In the study of Inan and Gonulol, longitudinal micrographs of the same instrument showed thread changes (straightening and unwinding of the thread) with numerous microfractures on the surface of the fractured instrument [14]. The same finding was observed on the fracture surface Mtwo (15/.05) of the instrument where the fracture site coincides with the position of maximum bending where the instruments of the smallest dimensions and the smallest cone (10/.04, 15/.05), ie, the greatest flexibility showed less resistance on torsional loads, which is in accordance with the results of this study [14].

Fractographic findings and SEM fracture images of Mtwo instruments are consistent with the results of the study done by Cheung et al. [20]. The torsional type of fracture is more common in narrow, curved, and complicated apical portions of the canal (where there is high probability of instrument screwing) [20].

The results of the Tzanetakis study show that the prevalence of refracted Ni-Ti instruments in the apical third (52.5%) was significantly higher compared to the middle (27.5%) and coronary (12.5%) third of the canal [22]. Ungerechts et al. also indicated that 39.5% of fractured Ni-Ti instruments were registered in mesobucal canals of the molars and that 76.5% of these fragments were located apically [23].

The occurrence of defects on the largest and most conical instrument in all three experimental groups (25/.06) is also confirmed in the literature [24, 25]. Tripi et al. SEM study analyzed the occurrence of defects, wear and fatigue, after instrumentation with Mtwo instruments and indicated more frequent occurrence of deformations in instruments of larger dimensions, which according to Ullman and Peters, are less flexible and less resistant to cyclic fatigue [24, 25]. In a study comparing the Mtwo and ProTaper Next systems, it was also observed that the resistance to cyclic fatigue is lower in instruments with larger diameter [26]. Schafer et al. in a study on blade efficiency reported significantly shorter time of canal instrumentation with Mtwo instruments and without the appearance of a fracture during instrumentation [12, 13].

The study by Canga et al. (2020) also indicated high efficiency of the Mtwo system in cleaning and shaping curved canals, without the appearance of fracture (after processing four canals in endo blocks) [8]. This finding is consistent with the results of this study where fractures were registered after the ninth and tenth application in extremely curved canals. The results of the study by Vadhana et al. also indicated higher resistance to cyclic fatigue of M-Two instruments compared to all other tested Ni-Ti instruments [27].

Following the design characteristics and specifics of the use of Mtwo instruments, Malagnino pointed out that increasing the speed inevitably leads to deformations and fractures of the instruments. The lower rotation speed does not reduce the efficiency of this system but allows maximum control and complete safety [8, 9].

Although the Mtwo system was created 18 years ago, due to its specific design and characteristic size, there are new possibilities of its application, ie the way of activation and starting in the canal (by changing the depth of progress and reducing the rotation speed) [28, 29].

CONCLUSION

The curvature of the root canal significantly affects the occurrence of deformations and fractures of Ni-Ti rotating instruments. Fractographic examination of fracture surfaces showed signs of torsional fracture, and Mtwo instruments showed deformations in the form of thread changes and microfractures. The appearance of these changes warns clinicians of the possibility of a fracture and the obligation to exclude instruments from further use.

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Analiza defekata MTwo instrumenata posle obrade kanala različite povijenosti (SEM)

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KRATAK SADRŽAJ

Uvod Deformacije i fraktura Ni-Ti instrumenata tokom hemomehaničke obrade kanala nastaju usled dejstva cikličnih i torzionih sila. Cilj ovog istraživanja je bio da se primenom SEM-a analiziraju površine radnog dela MTwo instrumenata nakon preparacije kanala različite povijenosti i utvrdi eventualno postojanje promena i deformacija nakon instrumentacije.

Materijali i metode U istraživanje su uključena tri seta MTwo (VDW, Munich, Germany) instrumenata. Svaki set je korišćen za obradu 10 kanala u tri eksperimentalne grupe (pravi, blago povijeni i izrazito povijeni kanali). Instrumentacija je realizovana krunično-apeksnom tehnikom, a kao iriganси su primenjeni u količini od po 5 cm³, 2% rastvor NaOCl (CHLORAXID 2%, Cerkamed, Poljska) i destilovana voda (Iva, Srbija). SE snimci apikalne i srednje trećine instrumenata iz dva različita pravca, snimani pomoću SEM-a, na različitim uvećanjima (150–2000×) analizirani su kvalitativnom analizom prisustva različitih nepravilnosti po Edžeru i sar. Statistička analiza dobijenih podataka urađena je primenom Fišerovog testa na nivou pouzdanosti od 5% ($\alpha = 0{,}05$).

Rezultati Najviše defekata (37,3%) uočeno je na instrumentima koji su upotrebljeni za obradu izrazito povijenih kanala, zatim na instrumentima druge grupe (35,6%), a najmanje defekata je bilo (27,1%) u grupi sa pravim kanalima. Veća zastupljenost defekata se uočava na apikalnoj trećini instrumenata (54,2%), posebno u trećoj eksperimentalnoj grupi, gde je uočeno najveće prisustvo – 20,3%. Uočeno je prisustvo proizvodnih žlebova na svim instrumentima, a najučestaliji tipovi defekta nakon instrumentacije su bili pojava korozije i promene sečivnih ivica. Uočene su frakture na dva instrumenta (10/0,04 i 15/0,05) u grupi sa izuzetno povijenim kanalima.

Zaključak Na osnovu rezultata ove studije može se zaključiti da povijenost korenskog kanala znatno utiče na pojavu deformacija i prelom Ni-Ti rotirajućih instrumenata. Najučestaliji tipovi defekata su bili žlebovi, korozija i promene sečivnih ivica. MTwo instrumenti su pokazali deformacije u vidi promene navoja, mikrofraktura i dve kompletne frakture.

Ključne reči: MTwo; Ni-Ti instrumenti; deformacije; povijeni kanali

UVOD

Rotirajući instrumenti su u odnosu na ručne efikasniji u gotovo svim aspektima (brzina, jednostavnost, ujednačenost i efikasnost instrumentacije), ali mnogo češće dovode do komplikacija u vidu neočekivanih fraktura [1]. Brojni su faktori koji utiču na pojavu defekata Ni-Ti instrumenata, koji se mogu klasifikovati u četiri osnovne kategorije: faktori vezani za operatere (veština, stručnost i procena terapeuta), anatomski faktori (preparacija pristupnog kaviteta i anatomija korenskog kanala), faktori vezani za instrumente (materijal, dizajn, proizvodni proces i greške pri izradi instrumenata) i tehnički faktori instrumentacije (tehnike instrumentacije, ponovna upotreba instrumenata, sterilizacija i irigacija tokom obrade kanala korena) [2].

Tokom izvođenja endodontskog zahvata najdominantniju ulogu ima operater, koji uz dobru kliničku obuku i adekvatnu manuelnu veštinu mora napraviti pravi izbor instrumenata i tehnika obrade, ali i prepoznati kompleksnu morfologiju endodontskog prostora.

Kompleksni morfološki endodontski sistemi (duple krivine, izrazite povijenosti apikalnog segmenta, interkanalne komunikacije i ramifikacije, apikalne delte) značajno otežavaju biomehaničku obradu [1, 3]. Stepen i nivo povijenosti kanala korena zuba takođe mogu značajno uticati na pojavu deformacija instrumenata, posebno tokom instrumentacije najkompleksnijeg, apikalnog segmenta [1, 3].

Iako primena nikl-titanijumskih instrumenata danas predstavlja standard u endodontskoj proceduri, poznavanje dizajna i njihovih osnovnih karakteristika je osnovni preduslov za planiranje i realizaciju endodontskog postupka u svakom pojedinačnom slučaju. Da bi se sprečila deformacija i lom Ni-Ti instrumenata, naučnici i proizvođači pronalaze nova dizajnerska rešenja, sa različitim konusima, nagibom uglova, poprečnim presekom i dizajnom sečiva, različitim tretmanima legure i gotovih instrumenata, odnosno različitim načinom aktivacije instrumenata u korenskim kanalima [1, 2, 4].

Puno različitih Ni-Ti sistema je trenutno na tržištu a svakim danom se pojavljuju novi sa brojnim inovacijama i unapređenim karakteristikama. MTwo sistem (VDW, Munich, Germany) stvorio je dr Malagnino 2003. godine. Iako je ovaj sistem nastao pre dve decenije, zbog svog specifičnog dizajna i tehnike upotrebe i danas se široko koristi i analizira [5]. Ove turpije su nastale od konvencionalne legure (austenitne na sobnoj temperaturi), imaju pasivan vrh i poprečni presek u obliku slova s. Instrumenti imaju pozitivne nagibne uglove sečiva od vrha do njegove drške, bez radijalnih krivina koji obezbeđuju prostor za evekuaciju dentinskog detritusa [6]. Dva skoro vertikalna sečiva sa agresivnim sečivnim ivicama zahtevaju manju silu sečenja u odnosu na instrumente sa neutralnim ili negativnim sečivnim uglom. Veća dubina navoja od vrha prema dršci ovih instrumenata omogućava delikatnije sečenje na vrhu i agresivnije u kruničnom segmentu (ovaj dizajn smanjuje prečnik jezgra i tako povećava fleksibilnost) [7].

Specifičan dizajn i promenljiva dužina sekvenci duž radnog dela MTwo instrumenata eliminiše mogućnost ušrafljivanja tokom kontinuirane rotacije i smanjuje mogućnost apikalne transportacije detritusa [5, 8, 9]. Drška od 11 mm Mtwo instrumenata je kraća od drugih mašinskih instrumenata i zbog toga izuzetno pogodna za rad u molaroj regiji.

Cilj ovog istraživanja je bio da se primenom SEM-a analiziraju površine radnog dela MTwo instrumenata nakon preparacije kanala različite povijenosti i utvrdi eventualno postojanje promena i deformacija nakon instrumentacije.

MATERIJAL I METODA

U istraživanje su uključena tri seta MTwo (VDW, Munich, Germany) instrumenata. Svaki set je sadržavao četiri instrumenata: 10/0,04; 15/0,05; 20/0,06 i sa 25/0,06 (Slika 1).

Studija je izvedena je u *in vitro* uslovima na humanim premolarima, ekstrahovanim iz različitih razloga nakon dobijene saglasnosti Etičkog odbora Stomatološkog fakulteta u Beogradu (br. 36/6). Odmah po ekstrakciji zubi su dva sata čuvani u 4% rastvoru natrijum-hipohlorita, a do početka preparacije u fiziološkom rastvoru sa 0,2% timola da bi se sprečio rast bakterija. Dijamantskim diskom krunica zuba je skraćivana na nivo 2 mm koronarno od gleđno-cementne granice. Nakon formiranja pristupnog kaviteta, inicijalna prohodnost kanala je utvrđena K-turpijama veličina #15 (Dentsply/Maillefer) i utvrđena radna dužina za svaki kanal. Radiografijom kanala sa instrumentima (#10) i pomoću onlajn uglomera određen je njegov stepen povijenosti (Šnajderovom rendgenografskom tehnikom) [10]. Na osnovu toga, zubi su podeljeni u tri kategorije:

a) 10 pravih kanala – nizak stepen povijenosti (manje od 10°),
b) 10 blago povijenih kanala – umereni stepen povijenosti (od 10° do 25°) i
c) 10 jako povijenih kanala – sa velikim stepenom povijenosti (preko 25°).

Da bi se postigli ujednačeni eksperimentalni uslovi, svaki instrument je upotrebljen u deset kanala ili do trenutka njegove frakture (po jedan set je primenjen za obradu 10 kanala u svakoj eksperimentalnoj grupi).

Eksperimentalni protokol

Preoperativna priprema je podrazumevala čišćenje u ultrazvučnoj kadici uz korišćenje blagog dezinficijensa Orocid Multisept plus („OCC“, Switzerland) u trajanju od 15 minuta.

Nakon dodatne provere obaveznog pravolinijskog pravca i prohodnosti kanala K-turpijama veličine 10 i 15 (MicroMega, France), usledila je obilna (5 ml) irigacija 2% rastvorom NaOCl. Instrumentacija kanala je realizovana u skladu sa uputstvima proizvođača krunično-apeksnom tehnikom i primenom X-Smart Endodontic Rotary Motora (Dentsply, Sirona, Maillefer, Ballaigues Salzburg, Austria). Ni-Ti turpije su redovno čišćene u sterilnom sunđeru da bi se uklonili ostaci dentina, a posle svakog mašinskog instrumenta izvršena je rekapitulacija radne dužine ručnim instrumentom #10. Kao irigans, posle svakog instrumenta, u količini od po 5 cm³, korišćeni su 2% rastvor NaOCl (CHLORAXID 2%, Cerkamed, Poljska) i potom destilovana voda (Iva, Srbija). Irigansi su aplikovani pomoću plastičnog šprica i endodontske igle za irigaciju sa zatvorenim vrhom i bočnim otvorima (Side-vented needle, SmearClear, SybronEndo). Kao lubrikant tokom preparacije korišćen je gel etilendiamin tetra-acetatne kiseline (Glyde-Dentsply, Maillefer, Switzerland), aplikovan na radni deo instrumenata. Tokom obrade kanala, svaki upotrebljeni instrument je pažljivo pregledan pomoću lupe, radi detekcije bilo kakve promene (eventualnih pukotina, lomova, odvrtanja navoja ili drugih deformacija).

Preparaciju je realizovao jedan operater.

Nakon instrumentacije instrumenti su očišćeni u ultrazvučnoj kadici uz primenu blagog dezinficijensa Orocid Multisept plus („OCC“, Switzerland) u trajanju od 15 minuta.

SEM analiza upotrebljenih instrumenata je izvršena u laboratoriji Rudarsko-geološkog fakulteta, Univerziteta u Beogradu, na SEM-u tipa JEOL JSM-6610LV, Japan. Izrađeni su snimci pomoću detektora za sekundarne elektrone (SE snimci – second electron) (150–2000×). Analizirane su apeksna i srednja trećina instrumenta iz dva različita pravca, a za svaku površinu instrumenta su napravljena po tri snimka. Apeksna trećina je obuhvatala apikalnih 5 mm, a srednja narednih 5 mm radnog dela rotirajućih Ni-Ti instrumenata.

Pregledano je 250 snimaka instrumenata nakon preparacije kanala, a usaglašavanje rezultata dva istraživača izvršeno je analizom Cohen Kappa.

Primenjena je kvalitativna analiza prisustva različitih nepravilnosti po Kristini Egert i saradnicima: Ocena 1 – bez vidljivog defekta, Ocena 2 – jamičasta udubljenja, Ocena 3 – žlebovi, Ocena 4 – mikrofrakture, Ocena 5 – potpune frakture, Ocena 6 – metalna uglačanost, Ocena 7 – metalni opiljci, Ocena 8 – tupe sečivne ivice, Ocena 9 – prekid sečivne ivice, Ocena 10 – korozija, Ocena 11 – prisustvo debrija [11]. Urađena je kvalitativna analiza, ali bez kvantifikovanja dobijenih rezultata.

Statistička analiza dobijenih podataka urađena je primenom Fišerovog testa na nivou pouzdanosti od 5% ($\alpha = 0,05$).

REZULTATI

Rezulatati SEM analize MTwo instrumenata nakon instrumentacije kanala različite povijenosti predstavljeni su u tabelama 1, 2, 3 i slikama 2–7.

Rezulati studije ukazuju da nakon instrumentacije nije postojao nijedan instrument bez deformacije. Analizom snimaka uočava se prisustvo defekata u vidu žlebova na svim instrumentima, koji su nastali kao rezulatat proizvodnog procesa (Tabela 1).

Najviše defekata (37,3%) uočeno je na instrumentima koji su upotrebljeni za obradu izrazito povijenih kanala, zatim na instrumentima druge grupe (35,6%), a najmanje defekata je uočeno u grupi pravih kanala (27,1%) (Tabela 2). Veća zastupljenost defekata je uočena na apikalnoj površini instrumenata (54,2%), posebno u trećoj eksperimentalnoj grupi (20,3%) (Tabela 2).

Defekti su uočeni na najtanjem (10/0,04) i najkoničijem instrumentu (25/0,06) u sve tri eksperimentalne grupe. Kod instrumenta 15/0,05 promene su zabeležene samo u trećoj, a kod instrumenta 20/0,06 samo u drugoj grupi (Tabela 3).

Najučestaliji tip defekta nakon instrumentacije je bila pojava korozije. Uočena je u jednom instrumentu prve grupe (10/0,04) (apikalna i srednja trećina); na dva instrumenta druge grupe (10/0,04 i 25/0,60) (apikalni i srednji deo) i jednom instrumentu u srednjoj trećini (20/0,06), dok je u trećoj grupi defekt registrovan u srednjoj trećini kod jednog instrumenta (15/0,05) (Tabela 3). Uz koroziju, uočena je zatupljenost, prekid sečivnih ivica i pojava mikrofraktura. Zatupljena sečivna ivica je uočena na apikalnoj trećini najtanjeg (10/0,04) instrumenta prve grupe (isti instrument na kome je primećena i korozija), apikalnoj trećini (25/0,06) instrumenta druge grupe i srednjoj trećini instrumenta (25/0,06) treće grupe.

Prekid sečivne ivice je notiran na apikalnoj trećini najmanjeg instrumenta (10/0,04) druge grupe i srednjoj trećini instrumenta (25/0,06) treće grupe. Mikrofraktura je primećena u apikalnoj trećini instrumenta (15/0,05) prve grupe, u apikalnoj trećini kod dva instrumenta treće grupe (10/0,04 i 15/0,05). Na istim instrumentima treće grupe (10/0,04 i 15/0,05) zabeležena je i KOMPLETNA FRAKTURA. Na instrumentu 10/0,04 fraktura je nastala posle devet korišćenja (dužina zalomljenog fragmenta 1,5 mm), a na instrumentu 15/0,05 nakon osme upotrebe (fragment od 0,8 mm) (Tabela 3, slike 2, 3).

Analizirajući fraktografsku mikrofotografiju (Slika 3), na uvećanjima ×1500 i ×2000 uočavaju se centralne zone frakturne površine sa mikroskopskim rupicama (koje su pokazatelj torzionih promena) i jasni tragovi kružne abrazije na njenim spoljašnjim delovima.

Defekt koji je uočen a nije predstavljen u kriterijumima je pojava promene navoja tj. njihovog odvijanja i uvrtanja (zastupljen samo posle preparacije povijenih (25% apikalna i srednja trećina) i jako povijenih kanala (50% apikalna i 25% srednja trećina) (Tabela 1). Ova promena je uočena u drugoj eksperimentalnoj grupi na dva instrumenta (na apikalnoj trećini instrumenta (10/0,04) i srednjoj trećini instrumenta (20/0,06)), i u trećoj grupi na tri instrumenta (na apikalnoj trećini instrumenata 10/0,04 i 20/0,06) i srednjoj trećini jednog instrumenta (15/0,05) (slike 4, 5, 6).

Analizirajući SE snimke (Slika 4) koji pokazuju uzdužni snimak frakturiranog MTwo instrumenta (15/0,05), takođe se uočavaju promene navoja (ispravljanje i odmotavanje navoja) sa obiljem mikrofraktura na površini zalomljenog instrumenta, posebno u neposrednoj blizini frakture.

Isti nalaz je uočen i na frakturnoj površini Mtwo 15/0,05 instrumenta (Slika 7). Pojava deformacije promene navoja u povijenim i izrazito povijenim kanalima pokazuje statistički značajnu razliku u odnosu na grupu sa pravim kanalima ($p < 0,05$).

DISKUSIJA

Eksperimentalni protokol primenjen u ovom radu razvijen je u skladu sa prethodno korišćenim modelima za ispitivanje promena na Ni-Ti rotirajućim instrumentima. Istraživanje je sprovedeno u laboratorijskim uslovima, kao *in vitro* studija na ekstrahovanim zubima kako bi se obezbedili uslovi bliski kliničkoj situaciji.

Rezultati ove studije potvrđuju stavove o najučestalijoj pojavi defekata u apikalnom segmentu instrumenta, posebno nakon instrumentacije komplikovanih endodontskih sistema [7, 8, 9, 12, 13, 14]. U literaturi se navodi da deformacije i frakture na instrumentima najčešće nastaju u kompleksnim molarnim sistemima (češće nego u frontalnoj i premolarnoj regiji) [7, 9, 14]. Najčešća pojava fraktura je uočena u meziobukalnim kanalima molara gornje i donje vilice, zbog njihove kompleksne povijenosti [12]. Mezijalni korenovi donjih molara su povijeni ne samo prema distalno već je vrlo često meziobukalni kanal dodatno povijen lingvalno, a meziolingvalni bukalno. Analizirajući incidencu frakture Ni-Ti instrumenata u različitim grupama zuba, Di Fiore iznosi stopu zalamanja kod prednjih zuba 0,28%, premolara 1,56% i molara 2,74% [15].

MTwo je jedini sistem koji ima instrumente malih dimenzija (10/0,04 i 15/0,05) i svi instrumenti u setu se koriste za instrumentaciju do pune radne dužine [16]. Specifična veličina i dizajn instrumenta 10/0,04 koristi se za uspostavljanje inicijalne prohodnosti i formiranje instrumentacione putanje [16]. Zatupljena sečivna ivica i prekid sečivne ivice, korozija, promene navoja, mikrofrakture i kompletne frakture na instrumentu 10/0,04 ukazuju na vulerabilnost MTwo instrumenta najmanjih dimenzija tokom preparacije jako povijenih kanalnih sistema. Rezultati ove studije su u saglasnosti sa rezultatima istraživanja gde su najtanji instrumenti pokazali najviše fraktura i najviše deformacija [17, 18, 19]. Potvrđeno je da oblik i veličina poprečnog preseka instrumenata mogu uticati na njihovu otpornost na zamor, pri čemu su tanji instrumenti otporniji na ciklični zamor i osetljiviji na torziona opterećenja, a deblji instrumenti mogu izdržati veći obrtni moment i osetljiviji su na ciklični zamor [17]. Inan i Ganulol su u svojoj studiji otkrili da kod većine manjih instrumenata (10/0,04 i 15/0,05) dolazi do zalamanja u apikalnoj trećini (fragmenta 1 mm i manje) [14]. Zbog malih dimenzija i lokalizacije frakturiranih vrhova instrumenata (u istmusima ili apikalnoj delti) kliničari često nisu ni svesni njihove pojave [18]. Kod MTwo sistema svi instrumenti se koriste za instrumentaciju do pune radne dužine, pa je zato i stres mnogo veći na tanjim i instrumentima manje koničnosti. Zbog toga su Shen i saradnici u svojoj studiji sugerisali jednokratnu upotrebu tanjih instrumenata, kako bi se izbegle deformacije i frakture [19].

Fraktura Ni-Ti instrumenta je najkompleksnija greška tokom mašinske instrumentacije. Za razliku od instrumenata od nerđajućeg čelika koji se vidno deformišu pre frakture (savijanje, odmotavanje navoja), rotirajući NiTi instrumenti se vrlo često lome bez upozorenja i vidljivih znakova deformacije [1, 2]. Fraktura mašinskih NiTi instrumenata može nastati kao rezultat torzionog naprezanja, cikličnog zamora, ili kombinacijom ova dva faktora. Pri prolasku kroz povijeni kanal, mašinski instrument je izložen dejstvu zateznih (tenzionih) sila na spoljašnjoj strani krivine, a na unutrašnjoj strani dejstvu kompresivnih sila. Ove sile tokom uvlačenja i izvlačenja naizmenično deluju na rotirajući instrument, što često dovodi do loma [2]. Uočeno je da dužina upotrebe i povećanje obrtnog momenta značajno redukuju otpornost instrumenta na ciklični zamor [4].

Frakture usled torzionog naprezanja nastaju kada postoji velika kontaktna površina između instrumenta i dentinskog zida i ukoliko je apikalni pritisak prejak tokom instrumentacije [1, 2]. Akumulacijom torzionog stresa instrumenta i prekoračenjem granice elastičnosti Ni-Ti legure dolazi do njegove plastične deformacije i preloma [1, 2]. Na frakturnoj površini najčešće se uočavaju zone mikroskopskih rupica koje ukazuju na torzionu promenu i bez koncentričnih znakova karakterističnih za frakture nastale usled cikličnog zamora [20]. Torzione promene odlikuje odmotavanje, ispravljanje i uvijanje navoja, a frakture su u direktnoj zavisnosti od anatomije kanala, karakteristika Ni-Ti legure, dizajna instrumenata, primenjene brzine, odnosno iskustva i spretnosti terapeuta [18].

Smanjenje torzionog opterećenja i mogućeg ušrafljivanja instrumenata u kanalu se postiže obaveznom upotrebom endomotora sa kontrolom torka. U sistemima pune rotacije, usled ponavljanih torzionih naprezanja instrumenata, ovo je najčešći uzrok deformacija i pojave fraktura [21].

Dve frakture MTwo instrumenata u trećoj eksperimentalnoj grupi potvrđuju torzioni stres kao uzrok. Na SE snimcima poprečnog preseka zalomljenog instrumenta (10/0,04) jasno se uočavaju centralne zone sa mikroskopskim rupicama koje ukazuju na torzione promene. Inan i Gonulol u studiji na uzdužnim mikrofotografijama istog instrumenta uočavaju promene navoja (ispravljanje i odmotavanje navoja) sa brojnim mikrofrakturama na površini zalomljenog instrumenta [14]. Isti nalaz je uočen na frakturnoj površini Mtwo (15/0,05) instrumenta, gde se mesto preloma poklapa sa položajem maksimalne povijenosti gde su instrumenti najmanjih dimenzija i najmanjeg konusa (10/0,04, 15/0,05), odnosno najveće fleksibilnosti, pokazali manju otpornost na torziona opterećenja, što je u saglasnosti sa rezultatima ove studije [14].

Fraktografski nalazi i SE snimci preloma Mtwo instrumenata su u skladu sa rezultatima studije koju su sproveli Cheung i saradnici (Cheung et al., 2007). Torzioni tip frakture je češći u uskim, povijenim i komplikovanim apikalnim delovima kanala (gde postoji velika verovatnoća ušrafljivanja instrumenta) [20].

Tzanetakis u svojoj studiji pokazuje da je prevalencija zalomljenih Ni-Ti instrumenata u apikalnoj trećini (52,5%) bila značajno veća u poređenju sa srednjom (27,5%) i koronarnom (12,5%) trećinom kanala. [22]. Ungerechts sa saradnicima takođe ukazuje da je 39,5% prelomljenih Ni-Ti instrumenata registrovano u mezobukalnim kanalima molara i da je 76,5% ovih fragmenata locirano apikalno [23].

Pojava defekata na najvećem i najkoničnijem instrumentu u sve tri eksperimentalne grupe (25/0,06) takođe ima potvrdu u literaturnim navodima [24, 25]. Tripi je SEM analizom analizirao pojavu defekata, habanja i zamora nakon instrumentacije MTwo instrumentima i ukazao na češću pojavu deformacija kod instrumenata većih dimenzija, koji su prema nalazima Ulmana i Petersa manje fleksibilni i manje otporni na ciklični zamor [24, 25]. U studiji koja je poredila MTwo i ProTaper Next sistem takođe je uočeno da je otpornost na ciklični zamor manja kod instrumenata sa većim dijametrom [26].

Schafer i sar. su u studiji o sečivnoj efikasnosti ukazali na značajno kraće vreme preparacije kanala MTwo instrumentima i bez pojave frakture tokom instrumentacije [12, 13].

Cang i sar. (2020) takođe su ukazali na visoku efikasnost MTwo sistema u čišćenju i oblikovanju povijenih kanala, bez pojave frakture (nakon obrade četiri kanala u endoblokovima) [8]. Ovaj nalaz je u saglasnosti sa rezultatima ove studije, gde su frakture registrovane posle devete i desete primene kod izuzetno povijenih kanala. Vadhan i sar. u svojoj studiji takođe ukazuju na veću otpornost na ciklični zamor MTwo instrumenata u odnosu na sve ostale ispitivane Ni-Ti instrumente [27].

Prateći karakteristike dizajna i specifičnosti upotrebe MTwo instrumenata, Malagnino je istakao da povećanje brzine neminovno dovodi do deformacija i fraktura instrumenata. Manja brzina rotacije ne umanjuje efikasnost ovog Sistema, ali omogućava maksimalnu kontrolu i potpunu sigurnost [8, 9].

Iako je MTwo sistem nastao pre 18 godina, zahvaljujući specifičnom dizajnu i karakterističnoj veličini, postoje nove mogućnosti njegove primene odnosno načina aktivacije i pokretanja u kanalu (promenom dubine napredovanja i smanjenjem brzine rotacije) [28, 29].

ZAKLJUČAK

Povijenost korenskog kanala značajno utiče na pojavu deformacija i preloma Ni-Ti rotirajućih instrumenata. Fraktografskim ispitivanjem frakturnih površina uočeni su znaci torzionog preloma, a MTwo instrumenti su pokazali deformacije u vidi promene navoja i mikrofraktura. Pojava ovih promena upozorava kliničare na mogućnost frakture i obavezu isključivanja instrumenata za dalju upotrebu.

REVIEW ARTICLE
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Artificial intelligence as a powerful tool in overcoming substantial health problems of the COVID-19 pandemic

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SUMMARY

Introduction This review aims to investigate modern methods of applying artificial intelligence to diagnose SARS Cov-2 and predict the development of potential emergencies.

Methods The most commonly used electronic databases, such as Scopus and Medline during 2020, were searched. A narrative approach was used to synthesize the extracted data.

Results In this review paper, it has been shown that the application of artificial intelligence plays a significant role in virus diagnosis and prognosis in clinical trials. It allows resources to be used much more rationally, such as respirators, in hospitals, during the treatment of SARS Cov-2 and the prediction of possible mortality. The obtained results are from the analysis performed on 120 papers and studies that were electronically taken from papers published on Scopus and Pub Med line. Most commonly used artificial intelligence techniques are convolutional neural networks and machine learning.

Conclusions Included studies showed that artificial intelligence can significantly improve the treatment of SARS Cov-2, although many of the proposed methods have not yet been clinically accepted. In addition, more effort is needed to develop standardized reporting protocols or guidelines on applying artificial intelligence into conventional clinical practice. This technology is suitable for fast and accurate diagnosis, prediction and monitoring of current patients and prognosis of disease development in future patients.

Keywords: machine learning; artificial intelligence; radiology; chest X-ray; CT

INTRODUCTION

Data from a large number of patients with COVID-19 can be integrated and analyzed using machine learning algorithms to have better understanding of the pattern of virus spread, improve diagnostic speed and accuracy, develop new practical therapeutic approaches, and identify the most vulnerable populations based on individual genetic and physiological characteristics. Machine learning techniques are used in the taxonomic classification of the COVID-19 genome, the CRISPR-based COVID-19 detection test, predicting the survival of severely ill COVID-19 patients, and identifying potential candidates for anti-COVID-19 drugs [1, 2, 3].

The recent discovery that more and more young adults are suffering from severe COVID-19 symptoms has challenged an earlier observation that older people are at higher risk for COVID-19, indicating urgent need for comprehensive risk assessment based on personalized genetic and physiological characteristics. The human enzyme for the conversion of angiotensin 2 (ACE2), expressed in the epithelial cells of the lung, small intestine, heart, and kidney, is the entry receptor for the glycoprotein SARS-CoV-2 spike. Some researchers believe that increased ACE2 expression, using drugs that stimulate ACE2 for treatment of hypertension and diabetes, worsens the clinical outcomes of COVID-19 infection [3, 4].

Accordingly, the biochemistry (ACE2 expression level) and clinical data (age, respiratory pattern, viral load, and survival) of patients with COVID-19 can be analyzed by machine learning approaches to predict risk based on ACE2. Genetic polymorphism that has been shown in ACE2, conditioned by various genetic variations in the human genome, affects the efficiency of virus binding; therefore, the analysis of machine learning of genetic variants in asymptomatic, mild or severe patients with COVID-19 is performed to classify and predict patient resistance to potential COVID-19 infection [2, 5].

Neural network classifiers have been developed for extensive screening of patients with COVID-19 based on their different respiratory patterns and for analysis of thoracic CT images based on machine learning to automatically detect infected patients and monitor them during disease development [2–5].

Chest X-ray and CT produce a large amount of data on COVID-19 very quickly, enabling the development of

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machine learning algorithms, as well as other forms of artificial intelligence. Methods that are highly adapted to the application of artificial intelligence, especially when it comes to diagnostics, are observed in this paper. Also, huge data files originating from various countries of the world have led to rapid development of artificial intelligence applications, that aim to speed up diagnosis and help elucidate various factors that affect the rate of transmission of this disease and the severity of the expected clinical picture are particularly discussed. The availability of objective tools for rapid assessment of patient health helps health professionals make difficult decisions about allocating scarce resources. For COVID-19, training of algorithms for predicting outcomes such as mortality, admission to the intensive care unit or the need for mechanical ventilation had a significant clinical effect. Availability of multiple chest X-rays at an early stage of the patient's disease, with accompanying respiratory disorders, are the strongest predictor of long-term outcome diseases. The inclusion of sequential chest X-rays in training artificial intelligence models reveals many pictorial characteristics of disease progression, which are inaccessible to human eye [5, 6].

In addition, machine learning to detect drugs allows the design and creation of new compounds similar to drugs against SARS-CoV-2. It can point us to protein structures that could be the basis of COVID-19 drugs, greatly accelerating traditional experimental approaches and serving as valuable information for formulating the COVID-19 vaccine [7].

Artificial intelligence and machine learning help us identify people who are most at risk for coronavirus infection by integrating electronic health records with a wealth of "data that is personal in nature and speaks to patients' habits". They can also determine which infected patients are more likely to get a more severe form of infection [8].

Because the symptoms and development of COVID-19 disease vary significantly from patient to patient, a simple approach to treatment is not applicable. Machine learning techniques can help us determine the most effective treatment for each patient based on observation data from previous patients, as it helps us answer key questions about when to undertake a therapeutic procedure. Machine learning can help us choose specific treatments for specific subgroups of patients to understand which treatments are appropriate for the population as a whole [8, 9].

Machine learning as a tool in protection against COVID-19

As the main methods of diagnostic imaging of patients, chest X-ray and CT quickly produced a large amount of data on COVID-19, enabling the development of machine learning algorithms, increased due to the existence of a pandemic, which has led to numerous publications around the world reporting on the applications of artificial intelligence to all aspects of diagnosis and treatment of COVID-19 [10].

When applying artificial intelligence to COVID-19, research questions run the risk of focusing too much on creating new machine learning models without considering its practical application and potential biases. Occasionally, the speed and accuracy of machine learning algorithms are derived based on performance in clinical scenarios that do not reliably reflect clinical practice. Sometimes comparisons between algorithm and human performance are unbalanced. In most cases, computer is trained to detect a particular abnormality (e.g., parenchymal diseases associated with COVID-19), while a radiologist is usually responsible for detecting any abnormality (such as pulmonary nodules or pulmonary emboli). Machine-based CT analysis is a promising COVID-19 screening tool and sometimes exceeds the reliability of PCR tests [11, 12].

Studies conducted during the pandemic were characterized by a high prevalence of the disease and the nature of the disease in selected participants, whose severity of the disease justified hospital admission and CT assessment. Ideally, algorithms should be trained to recognize the full spectrum of diseases, including asymptomatic and early-stage cases, so that machine-assisted CT interpretation can be reliably applied to real-world data. Further, consensus must be reached on the best data labeling strategy and whether to include only patients with real-time PCR-positive SARS-CoV-2 infection. It should be decided whether the data labeling should contain multidisciplinary information such as cough or fever, how the participant's exposure to an infected household member changes the training algorithm, etc. In most cases, machine-learning algorithms develop on retrospective, clinically indicated data that are often imperfect. Additionally, it is necessary to include the noise effect to improve the algorithm's clinical applicability [13, 14].

Without any doubt, COVID-19 offers many exciting opportunities for applied artificial intelligence research. As we learn more about the history of COVID-19, it is becoming increasingly clear that the disease is progressing in stages. The need to prevent deterioration and personalize preventive interventions has emerged as a priority. Currently, research on images focuses on diagnosis based on the appearance after the disease progresses. Detection of the disease in the earliest stages, when initiating appropriate therapy is most effective, would be useful to develop a prognostic tool, for many lung diseases, especially in combination with clinical data, which is especially important for patients who need intensive care and support for ventilation [15, 16].

An untapped resource in COVID-19 patients is the availability of chest X-rays at multiple time points in the early stages of the patient's disease. In other respiratory disorders, short-term disease behavior is the strongest predictor of long-term outcome. By including sequential chest X-rays in model training, new imaging features of disease progression can be detected, including those inaccessible to human eye. In general, although patients with comorbid diseases represent a population at high clinical risk, it is currently not possible to identify patients without underlying health problems but who also often develop similar disease progression. The availability of objective tools for rapid assessment of the patient's condition would help healthcare professionals make difficult decisions about allocating scarce resources [17, 18].

Machine learning algorithms are often modular, which means that new algorithms generated during this pandemic could be successfully repurposed for other lung diseases in the future. There will always be a balance of risk and speed, and the key to this balance is defining the needs for which the solutions will have the most significant clinical value. With the right collaboration between clinical expertise and machine learning expertise, the current public health crisis could mark the beginning of a decade when artificial health intelligence is fulfilling its broad, transformative clinical impact [18, 19].

Advantages of application of artificial intelligence in COVID-19 diagnostics

The main advantage of machine learning is its ability to "learn" how an individual's characteristics (risk factors), along with clinical and social information, can be mapped into personalized risk predictions. Although standard epidemiological approaches, such as Cock's model of proportional hazards, are not able to effectively combine data from different data sources and modalities (demographic, social, longitudinal, image, multi-omics), modern neural network-based learning techniques can easily and efficiently provide personalized risk predictions, updating them and improving the possibilities of their use. Such risk prediction mechanisms can be used to prevent, monitor and detect disease [20].

For people who are already infected with SARS-CoV-2, it is crucial to anticipate the risk of adverse events (including death) and the dynamics of the necessary health resources to provide appropriate care to patients. Key risk factors are the patient's age and / or the presence of comorbidities, such as hypertension, cystic fibrosis, transplant-related immunosuppression, and chemotherapy for cancer. Current risk assessment methods for infected patients use only a few factors (assessment of clinical weakness, number of comorbidities, previous therapeutic procedures, and administrative data from previous hospital admissions, to assess which patients are most at risk. These relatively simple approaches may be appropriate in the acute stages of an epidemic. However, they fail to capture and explain subtle interactions between age, specific comorbidities (including duration), assessments of the extent of organ dysfunction, and the impact of other relevant health factors [21, 22].

Reliance on such measures often leads to discovering previously undetermined, completely new risk factors - that is especially important for diseases that little is known about. These methods provide increasingly accurate subtypes of COVID-19 disease as more data are collected. They can define an estimate of the probability with which a patient may experience various adverse events and change that probability over time, allowing for improved prediction accuracy compared to conventional epidemiological methods [23].

As mentioned, patients diagnosed with COVID-19 have many possible disease outcomes in terms of incubation time and changes in lung oxygen capacity, and the development of disease severity. It provides a way to predict the dynamics of the patient's disease progression and an understanding of how certain events (worsening of symptoms) can abruptly change the dynamics of the disease. This is essential for rational use of systems that enable dynamic management of limited health resources [24, 25].

When it comes to patients, it is essential to know which patients require early admission to the hospital, when a patient can safely leave intensive care or be discharged from the hospital. Such timely admission and discharge questions are often answered based on simple basic rules (e.g., examining the latest measurements for several selected variables and making decisions based on limit values). However, such decisions should include data from the history of each patient. Using all available observations at any time, artificial intelligence, has the possibility of a deeper understanding of the patient's condition, and it can participate in making such a decision, predicting the patient's future health needs, pointing to significant predictors of the patient's treatment outcome (specific comorbidities that are likely to worsen the patient's prognosis with COVID-19) [26, 27].

Monitoring and collecting health data is expensive because it takes a lot of time and staff engagement, although not all data is equally valuable. Therefore, it is necessary to set priorities, what we must actively measure, when it should be measured, and on which patients and the monitoring of each patient should be active and transparent. Active reading of data and their appropriate selection by importance enable institutions to dynamically allocate hospital resources depending on the needs of their patients. This, in turn, allows physicians to make competent decisions about delaying treatment for conditions that are not immediately life-threatening so that resources can be used for critically ill patients with COVID-19 [28, 29].

Models based on artificial intelligence make it possible to monitor and determine the effects of existing medical treatments of individuals, given their specific features, which include existing comorbidities, creating conditions for choosing the best approach to treatment for each patient, which includes the use of mechanical ventilation and potentially new therapeutic treatments. Models based on Gaussian processes of contradictory generative network and deep neural network can help in experimental treatment phases, based on observational data, without resorting to randomized trials [30, 31].

They answer questions "what would happen to a given patient if mechanical ventilation were delayed for a few hours?" or "What would be the outcome of treatment if the appropriate experimental care procedure has been applied a week earlier? This can help us learn the best treatment plan for each individual when it comes to available health resources. This is not just about which intervention should be applied for each patient individually, but also about when a given patient needs a specific intervention, which is extremely important, given the limited available resources [32, 33].

Using longitudinal patient observation data, the counterfeit recurrence network is learned to predict counterfeit health pathways according to different management plans for each individual. Such predictions can be made dynamically by modeling and updating the patient's condition over time to account for all past medical events. This way, it is possible to determine the time frame during which the intervention would be most effective and select a specific sequence of interventions that would result in the best outcome for each patient. In addition, this method can show when interventions, such as a mechanical ventilator, are not necessary for the patient and for how long their use can be delayed without significant deterioration in the patient's health [34, 35, 36].

Recently, improving the design of adaptive clinical trials has shown that their efficiency and effectiveness can be significantly improved through machine learning. Customizable ML-enabled clinical trials in recruiting patients in groups (instead of all at once), monitoring its effect on each group before recruiting the next group, so that instead of randomly recruiting patients, machine methods the studies make it possible to recruit subjects from the subgroups, more suitable for a particular type of treatment, thus requiring much fewer patients to check the effectiveness of treatment with a given drug. Another important application of ML in the field of RCT is a post-hoc analysis of clinical trials and in particular, identification of subpopulations that show the most similar response to a given type of treatment, which facilitates the treatment of specific subpopulations and understanding treatments that might be appropriate for the population as a whole [37, 38].

The problem of biased machine learning models can be solved by transfer learning methods, which implicitly deal with uncertainty in predicting individuals from populations not used for training. International cooperation could create an extensive data set containing data from multiple infected populations, and a unique two-step risk assessment model can be trained for such a data set and applied worldwide. Transfer learning models work well for disease prognosis in different countries or health systems [39].

Transfer learning is desirable for transferring models between populations and updating machine learning models for a given population over time. It shows how the disease develops within a given population over time, linking it to certain specifics of the patients themselves, using successive data series developed by Bayesian optimization technique to update the model with new information. When we provide information-based information to decision-makers based on artificial intelligence systems, it is important to determine what we know reliably and what we do not know. For this purpose, a technology has been developed to systematically quantify uncertainties in predictions, which follow from the machine-learning model. All data entered must include a confidence assessment so that decision-makers know when and for which patients they can trust the predictions provided by the artificial intelligence system and when they should be careful about the information obtained. Quantifying uncertainty in predicting outcomes at the patient level is crucial for hospitalization management and for making optimal therapeutic decisions. The obtained confidence interval in machine learning should cover the true outcome [40–48].

CONCLUSIONS

The application of methods based on artificial intelligence can be achieved through three levels of human-machine interface: Interface at the individual level, implies the existence of mobile applications powered by GPS, which individuals install on their mobile phones. These applications can be used to target social distancing by informing individuals that they are in high-risk geographic locations where a significant number of COVID-19 cases have been diagnosed or where a significant number of virus carriers are currently present. The application of this system can be primarily based on software applications, which can be quickly connected to GP patient registries held in the NHS.

For public health risk assessments, the existing hospital EHR infrastructure can be supplemented with risk modeling applications that show alert clinicians to new risks in patients in each hospital. Such applications can be used for remote diagnosis and care of self-isolated persons with evident disease symptoms. The application of models based on artificial intelligence in hospitals relies on the existing hardware infrastructure to connect input data streams with software (driven by machine learning models). It shows the risks for patients at the clinical level.

At the national level, the artificial intelligence-human interface enables government officials and decision-makers to continuously update the latest epidemiological data on COVID-19, with a geographically stratified overall risk assessment and hospital occupancy rate for the entire population. This application can be directly linked to the NHS patient registration database and other applications to collect data on the risk to which a given population is exposed, enabling administrators to make selective strategic decisions about which locations to lock and which hospitals need more funding.

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Veštačka inteligencija kao moćno sredstvo u prevazilaženju zdravstvenih problema u toku pandemije bolesti COVID-19

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KRATAK SADRŽAJ

Uvod Cilj ovog rada bio je da istraži savremene metode primene veštačke inteligencije u dijagnozi virusa SARS Cov-2 i da predvidi razvoj potencijalnih hitnih stanja.

Metode Pretražene su najčešće korišćene elektronske baze podataka, npr. Scopus i Medline, tokom 2020. godine. Za sintezu dobijenih podataka korišćen je narativni pristup.

Rezultati U ovom preglednom radu pokazalo se da primena veštačke inteligencije igra veoma važnu ulogu u dijagnozi i prognozi virusa u kliničkim ispitivanjima. Omogućava da se resursi (kao što su respiratori u bolnicama) koriste mnogo racionalnije tokom lečenja SARS Cov 2 i predviđanje mogućeg mortaliteta. Rezultati su dobijeni nakon analize izvedene na 120 radova i studija koje su elektronski preuzete iz radova objavljenih u bazama podataka Scopus i Pub Medline. Najčešće korišćene tehnike veštačke inteligencije su konvolucione neuronske mreže i učenje uz pomoć računara.

Zaključci Obuhvaćene studije pokazale su da veštačka inteligencija ima potencijal da značajno poboljša lečenje SARS Cov-2, iako mnoge od predloženih metoda još uvek nisu klinički prihvaćene. Iz toga sledi da je potrebno mnogo više napora za razvijanje standardizovanih protokola izveštavanja ili smernica o tome kako primeniti veštačku inteligenciju na konvencionalnu kliničku praksu. Ova tehnologija je pogodna za brzu i tačnu dijagnozu, predviđanje i praćenje pacijenata, odnosno prognozu razvoja bolesti kod budućih pacijenata.

Ključne reči: učenje uz pomoć računara; veštačka inteligencija; snimanje; RTG snimanje grudnog koša; CT

UVOD

Podaci velikog broja pacijenata sa bolešću COVID-19 mogu se integrisati i analizirati uz pomoću algoritama na računarima kako bi se bolje razumeo obrazac širenja virusa, poboljšala brzina dijagnostike, razvili novi efikasni terapijski pristupi i identifikovali najugroženiji pripadnici populacije na osnovu individualnih genetskih i fizioloških karakteristika. Tehnike mašinskog učenja koriste se u taksonomskoj klasifikaciji genoma COVID-19, testu otkrivanja bolesti COVID-19 zasnovanog na detekcionom testu CRISPR, u predviđanju preživljavanja teško bolesnih pacijenata sa bolešću COVID-19 i u identifikovanju potencijalnih kandidata za lekove protiv bolesti COVID-19 [1, 2, 3].

Ranije zapažanje da su stariji ljudi pod većim rizikom od bolesti COVID-19 ponovo je postalo upitno nedavnim otkrićem da sve više mladih pati od ozbiljnih simptoma bolesti COVID-19, što ukazuje na hitnu potrebu za sveobuhvatnom procenom rizika na osnovu personalizovanih genetskih i fizioloških karakteristika. Ljudski enzim za konverziju angiotenzina 2 (ACE2), izražen u epitelnim ćelijama pluća, tankog creva, srca i bubrega, ulazni je receptor za glikoproteinski SARS-CoV-2 protein. Neki istraživači veruju da povećana ekspresija ACE2, do koje dolazi korišćenjem lekova koji stimulišu ACE2 za lečenje hipertenzije i dijabetesa, može pogoršati kliničke ishode infekcije COVID-19 [3, 4].

Shodno tome, biohemijski rezultati (nivo ekspresije ACE2) i klinički podaci (starost, respiratorni obrazac, virusno opterećenje i preživljavanje) pacijenata sa bolešću COVID-19 mogu se analizirati učenjem uz pomoć računara i predvideti rizik na osnovu ACE2. Pokazalo se da genetski polimorfizam ACE2, uslovljen raznim genetskim varijacijama u ljudskom genomu, utiče na efikasnost vezivanja virusa, pa se analizom uz pomoć računara kod asimptomatskih i pacijenata sa blagom i teškom kliničkom slikom može predvideti otpornost pacijenata na moguću infekciju COVID-19 [2, 5].

Na osnovu različitih respiratornih obrazaca, kao i analize torakalnih CT snimaka zasnovanih na mašinskom učenju, razvijeni su klasifikatori neuralne mreže za opsežni skrining pacijenata sa bolešću COVID-19, kako bi se automatski otkrili zaraženi pacijenti i nadgledali tokom razvoja bolesti [2–5].

U ovom radu uočeno je da RTG i CT grudnog koša daju vrlo brzo veliku količinu podataka o bolesti COVID-19, omogućavajući razvoj algoritama računarskog učenja kao i drugih oblika veštačke inteligencije, prilagođenih za brzu dijagnostiku. Takođe, posebna pažnja je posvećena ogromnim datotekama sa podacima poreklom iz različitih zemalja sveta koje su dovele do brzog razvoja aplikacija veštačke inteligencije, sa ciljem ubrzanja dijagnoze i pomoći u rasvetljavanju uticaja različitih faktora koji utiču na brzinu prenosa bolesti i težinu očekivane kliničke slike. Dostupnost objektivnih alata za brzu procenu zdravlja pacijenta pomaže zdravstvenim radnicima da donesu pravilne odluke o raspodeli oskudnih resursa. Za COVID-19, algoritmi kao što su smrtnost, prijem u jedinicu intenzivne nege ili potreba za mehaničkom ventilacijom imaju značajan klinički efekat. Dostupnost višestrukog rendgenskog snimanja grudnog koša u ranoj fazi bolesti, sa pratećim respiratornim poremećajima, najsnažniji je prediktor dugoročnih ishodnih bolesti. Uključivanje sekvencijalnih rendgenskih snimaka grudnog koša u modele veštačke inteligencije otkriva mnoge karakteristike progresije bolesti, koje su nevidljive ljudskim okom [5, 6].

Pored toga, učenje uz pomoć računara omogućava i njihov dizajn, ali i stvaranje novih jedinjenja i sličnih lekova protiv SARSCoV-2. Može nas uputiti na proteinske strukture koje mogu biti osnova lekova koji mogu ubrzati tradicionalne eksperimentalne pristupe i pružiti dragocene informacije za formulaciju vakcine protiv bolesti COVID-19 [7].

Veštačka inteligencija i mašinsko učenje mogu pomoći u identifikaciji ljudi koji su najviše izloženi riziku od infekcije koronavirusom integrišući elektronske zdravstvene kartone sa brojnim podacima lične prirode koji govore o navikama pacijenata. Veštačka inteligencija i mašinsko učenje mogu pomoći da se utvrdi kod kojih pacijenata je veća verovatnoća da će dobiti teži oblik infekcije [8].

Budući da se simptomi i razvoj bolesti COVID-19 uveliko razlikuju od pacijenta do pacijenta, jednostavan pristup lečenju nije primenljiv. Tehnike mašinskog učenja mogu pomoći da se odredi najefikasniji tretman za svakog pacijenta na osnovu podataka posmatranja prethodnih pacijenata, jer pomažu da se odgovori na ključna pitanja o tome kada treba preduzeti terapijski postupak. Mašinsko učenje nam može pomoći da odaberemo specifične tretmane za određene podgrupe pacijenata da bismo razumeli koji su terapijski postupci prikladni za populaciju u celini [8, 9].

Računarsko učenje kao sredstvo za zaštitu od bolesti COVID-19

Kao glavne metode za postavljanje dijagnoze, rendgen i CT grudnog koša brzo su proizveli veliku količinu podataka o bolesti COVID-19 i omogućili razvoj algoritama mašinskog učenja, povećanih zbog postojanja pandemije, što je dovelo do brojnih publikacija širom sveta o primeni veštačke inteligencije na sve aspekte dijagnoze i lečenja bolesti COVID-19 [10].

Kada primenjuju veštačku inteligenciju na bolest COVID-19, istraživačka pitanja rizikuju da se previše usredsrede na stvaranje novih modela mašinskog učenja, pri čemu ne uzimaju u obzir njegovu praktičnu primenu i potencijalne pristrasnosti. Povremeno se brzina i tačnost algoritama mašinskog učenja izvode na osnovu performansi u kliničkim scenarijima koji ne odražavaju potpuno kliničku praksu. Ponekad su poređenja između algoritma i ljudskih karakteristika neuravnotežena. U većini slučajeva, računar je obučen za otkrivanje određene abnormalnosti (npr. parenhimske bolesti povezane sa bolešću COVID-19), dok je radiolog obično odgovoran za otkrivanje poremećaja (kao što su plućni čvorovi ili plućne embolije). Mašinska CT analiza je obećavajući alat za skrining bolesti COVID-19 i ponekad premašuje pouzdanost PCR testova [11, 12].

Studije sprovedene tokom pandemije pokazale su visoku prevalencu bolesti i prirodu bolesti kod izabranih učesnika čija je težina bolesti zahtevala prijem u bolnicu i CT procenu. U idealnom slučaju, algoritme treba prilagoditi za prepoznavanje čitavog spektra oboljenja, uključujući asimptomatske slučajeve i slučajeve u ranoj fazi, kako bi se interpretacija CT uz pomoć računara mogla pouzdano primeniti na podatke u realnom svetu. Dalje, mora se postići konsenzus o tome koja je najbolja strategija odabira podataka i da li treba uključiti samo pacijente sa pozitivnim PCR testom na infekciju SARS-CoV-2. Treba odlučiti da li podaci treba da sadrže multidisciplinarne informacije kao što su prisustvo kašlja ili temperature, i kako izloženost učesnika studije menja algoritam zaraženom članu domaćinstva. U većini slučajeva algoritmi računarskog učenja se razvijaju na osnovu retrospektivnih kliničkih podataka, koji su često nesavršeni. Pored toga, neophodno je uključiti i efekat buke kako bi se poboljšala klinička primenljivost algoritma [13, 14].

Nesumnjivo, COVID-19 nudi mnoge mogućnosti za primenjena istraživanja veštačke inteligencije. Kako sve više saznajemo o istoriji bolesti COVID-19, postaje sve jasnije da bolest napreduje u fazama. Potreba za sprečavanjem pogoršanja i personalizacijom preventivnih mera pojavila se kao prioritet. Trenutno se istraživanja fokusiraju na dijagnozu zasnovanu na izgledu nakon napredovanja bolesti. Otkrivanje bolesti u najranijim fazama, kada je započinjanje odgovarajuće terapije najefikasnije, bilo bi korisno za razvoj prognostičkih alata za mnoga plućna oboljenja, što je posebno važno za pacijente kojima je potrebna intenzivna nega [15, 16].

Neiskorišćeni resurs kod pacijenata sa bolešću COVID-19 je dostupnost rendgenskog snimanja grudnog koša u više vremenskih intervala u ranim fazama bolesti. Kod ostalih respiratornih poremećaja kratkotrajni tok bolesti je najsnažniji prediktor ishoda oboljenja. Uključivanjem sekvencijalnih rendgenskih snimaka grudnog koša u model, mogu se otkriti nove karakteristike napredovanja bolesti, uključujući i one nedostupne ljudskom oku. Generalno, iako pacijenti sa komorbiditetima predstavljaju populaciju sa visokim kliničkim rizikom, trenutno nije moguće identifikovati pacijente bez osnovnih zdravstvenih problema, kod kojih se često razvija slična progresija bolesti. Dostupnost objektivnih alata za brzu procenu stanja pacijenta pomogla bi zdravstvenim radnicima u donošenju teških odluka u situacijama sa oskudnim resursima [17, 18].

Algoritmi računarskog učenja su često modularni, što znači da bi se novi algoritmi generisani tokom ove pandemije mogli uspešno prenameniti za druge plućne bolesti u budućnosti. Kao i uvek, postoji ravnoteža rizika i brzine, a ključ za optimizaciju ove ravnoteže je definisanje potreba za rešenjima koja će imati najveću kliničku vrednost. Uz pravilnu saradnju kliničkih eksperata i stručnjaka za mašinsko učenje, trenutna kriza javnog zdravlja bi mogla označiti početak kada veštačka zdravstvena inteligencija ispunjava svoj široki, transformativni klinički uticaj [18, 19].

Prednosti primene veštačke inteligencije u dijagnozi bolesti COVID-19

Glavna prednost učenja uz pomoć računara je njegova mogućnost da „nauči" kako se osobine pojedinca (faktori rizika), u kombinaciji sa kliničkim i socijalnim informacijama, mogu preslikati u personalizovana predviđanja rizika. Iako standardni epidemiološki pristupi, poput Kokovog modela proporcionalnih opasnosti, nisu u stanju da efikasno kombinuju podatke iz različitih izvora i modaliteta (demografski, socijalni, longitudinalni, slikovni), savremene tehnike učenja zasnovane na neuronskim mrežama mogu lako i efikasno pružiti personalizovana predviđanja rizika, ažurirajući ih i poboljšavajući mogućnosti njihove primene. Takvi mehanizmi predviđanja rizika mogu se koristiti za sprečavanje, praćenje i otkrivanje bolesti [20].

Za ljude koji su već zaraženi SARS-CoV-2, važno je predvideti rizik od neželjenih događaja (uključujući smrt), kao i dinamiku potrebnih zdravstvenih resursa, kako bi se pacijentima pružila odgovarajuća nega. Ključni faktori rizika su starost pacijenta i/ili prisustvo komorbiditeta, kao što su hipertenzija, cistična fibroza, imunosupresija povezana sa transplantacijom i hemoterapija kod obolelih od raka. Trenutne metode procene rizika za zaražene pacijente koriste samo nekoliko faktora – procena kliničkog stanja, broja komorbiditeta, prethodnih terapijskih postupaka i administrativnih podataka iz prethodnih prijema u bolnice. Ovi relativno grubi pristupi su korisni u akutnim fazama epidemije, iako ne uspevaju da obuhvate i objasne suptilne interakcije između godina starosti, specifičnih komorbiditeta (uključujući trajanje), procene obima disfunkcije organa i uticaja drugih relevantnih zdravstvenih faktora [21, 22].

Oslanjanje na takve mere često dovodi do otkrivanja ranije neodređenih, potpuno novih faktora rizika – što je posebno važno za bolesti o kojima se malo zna. Ove metode pružaju mogućnost otkrivanja bolesti COVID-19 ukoliko je više prikupljenih podataka. Oni mogu definisati procenu verovatnoće za različite neželjene reakcije i promeniti tu verovatnoću tokom vremena, omogućavajući efikasnija predviđanja u poređenju sa konvencionalnim epidemiološkim metodama [23].

Kao što je pomenuto, pacijenti sa dijagnostikovanom bolešću COVID-19 mogu imati veliki broj mogućih ishoda bolesti, vezano za vreme inkubacije i promenu kapaciteta plućnog kiseonika, odnosno razvoja i toka bolesti. Nove metode ne pružaju samo mogućnost predviđanja dinamike napredovanja bolesti već i razumevanje kako određeni događaji (pogoršanje simptoma) mogu naglo promeniti dinamiku bolesti. Ovo je neophodno za racionalno funkcionisanje sistema sa ograničenim zdravstvenim resursima [24, 25].

Kada je reč o pacijentima, važno je znati koji pacijenti zahtevaju rani prijem u bolnicu, kada on može bezbedno napustiti intenzivnu negu ili biti otpušten iz bolnice. Na takva pitanja o pravovremenom prijemu i otpustu često se daje odgovor na osnovu jednostavnih osnovnih pravila (npr. najnovija merenja za nekoliko izabranih faktora i donošenje odluka na osnovu graničnih vrednosti), iako bi takve odluke trebalo da uključuju podatke iz zdravstvene istorije svakog pacijenta. Koristeći sva dostupna zapažanja u bilo kom trenutku, veštačka inteligencija bi, zbog mogućnosti dubljeg razumevanja stanja pacijenta, mogla učestvovati u donošenju takve odluke, uz predviđanje budućih zdravstvenih potreba pacijenta i ukazivanje na važne prediktore ishoda lečenja pacijenta (specifični komorbiditeti koji će verovatno pogoršati prognozu pacijenta sa bolešću COVID-19) [26, 27].

Nadgledanje i prikupljanje zdravstvenih podataka je skupo, jer oduzima puno vremena i angažovanja osoblja, a svi podaci nisu jednako vredni. Stoga je neophodno odrediti prioritete, šta se mora aktivno meriti, kada to treba meriti i na kojim pacijentima, uz aktivno praćenje svakog pacijenta. Aktivno čitanje podataka i njihov odgovarajući odabir omogućavaju institucijama da dinamički raspoređuju bolničke resurse u zavisnosti od potreba pacijenata. To omogućava lekarima da donose kompetentne odluke o odlaganju lečenja za stanja koja nisu odmah opasna po život, čime se resursi mogu koristiti za kritično bolesne pacijente sa bolešću COVID-19 [28, 29].

Modeli zasnovani na veštačkoj inteligenciji omogućavaju praćenje i utvrđivanje efekata postojećih medicinskih tretmana, uključujući postojeće komorbiditete, čime se stvaraju uslovi za izbor najboljeg pristupa lečenju za svakog pacijenta, i eventualnu upotrebu mehaničke ventilacije i potencijalno novih terapijskih mogućnosti. Modeli zasnovani na Gausovim procesima generativne kontradiktorne mreže i duboke neuronske mreže mogu pomoći u eksperimentalnim fazama lečenja, samo na osnovu podataka posmatranja, i bez randomiziranih ispitivanja [30, 31].

Oni odgovaraju na pitanja poput „šta bi se dogodilo sa datim pacijentom ako bi se mehanička ventilacija odgodila na nekoliko sati?" ili „Kakav bi bio ishod lečenja da je odgovarajući eksperimentalni postupak primenjen nedelju dana ranije?" Ovo nam može pomoći da odlučimo koji je najbolji plan lečenja za svakog pojedinca u skladu sa dostupnim zdravstvenim resursima. Ovde se ne radi samo o tome koju intervenciju treba primeniti za svakog pacijenta pojedinačno već i o tome kada je određenom pacijentu potrebna specifična intervencija, što je izuzetno važno, s obzirom na ograničene resurse [32, 33].

Koristeći podatke longitudinalnog posmatranja pacijenta, mreža je naučena da predviđa puteve neadekvatnog lečenja u skladu sa različitim planovima za svakog pojedinca. Takva predviđanja se mogu dinamički davati modeliranjem i ažuriranjem stanja pacijenta tokom vremena, uzimajući u obzir informacije o prošlim medicinskim događajima. Na ovaj način je moguće odrediti vremenski okvir kada bi intervencija bila najefikasnija, odnosno odabrati određeni redosled intervencija koji bi rezultirali najboljim ishodom za svakog pacijenta. Pored toga, ovaj metod može pokazati kada intervencije, poput mehaničkog ventilatora, nisu neophodne za pacijenta i koliko dugo se njihova upotreba može odložiti, bez značajnog pogoršanja zdravstvenog stanja pacijenta [34, 35, 36].

Nedavni rad na poboljšanju dizajna adaptivnih kliničkih ispitivanja pokazao je da se njihova efikasnost i delotvornost mogu značajno poboljšati primenom mašinskog učenja. Prilagodljiva klinička ispitivanja omogućavaju upotrebu mačinskog učenja u regrutovanju pacijenata u grupe (umesto svih odjednom), nadgledanje efekta na svaku grupu, pre nego što se regrutuje sledeća grupa, tako da mačinske metode umesto slučajnog regrutovanja pacijenata omogućavaju regrutovanje najpogodnijih ispitanika, zahtevajući tako mnogo manje pacijenata za proveru efikasnosti lečenja određenim lekom. Druga važna primena mašinskog učenja u polju RCT je post-hoc analiza kliničkih ispitivanja, i posebno identifikacija subpopulacija koje pokazuju najsličniji odgovor na određenu vrstu lečenja, čime se olakšava lečenje i razumevanje terapijskog postupka, koji bi mogao biti prikladan za stanovništvo u celini [37, 38].

Problem pristrasnosti modela mašinskog učenja može se rešiti metodama učenja koje se implicitno bave neizvesnošću predviđanja kod pojedinaca iz populacija koji nisu učestvovale u obuci. Međunarodna saradnja mogla bi stvoriti skup podataka iz više zaraženih populacija, a jedinstveni model procene rizika u dva koraka mogao bi odabrati ove podatke i primeniti ih širom sveta. Modeli transfera učenja dobro funkcionišu u prognozi toka bolesti u različitim zemljama ili zdravstvenim sistemima [39].

Transfer učenja nije poželjan samo za prenos modela informacija između populacija već i za ažuriranje mašinskog učenja za određenu populaciju tokom vremena. Pokazuje kako se bolest razvija u određenoj populaciji tokom vremena, povezujući je sa određenim specifičnostima samih pacijenata, i koristeći serije podataka razvijene u skladu sa Bajesovom tehnikom optimizacije kako bi se model ažurirao novim informacijama. Važno je utvrditi šta pouzdano znamo a šta ne znamo kada donosiocima odluka pružamo informacije zasnovane na informacijama zasnovanim na sistemima veštačke inteligencije. U tu svrhu je razvijena i tehnologija za sistematsko kvantifikovanje neizvesnosti u predviđanjima, na osnovu modela mašinskog učenja. Svi uneti podaci moraju da sadrže procenu poverenja, tako da donosioci odluka znaju kada i za koje pacijente mogu da veruju predviđanjima koja pruža sistem veštačke inteligencije, a kada treba da budu oprezni u vezi sa dobijenim informacijama. Kvantifikovanje nesigurnosti u predviđanju ishoda presudno je za upravljanje hospitalizacijom, ali i za donošenje optimalnih terapijskih odluka. Dobijeni interval poverenja u učenju uz pomoć računara treba da obezbedi pravi ishod [40–48].

ZAKLJUČCI

Primena metoda zasnovanih na veštačkoj inteligenciji može se postići kroz tri nivoa interfejsa čovek–računar. Interfejs na individualnom nivou podrazumeva postojanje mobilnih aplikacija koje pokreće GPS, a koje pojedinci instaliraju na svoje mobilne telefone. Ove aplikacije mogu se koristiti za obezbeđivanje socijalnog distanciranja obaveštavanjem pojedinaca da se nalaze na visokorizičnim lokacijama gde je dijagnostikovan značajan broj slučajeva COVID-19 ili gde je trenutno prisutan značajan broj nosilaca virusa.

Za procenu rizika po javno zdravlje postojeća bolnička infrastruktura može se dopuniti aplikacijama za modeliranje rizika koje pokazuju i upozoravaju kliničare na nove rizike kod pacijenata u svakoj bolnici. Takve aplikacije mogu se koristiti za daljinsku dijagnozu i negu samoizolovanih osoba sa evidentnim simptomima bolesti. Primena modela zasnovanih na veštačkoj inteligenciji u bolnicama oslanja se na postojeću hardversku infrastrukturu za povezivanje ulaznih podataka sa softverom (vođenim modelima mašinskog učenja). Ovaj model prikazuje rizike za pacijente na kliničkom nivou.

Na nacionalnom nivou veštačka inteligencija – ljudski interfejs omogućava vladinim službenicima i donosiocima odluka da kontinuirano ažuriraju najnovije epidemiološke podatke o bolesti COVID-19, sa geografski stratifikovanom procenom rizika i stopom popunjenosti bolnica. Ova aplikacija se može direktno povezati sa bazom podataka o registraciji pacijenata i drugim aplikacijama za prikupljanje podataka o mogućem riziku kojem je populacija izložena, omogućavajući administratorima da donesu pravilne strateške odluke o tome koje lokacije treba zaključati i kojim bolnicama je potrebno više sredstava.

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CASE REPORT
PRIKAZ BOLESNIKA

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Implant-supported single zirconia crowns for posterior teeth using completely digital work-flow – a case report

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SUMMARY

Introduction Planning fixed prosthodontic reconstruction can be challenging task in everyday practice. When the last tooth in dental arch is missing, a single implant-supported crown is recommended. With the evolution of digital technology, it became possible that these restorations can be made using completely digital approach.
The aim of this case report was to present complete clinical procedure of making implant supported single zirconia crowns for posterior teeth using completely digital approach.
Case report A 53-year-old patient presented to the dental office with missing both first molars in the lower dental arch. The decision was made to make two implant-supported single screw-retained crowns, using digital approach. Intraoral scanning of the soft tissues and the implants' position was done using intraoral scanner Medit i500. The laboratory steps followed: computer-assisted design (CAD) and computer-assisted manufacturing (CAM) of zirconia crowns.
Conclusion Implant-supported single crowns for posterior teeth are an excellent solution for patients when the last tooth in dental arch is missing. Digital approach -from initial intraoral scanning (IOS), to designing the restoration in software and further processing of monolithic CAD/CAM generated crowns out of zirconia gives predictable, highly esthetic and functional results for implant-supported single crowns.
Keywords: digital approach; IOS; screw-retained crowns; implant-supported crowns; implants

INTRODUCTION

Planning fixed prosthodontic reconstruction can be challenging task in everyday practice, considering all biological and technical risks during the procedure. Prosthodontic restorations can be tooth or implant-supported. In the posterior region, the decision about gap reconstruction is made based on the condition of adjacent teeth. If they are intact or with minimal restoration, then bridge would be poor choice as it would damage abutment teeth. In that case, implant-supported single crown is the first choice, presenting the most tissue-preserving option [1]. Also, when the last tooth in the dental arch is missing, a single implant-supported crown is a recommended.

When making an implant-supported single crown, there are two options: screw-retained and cemented restorations. The choice is usually made according to clinician preferences since there is no evidence that any method is better [2].

The evolution of intraoral scanning technology (IOS) completely changed dental practice. The digital workflow begins with intraoral scanning of the soft tissues and implants' position. Afterward, the laboratory steps follow: computer-assisted design (CAD) and computer-assisted manufacturing (CAM). According to design, final monolithic restoration is manufactured from zirconia, lithium disilicate, or hybrid ceramic materials [3, 4].

The aim of this case report is to present complete clinical procedure of making an implant supported single zirconia crown for posterior teeth using completely digital approach.

CASE REPORT

A 53-year-old patient presented to the dental office with missing both first molars in the lower dental arch. First molars were his last teeth in the lower dental arch. The decision was made to restore them with implant-supported single crowns, because other fixed prosthodontic restorations were not possible. Implants Blue Sky (Bredent Medical Gmbh&Co.KG, Germany) were placed in the region of the teeth 36 and 46. After the healing period of 6 months, gingival formers were placed and peri-implant mucosa was allowed to heal for 14 days. At the very beginning of the procedure, shade determination was done to avoid dehydration and change of teeth color later on (Figure 1). Intraoral photographs were taken with camera (Canon R, Canon 100mm 2.8 L, Yongnuo YN-24EX TTL Macro Flash) and sent to the laboratory to achieve better color effects and matching with adjacent teeth.

The scanning was done using Medit i500 intraoral scanner (Medit corp., Seoul, Korea). Firstly, the whole lower dental arch was scanned, with gingival formers on

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Figure 1. Colour determination of adjacent tooth using Vita Classic shade guide
Slika 1. Određivanje boje susednog zuba korišćenjem ključa boja *Vita Classic*

Figure 2. Dental implant with gingival former after healing of surrounding tissues
Slika 2. Implanant sa gingiva formerom posle perioda zarastanja okolne gingive

Figure 3. Initial scan of the lower dental arch with gingival formers, and after deleting parts of the scan where implant position was determined using one scan body, and scanning one implant at a time
Slika 3. Inicijalni sken sa gingiva formerima i posle brisanja delova skena koji će biti naknadno skenirani nakon postavljanja otisnog elementa jedan po jedan

implants (Figure 2). Then, using a tool in MEDIT software part of the digital impression with gingival formers was deleted (Figure 3). To represent the position and orientation of dental implants in intraoral scanning procedure scan body SKYUSCAI (Bredent Medical Gmbh&Co.KG, Germany) was used (Figure 4). One scan body was used for both sides, scanning one implant at a time, using HD (high definition) option of the scanner (Figure 5).

The scan was saved as STL file that was sent to the dental laboratory (Figure 6). Digital models were printed in dental laboratory using printer DWS xfab2500pd and resin DWS Precisa RD097 and restorations were designed

Figure 4. Scan body positioned on implant 46
Slika 4. Otisni element postavljen na implantant u regiji 46

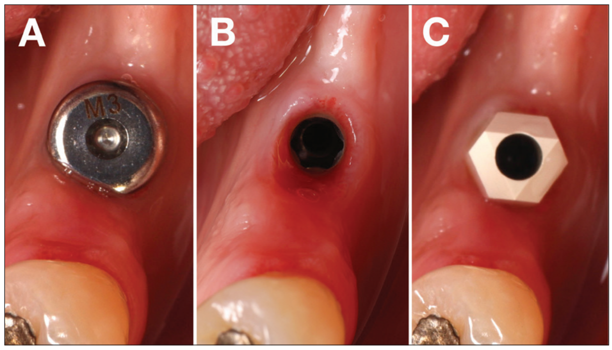

Figure 6. Final digital impression
Slika 6. Konačni digitalni otisak

Figure 5. Gingiva around the implant 36: a) with gingival former, b) after removing gingival former and c) after scan body positioning
Slika 5. Izgled gingive oko implantata 36: a) sa gingiva formerom, b) nakon njegovog uklanjanja i c) nakon postavljanja digitalnog otisnog elementa (scan body) u regiji 36

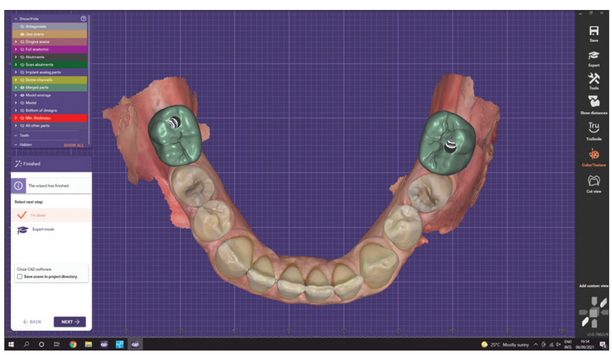

Figure 7. Final design of future restorations in EXOCAD software
Slika 7. Definitivni dizajn i izgled budućih kruna u softveru Exocad

Figure 8. Plastic crowns according to the design – the same shape and size as final restorations
Slika 8. Plastične krune izrađene prema dizajnu – iste veličine i oblika kao i definitivne buduće krunice

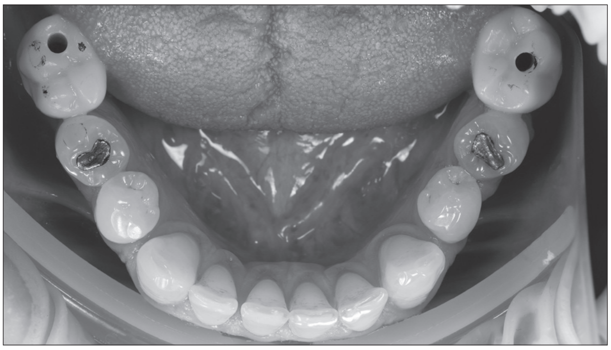

Figure 9. Try-in of plastic crowns- correction of occlusal contacts
Slika 9. Proba plastičnih kruna i korigovanje okluzalnih kontakata

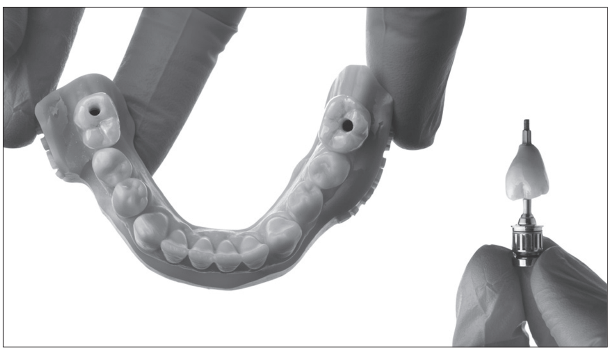

Figure 10. Screw-retained zirconia single crowns on the printed model, as received from dental laboratory
Slika 10. Šrafom retinirane krune od cirkonije na modelu, dobijene iz dentalne laboratorije

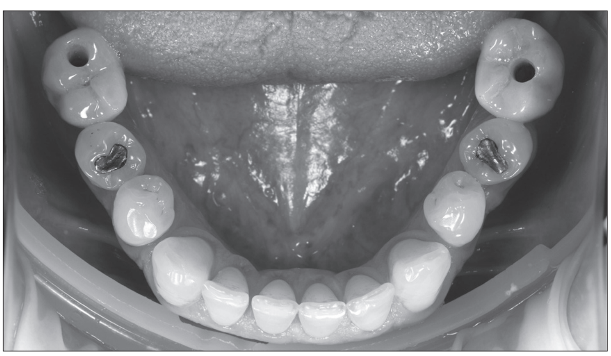

Figure 11. Screw-retained zirconia single crowns positioned on implants
Slika 11. Šrafom retinirane krune od cirkonije postavljene na implantate

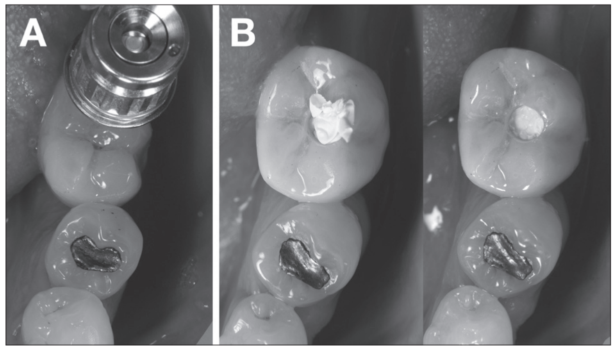

Figure 12. a) Rotating force applied until wanted torque is reached (25 Ncm), b) Teflon tape plug positioned in screw access holes
Slika 12. a) Ušrafljivanje krunice do postizanja željenog torka (25 Ncm), b) Teflon traka postavljena u pristupni otvor

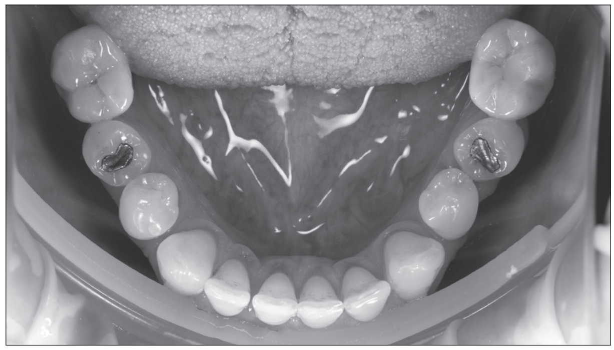

Figure 13. Screw access holes closed with resin composite restorative material
Slika 13. Zatvaranje pristupnog otvora kompozitnim materijalom

in EXOCAD software (GMBh, Darmstadt, Germany). According to the design (Figure 7), plastic crowns ((DWS, Temporis DD-100 A2) (Figure 8) completely the same size and shape as final restorations, were made for try-in in the patient's mouth (Figure 9). It was easier to make all shape changes in this phase instead of on a full-ceramic crown. Since only minor changes were made, they were sent back to the laboratory. The occlusal surfaces of the crowns were designed to avoid premature contacts during mastication and movements. According to the new situation, final full-ceramic restorations were made of zirconia and sent back for the final step (Figure 10). Before positioning crowns in patient's mouth, the crowns were left in chlorhexidine antiseptic for 2 minutes. Final crowns were screwed on the top of the implants in patients' mouths using a torque wrench calibrated at 25 Ncm (Bredent Medical Gmbh&Co.KG, Germany) (Figure 11). The screw access holes on the occlusal surfaces of the restorations were closed with teflon tape plug (Figure 12) and composite resin (GC gradia direct, GC Corporation, Tokyo, Japan) without using bond (Figure 13).

DISCUSSION

Implant-supported single crowns in the posterior region are the first choice when the adjacent teeth are intact or with minimal restorations. They show high survival rates after an observation period of 5 years (94.5% and 96.3%)

[5, 6]. Another study showed that biological and technical complications are frequent (33.6%) [7].

Biological complications of tooth-supported reconstructions include dental caries, loss of pulp vitality, and periodontal disease progression. In implant reconstructions, technical complications are more common, and they include mechanical damage of implants, implant components and/or suprastructures [1]. According to meta-analysis, the incidence of screw or abutment loosening is 12.7% and 0.35% for screw or abutment fracture after 5 years, and for supra-structure-related complications, the incidence of ceramic or veneer fractures is 4.5% [5].

The crowns made in this report were screw-retained. Screw-retained crowns have many advantages, and the most important one is retrievability. Since the cumulative incidence of screw or abutment loosening was 12.7% in a 5-year period according to Jung et al. [5], it is important that they can be easily removed and retightened if needed, which is not the case with cemented ceramic crowns. Screw retained crowns also eliminate the risk of excess cement that can compromise soft tissues surrounding the implant [8].

The use of digital impressions is becoming more and more popular due to its numerous advantages- they are more comfortable for the patients, less time-consuming, and easier to store and share than conventional models. However, the conventional impressions are still considered the gold standard in fixed prosthodontics. The accuracy of digital models and comparison with conventional models is a topic of numerous investigations [9–12]. According to recent studies, intraoral scanning accuracy is high for single crowns, and the deviations in virtual implant positions are clinically acceptable [10, 13, 14]. In our case, the results showed great precision of digital impression, and just minor changes regarding occlusion were made on plastic crowns.

Generally, patients report less inconvenience and they prefer digital impression procedure than the conventional procedure [15]. Moreover, one of the advantages of digital impression is that if there is an error in the scan, it is not necessary to retake complete impression; only the critical spot can be scanned again, which significantly saves time. Also, the communication with the dental laboratory is faster and safer, since digital impression is sent digitally and it is not possible to damage it during transport.

CONCLUSION

Implant-supported single crowns for posterior teeth are an excellent solution for patients when the last tooth in dental arch is missing. Digital approach -from initial intraoral scanning (IOS) to designing the restoration in the software and further processing of monolithic CAD/CAM-generated crowns out of zirconia gives predictable, highly esthetic and functional results for implant-supported single crowns.

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Digitalni pristup izrade cirkonijumskih krunica na implantima u bočnoj regiji – prikaz slučaja

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KRATAK SADRŽAJ

Uvod Planiranje fiksne protetske nadoknade je vrlo zahtevan i izazovan zadatak u svakodnevnoj stomatološkoj praksi. Kada nedostaje poslednji zub u zubnom nizu, preporučuje se izrada krune na zubnom implantatu. Razvoj digitalnih tehnologija omogućio je da se ova vrsta nadoknade izrađuje kompletno digitalnim pristupom.

Cilj ovog prikaza slučaja bio je da se predstavi klinička procedura izrade šrafom retiniranih cirkonijumskih krunica na implantatima u bočnoj regiji kompletno digitalnim pristupom.

Prikaz slučaja Pacijent starosti 53 godine, sa nedostatkom oba donja prva molara, koji su u ovom slučaju poslednji zubi u zubnom nizu, želeo je da ovaj nedostatak nadoknadi fiksnim protetskim nadoknadama. Odlučeno je da se izrade dve šrafom retinirane krune na implantatima, kompletno digitalnim pristupom. Intraoralno skeniranje mekih tkiva i pozicije implantata urađeno je uz pomoć intraoralnog skenera Medit i500. Zatim su usledile laboratorijske procedure: komjuterski asistirano dizajniranje i kompjuterski asistirana izrada cirkonijumskih krunica.

Zaključak Krune na implantatima su odlično rešenje za pacijente kod kojih nedostaje poslednji zub u zubnom nizu. Digitalni pristup – od inicijalnog intraoralnog skeniranja, dizajniranja nadoknada u softveru i konačne izrade monolitnih kruna od cirkonije, daje predvidive, visokoestetske i funkcionalne rezultate pri izradi pojedinačnih kruna na implantatima.

Ključne reči: digitalni pristup; intraoralno skeniranje; krunice na implantatima; šrafom retinirane krunice; implantati

UVOD

Planiranje fiksnih protetskih nadoknada je izuzetno izazovan zadatak u svakodnevnoj praksi, ukoliko se uzmu u obzir svi biološki i tehnički rizici koji mogu nastati u toku izvođenja same procedure.

Fiksne protetske nadoknade se mogu izrađivati na zubima ili zubnim implantatima. U bočnoj regiji, odluka o vrsti nadoknada u regiji bezubih prostora donosi se na osnovu stanja susednih zuba. Ukoliko su zubi intaktni ili sa minimalnim restauracijama, nije poželjna njihova preparacija. U tom slučaju metod izbora je postavljanje implantata i izrada krunice na implantatu, maksimalno čuvajući zubna tkiva [1]. Takođe, ukoliko nedostaju poslednji zubi u zubnom nizu, preporučuje se izrada zubnih nadoknada na implantatima.

Zubne krune na implantatima, u zavisnosti od načina povezivanja mogu biti: šrafom retinirane krune ili cementom retinirane krune.

I pored brojnih prednosti šrafom retiniranih kruna, navodi u literaturi ne pokazuju precizne dokaze o tome koji je metod bolji, tako da kliničar donosi odluku na osnovu slučaja i ličnih preferenci [2].

Napredak digitalnih tehnologija i evolucija intraoralnih skenera (IOS) značajno su promenili savremenu stomatološku praksu.

Digitalni pristup počinje intraoralnim skeniranjem okolnih zuba i mekih tkiva, kao i pozicije samih implantata korišćenjem intraoralnih otisnih elemenata (scan body).

Nakon toga, otisak se digitalnim putem šalje laboratoriji, gde se pristupa digitalnom dizajniranju restauracija (CAD), a zatim rezanju kruna od odabranog materijala (CAM). Nakon definisanja potrebnih korekcija, ukoliko su prisutne, u laboratoriji se pristupa izradi definitivnih kruna od izabranog materijala: zirkonije, litijum-disilikata ili hibridnih keramičkih materijala [3, 4].

Cilj ovog prikaza slučaja bio je da se predstavi klinička procedura izrade šrafom retiniranih cirkonijumskih krunica na implantatima u bočnoj regiji kompletno digitalnim pristupom.

PRIKAZ SLUČAJA

Pacijent starosti 53 godine došao je u stomatološku ordinaciju i utvrđen mu je nedostatak oba prva molara u donjoj vilici, koji su ujedno i poslednji zubi u donjem zubnom nizu. Odlučeno je da se nedostajući molari rehabilituju sa krunama na implantatima. Postavljeni su implantati Bredent blueSKY (Bredent Medical Gmbh&Co.KG, Germany) u regiji 36 i 46. Nakon perioda oseointegracije od šest meseci, postavljeni su gingiva formeri na period od 14 dana.

Na samom početku intervencije određena je boja budućih restauracija, kako bi se izbegao mogući problem usled dehidratacije zubnih tkiva i promena njihove boje (Slika 1). Takođe, napravljene su intraoralne fotografije pacijenta kamerom (Canon EOS RCanon 100 mm 2,8 L, Yongnuo YN-24EX TTL Macro Flash for Canon) i poslate laboratoriji, kako bi se postigli bolji estetski efekti i slaganje boje sa okolnim zubima. Prilikom uzimanja digitalnog otiska intraoralnim skenerom, u prvoj fazi je skenirana cela donja vilica sa gingiva formerima (Slika 2). Zatim je u softveru MEDIT samog skenera korišćen alat za brisanje dela otiska u regiji implantata, u ovom slučaju sa gingiva formerom (Slika 3). Za tačnu poziciju i orijentaciju implantata u intraoralnom skeniranju korišćen je SKY uni. fitscan abutment SKYUSCAI (Bredent Medical Gmbh&Co.KG, Germany) (Slika 4). Korišćen je jedan otisni element za oba implantata, prvo na poziciji 36, a zatim zuba 46, uz pomoć opcije HD (high definiton) koju nudi intraoralni skener MEDIT i500 (Medit corp., Seoul, Korea) (Slika 5).

Dobijeni digitalni otisak, sačuvan kao .STL fajl, poslat je dentalnoj laboratoriji (Slika 6). Digitalni modeli su štampani u dentalnoj laboratoriji koristeći printer DWS xfab2500pd sa materijalom DWS Precisa RD097, a restauracije dizajnirane u softveru EXOCAD (GmbH, Darmstadt, Germany) (Slika 7). Prema definitvnom dizajnu budućih nadoknada izrađene su krunice od plastike (DWS, Temporis DD-100 A2) (Slika 8) identične veličine i oblika kao definitivne nadoknade, za još jednu probu u pacijentovim ustima (Slika 9). U ovoj fazi je lakše napraviti korekcije, ukoliko su one potrebne, nego na definitivnim keramičkim krunama. Nakon minimalnog korigovanja okluzalnih kontakata na plastičnim krunama, korekcije su poslate na uvid laboratoriji, a zatim su finalne keramičke nadoknade izrezane od cirkonije i poslate ordinaciji za finalni korak (Slika 10). Krunice su ostavljene u rastvoru hlorheksidina 2 minuta, a zatim ušrafljene na svoju poziciju korišćenjem moment ključa silom od 25 Ncm (Slika 11). Otvori za pristup šrafu su zatvoreni teflonskom trakom (Slika 12) i kompozitom GC gradia direct (GC corporation, Tokyo, Japan) bez korišćenja bonda (Slika 13).

DISKUSIJA

Pojedinačne krune na implantatima u bočnoj regiji predstavljaju terapiju izbora kada se bezubi prostor nalazi između intaktnih zuba ili zuba sa minimalnim restauracijama. Pokazuju visok stepen opstanka u posmatranom periodu od pet godina (94,5% i 96,3%) [5, 6]. Druga studija pokazuje da su moguće česte biološke i tehničke komplikacije (33,6%) [7].

Biološke komplikacije kod restauracija na zubima predstavljaju karijes, gubitak vitaliteta pulpe i pogoršanje stanja periodoncijuma. U implantnoj rehabilitaciji tehničke komplikacije su češće i one uključuju mehanička oštećenja samog implantata, neke od komponenti ili suprastruktura [1].

Prema istraživanjima, verovatnoća oslabljenja veze šrafa i suprastrukture je 12,7%, a 0,35% da dođe do pucanja šrafa ili abatmenta nakon perioda od pet godina. Najčešća komplikacija vezana za suprastrukturu je lom keramike, čija je učestalost oko 4,5% [5].

Krunice pravljene u ovom prikazu slučaja su retinirane šrafom. Šrafom retinirane krune imaju dosta prednosti, od koji je najbitnija dostupnost implantatu. S obzirom na to da učestalost slabljenja veze šrafa ili abatmenta iznosi 12,7% u periodu od pet godina prema Jungu i autorima [5], važno je da se, ukoliko je potrebno, sa lakoćom može pristupiti otvoru na kruni i vezu dodatno pojačati, što nije slučaj sa cementom retiniranim krunama. Šrafom retinirane krune takođe isključuju rizik od ostatka cementa subgingivalno, koji može da kompromituje okolna meka tkiva i prouzrokuje peri-implantitis [8].

Upotreba digitalnih otisaka u stomatologiji značajno dobija na popularnosti usled brojnih prednosti. Intraoralno skeniranje je prijatnije za pacijenta, zahteva manje vremena za uzimanje otiska, i digitalni otisci su jednostavniji za čuvanje od konvencionalnih. Ipak, konvencionalni otisci se i dalje smatraju zlatnim standardom u fiksnoj protetici. Preciznost digitalnih modela i njihovo poređenje sa konvencionalnim modelima su predmet brojnih istraživanja [9–12]. Prema poslednjim istraživanjima, za pojedinačne krune intraoralno skeniranje je izuzetno precizno, a diskrepance u virtuelnim modelima su klinički prihvatljive [10, 13, 14].

U prikazanom slučaju, rezultati su pokazali veliku preciznost digitalnog otiska, uz minimalne korekcije okluzalnih kontakata pri probi privremenih kruna izrađenih od plastike.

Uopšteno, pacijentima je manje neprijatno i više vole digitalno otiskivanje nego kovencionalno [15]. Takođe, jedna od glavnih prednosti digitalnog otiskivanja je i činjenica da ukoliko dođe do bilo kakve greške, bilo u samom otiskivanju ili u preparaciji zuba, nije potrebno uzimati čitav otisak iz početka, nego je dovoljno obrisati i ponovo skenirati samo kritični deo, čime se dobija značajna ušteda vremena. Takođe, komunikacija sa zubnom laboratorijom je značajno brža i sigurnija, jer se skenirani otisci šalju u digitalnoj formi i nije ih moguće oštetiti prilikom slanja.

ZAKLJUČAK

Digitalni pristup, od početnog intraoralnog skeniranja (IOS) do dizajna restauracija korišćenjem softvera, i izrade monolitnih CAD/CAM cirkonijimskih zubnih kruna, daje predvidive, visokoestetske i funkcionalne rezultate u procesu izrade kruna na implantatima u bočnoj regiji.

Da li ste pažljivo čitali radove?

1. Mandibularni kanal može biti u bliskom kontaktu:
   a) sa vrhovima donjih sekutića
   b) sa vrhovima donjih očnjaka
   c) sa vrhovima donjih molara

2. Dentinski graft od ekstrahovanih zuba:
   a) može se koristiti u vođenoj regeneraciji kosti
   b) ne može se koristiti u vođenoj regeneraciji kosti
   c) koristi se samo u određenim indikacijama

3. Deformacije NiTi instrumenata su analizirane:
   a) SEM-om
   b) pomoću stereo lupe
   c) optičkim mikroskopom

4. Najčešći defekti posle instrumentacije su bili:
   a) pojava korozije
   b) promena sečivnih ivica
   c) pojava korozije i promena sečivnih ivica

5. Na osnovu korišćenja veštačke inteligencije se mogu:
   a) efikasnije koristiti bolnički resursi
   b) olakšati klinički simptomi oboljenja
   c) otežati klinički simptomi oboljenja

6. Gingiva formeri na implantatima su postavljeni posle:
   a) 3 meseca
   b) 6 meseci
   c) 9 meseci

7. Prosečna udaljenost korenova donjih premolara i molara je merena:
   a) na ST preseku SVST
   b) na lateralnom preseku SVST
   c) na uzdužnom preseku SVST

8. Ekstrahovani zubi se smatraju:
   a) klinički prihvatljivim
   b) otpadnim materijalom
   c) upotrebljivim protetičkim materijalom

9. Najveća prosečna udaljenost apeksa korena zuba je uočena:
   a) kod premolara
   b) kod drugog donjeg molara
   c) kod prvog donjeg molara

10. Frakture su uočene kod:
    a) dva instrumenta
    b) tri instrumenta
    c) pet instrumenata

11. Primena veštačke inteligencije je analizirana:
    a) na osnovu 110 radova i studija
    b) na osnovu 120 radova i studija
    c) na osnovu 150 radova i studija

12. Implantati su postavljeni u regiji:
    a) 35 i 45
    b) 36 i 46
    c) 37 i 47

13. Istraživanje prosečne udaljenosti korenova SVST tehnički je realizovano:
    a) u Foči
    b) u Banjoj Luci
    c) u Beogradu

14. Dentinski grafit se može koristit zbog:
    a) biohemijskih karakteristika sličnih kosti
    b) biohemijskih karakteristika sličnih hrskavici
    c) mehaničkih karakteristika sličnih restaurativnim materijalima

15. Najveća prosečna vertikalna udaljenost apeksa korena je iznosila:
    a) 4,28 mm
    b) 4,48 mm
    c) 4,88 mm

16. Deformacije i frakture NiTi instrumenata nastaju usled:
    a) torzionih sila
    b) cikličnih sila
    c) torzinih i cikličnih sila

17. U apikalnom segmentu radnog dela MTwo instrumenta uočeno je:
    a) 54,2% defekata
    b) 64,2% defekata
    c) 70,3% defekata

18. Veštačka inteligencija se može koristiti:
    a) da predvidi razvoj potencijalnih hitnih stanja kod virusa korona
    b) da predvidi pojavu malignih ćelija
    c) da predvidi pojavu tumora vilica

19. Digitalni pristup u izradi cirkonijumskih krunica je prikazan:
    a) kod pacijenata od 30 godina
    b) kod pacijenata od 40 godina
    c) kod pacijenata od 50 godina

20. Dentinski grafit je korišćen:
    a) na mestu ekstrahovanog zuba
    b) na mestu koštanog defekta
    c) na mestu ekstrakcije i koštanog defekta

21. U istraživanju prosečne udaljenosti korenova je merena:
    a) horiznotalna udaljenost korenova od mandibularnog kanala
    b) vertikalna udaljenost korenova od mandibularnog kanala
    c) i horizontalna i vertikalna udaljenost korenova od mandibularnog kanala

22. Najmanja prosečna vertikalna udaljenost apeksa korena je iznosila:
    a) 2,56
    b) 2,76
    c) 2,96

23. Deformacije instrumenata su analizirane na setovima:
    a) K3
    b) RaCl
    c) MTwo

24. Najveća zastupljenost defekata MTwo instrumenata je uočena:
    a) u delu blizu drške instrumenta
    b) u srednjem delu instrumenta
    c) u apikalnom delu instrumenta

25. Primena veštačke intečigencije je opisana u:
    a) dijagnostikovanju SARS Cov2
    b) tumora vilice
    c) tumora mekih tkiva lica

26. Zubne krune na implantatima se mogu vezati:
    a) samo šrafom
    b) samo cementiranjem
    c) šrafom i cementom

27. Kontrola kliničkih i radioloških promena na defektima u viličnoj kosti je urađena:
    a) posle 3 meseca
    b) posle 6 meseci
    c) posle 12 meseci

28. Dentinske čestice korišćene kao graft:
    a) imaju osteoindukovani potencijal
    b) nemaju osteoindukovani potencijal
    c) samo u posebnim indikacijama imaju osteoindukovani potencijal

29. Najveća udaljenost apeksa korena je uočena kod:
    a) distalnog korena prvog molara
    b) distalnog korena drugog molara
    c) medijalnog korena drugog molara

30. U istraživanju deformacija NiTi instrumenata uključena su:
    a) 3 seta NiTi
    b) 5 setova NiTi
    c) 8 setova NiTi

31. U grupi sa pravim kanalima uočeno je:
    a) 27,1% defekata
    b) 35,1% defekata
    c) 36,1% defekata

32. Mikrofrizure su uočene kod MTwo instrumenta?
    a) Da
    b) Ne
    c) Ni u jednom slučaju

33. Fiksne nadoknade se mogu izrađivati:
    a) samo na zubima
    b) samo na implantatima
    c) na zubima ili zubnim implantatima

34. Posle perioda od šest meseci uočena je:
    a) minimalna horizontalna i vertikalna resorpcija
    b) maksimalna horizontalna i vertikalna resorpcija
    c) minimalna horizontalna i maksimalna vertikalna resorpcija kosti

35. Dentinske čestice korišćene kao graft se smatraju:
    a) zlatnim standardom zbog osteoindukovanih potencijala
    b) neadekvatnim za primenu u kliničkim uslovima
    c) potencijalnim materijalom za primenu u regeneraciji koštanih tkiva

36. Najmanja udaljenost apeksa korena je uočena kod:
    a) medijalnog korena drugog donjeg molara
    b) distalnog korena drugog donjeg molara
    c) distalnog korena prvog donjeg molara

37. U istraživanju deformacija NiTi uključene su:
    a) 2 eksperimentalne grupe kanala
    b) 3 eksperimentalne grupe kanala
    c) 4 eksperimentalne grupe kanala

38. Kod blago povijenih kanala uočeno je:
    a) 31,5% defekata
    b) 35,6% defekata
    c) 37,3% defekata

39. Kod MTwo uočene su promene navoja?
    a) Da
    b) Ne
    c) Samo u jednom slučaju

40. Algoritmi mašinskog učenja:
    a) omogućuju primenu veštačke interakcije u učenju o bolesti COVID-19
    b) ne omogućuju primenu veštačke interakcije u učenju o bolesti COVID-19
    c) izuzetno se koriste kod bolesti COVID-19

41. Posle perioda od šest meseci uočen je:
    a) ubrzan proces koštane regeneracije
    b) usporen proces koštane regeneracije
    c) izuzetno usporen proces koštane regeneracije

42. Posle perioda od šest meseci uočene su:
    a) beznačajne postoperativne komplikacije
    b) značajne postoperativne komplikacije
    c) jako izražene komplikacije

43. Značajna razlika u udaljenosti apeksa korenova je uočena između:
    a) drugog molara medijalno i drugog molara distalno
    b) prvog molara medijalno i prvog molara distalno
    c) prvog molara distalno i drugog molara medijalno

44. Prisustvo nepravilnosti kod korišćenih NiTi instrumenata je analizirano uz pomoć kriterijuma:
    a) po Egertu
    b) po Breku
    c) po Vilsonu

45. Kod izrazito povijenih kanala uočeno je:
    a) 37,3% defekata
    b) 27,1% defekata
    c) 25,3% defekata

46. Na pojavu deformiteta NiTi najviše utiče:
    a) povijenost kanala
    b) dužina instrumenta
    c) količnost instrumenta

47. Poznavanje udaljenosti vrha korena od mandibularnog kanala je značajno zbog planiranja:
    a) endodontskih zahvata
    b) oralnohirurških zahvata
    c) endodontskih i oralnohirurških zahvata

48. Najčešće korišćene tehnike veštačke inteligencije su:
    a) konvolucione neuronske mreže uz pomoć računara
    b) primena novih laboratorijskih modela
    c) primena računara u kliničkom lečenju

49. Najviše defekata MTwo instrumenata je uočeno posle obrade:
    a) pravih kanala
    b) blago povijenih kanala
    c) izrazito povijenih kanala

50. Otpornost pacijenata na potencijalnu COVID infekciju se može odrediti uz pomoć računara?
    a) Da
    b) Ne
    c) Samo u određenim indikacijama

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