NAUČNO-NASTAVNOM VEĆU
STOMATOLOŠKOG FAKULTETA
UNIVERZITETA U BEOGRADU

17.06.2013.

Predmet: Izveštaj komisije za ocenu i odbranu doktorske disertacije kandidata mr. sc. dr Evgenije Marković

Na V redovnoj sednici Naučno-nastavnog veća Stomatološkog fakulteta Univerziteta u Beogradu održanoj 21.05.2013. godine, imenovana je Komisija za ocenu i odbranu doktorske disertacije mr. sc. dr Evgenije Marković pod nazivom: "UTICAJ STRUKTURE ORTODONTSKIH ŽICA NA BIOKOMPATIBILNOST I PERCEPCIJU BOLA TOKOM POČETNE FAZE LEČENJA FIKSNIM APARATIMA".

Imenovana komisija u sastavu:

- Prof. Dr Ivana Šćepan, Klinika za ortopediju vilica, Stomatološki fakultet u Beogradu;
- Prof. Dr Dragoslav Stamenković, Klinika za stomatološku protetiku, Stomatološki fakultet u Beogradu;
- Doc. Dr Predrag Vučinić, Odsek za stomatologiju, Medicinski fakultet u Novom Sadu

nakon pregleda doktorske disertacije, podnosi Nastavno-naučnom veću sledeći

IZVEŠTAJ

BIOGRAFSKI I BIBLIOGRAFSKI PODACI O KANDIDATU

Mr. sc. dr Evgenija Marković (rođena Stamenić) je rođena 28.03.1970. godine u Beogradu gde je diplomirala na Stomatološkom fakultetu u Beogradu 1996. godine sa prosečnom ocenom 9.18. Obavezan pripravnički staž obavila je na klinikama Stomatološkog fakulteta u Beogradu i položila stručni ispit 1997. godine.

Posle diplomiranja upisala je poslediplomske studije na Stomatološkom fakultetu u Beogradu iz predmeta Ortopedija vilica gde je radila u svojstvu naučno-istraživačkog radnika dve godine. Od 1998-2002. godine, nakon nostrifikacije diplome u Kanadi radila je u privatnoj praksi u Vankuveru, Kanada. Specijalizaciju iz predmeta Ortopedija vilica upisala je 2002. godine na Stomatološkom fakultetu u Beogradu i položila specijalistički ispit 2006. godine sa odličnom ocenom. Magistarsku tezu pod naslovom "Analiza otpornosti ortodontskih lepkova na dejstvo sile" odbranila je 2007.godine. na Stomatološkom fakultetu u Beogradu. Od 2007-2011. zaposlena je na Klinici za Ortopediju vilica, Stomatološkog fakulteta u Beogradu kao klinički lekar. U zvanje asistenta izabrana je 2011. godine. Govori i piše engleski jezik i poznaje rad na računaru. Na Klinici za ortopediju vilica aktivno učestvuje u izvodjenju praktične i teoretske nastave, kako na osnovnim, tako i na specijalističkim i studijama iz Ortopedije vilica.

Do sada je objavila 25 naučnih radova koji su objavljeni u domaćim i stranim časopisima i prezentovani na naučnim skupovima u zemlji i inostranstvu.

Od oktobra 2011. godine učesnik je na Eureka projektu 6788 ORTO-NITI - Development of advanced NiTi orthodontic wire.

ČLANSTVO U DOMAĆIM I INTERNACIONALNIM UDRUŽENJIMA:

Udruženje Ortodonata Srbije

European Orthodontic Society

British Columbia Association of Dental Surgeons

Canadian Dental Association

College of Dental Surgeons of British Columbia

SPISAK OBJAVLJENIH RADOVA, PREZENTACIJA I PREDAVANJA:

Rad u istaknutom međunarodnom časopisu M22

1. I. Scepan, B. Glisic, **E. Markovic**, M. Babic. Craniofacial complex specificities in five men with sex reversal syndrome, Clinical Oral Investigation. 2008; Sep;12(3):265-9. E pub 2008 Feb 5;

Rad u međunarodnom časopisu M23

1. J. Ferčec, B Glišić, I Šćepan, **E Marković**, D Stamenković, I Anžel, J Flašker, R Rudolf. Determination of stresses and forces on the orthodontic system by using numerical simulation of the Finite Elements Method. Acta Physica Polonica A 2012; Oct vol.122:pp. 659-665.
2. R. Rudolf, M. Anžel, **E. Marković,** M. Čolic, D. Stamenković: Gold in the past, today and future. Metalurgija 51 (2012) 2, 261-264;
3. N. Nedeljković, I. Šćepan, B. Glišić, **E. Marković**. Dentoalveolarni terapijski efekti Herbst aparata i aktivatora kod osoba u postpubertetskom uzrastu sa malokluzijom klase II/1 (Dentaoalveolar changes in young adult patients with Class II/1 malocclusion treated with the Herbst appliance and an activator). Military Medical and Pharmaceutical Journal of Serbia 2010; Feb vol. 62 (23): pp. 170-175;

Rad u časopisu međunarodnog značaja verifikovanog posebnom odlukom M24

1. N. Nedeljković, B. Glišić, **E. Marković,** I. Šćepan, Z. Stamenković. Orthodontic treatment of nongrowing patient with Class II Division 2 malocclusion by Herbst. Military Medical and Pharmaceutical Journal of Serbia 2009; Oct vol. 66 (10): pp. 840-844;

Rad u vodećem časopisu nacionalnog značaja M51

2. N. Jaksic, I. Scepan, B. Glisic, **E. Stamenic**, Z. Stamenkovic. Mesiodistal size of deciduous teeth in subjects with unilateral cleft lip and palate. Orthodontics Craniofacial Res. 5, 2002; 17-21;

Rad u časopisu nacionalnog značaja M52

1. **E. Markovic**, B. Glisic, I. Scepan, D. Markovic, V. Jokanovic. Bond strength of orthodontic adhesives, AMES 2008;14(2): 79-88;
2. Z. Nikolić, I. Šćepan, **E. Marković**. Correlation of dental and chronological maturity in girls and boys aged 7 to 14 years Stomatoloski glasnik Srbije, 2005; 52(1):41-45;

Saopštenje sa skupa međunarodnog značaja štampano u izvodu M34

1. J. Ferčec, R. Rudolf, I. Anžel, I. Pulko, **E. Marković**, D. Stamenković, B. Glišić· Methods of investigation of the stress-induced martensite in the orthodontic wire from shape memory alloy niti under different stress states. 1st Metallurgical and Materials Enginering Congress of South East Europe. Proceedings and book of abstracts. 147-153. May 23-25, 2013. Belgrade, Srebia;
2. R. Rudolf, J. Ferčec, S. Tomić, D. Stamenković, B. Glišić **E. Marković**,· New approach to determination of NiTi orthodontic archwires characteristic properties. 18th Congress of the Balkan Stomatological Society (BaSS). April 25-28, 2013 Skopje;
3. T. Pajevic, **E. Marković**, I. Šćepan. Early protraction mask therapy in a patient with Crouzon syndrome: A case study report. 87th Congress of the European Orthodontic Society, June 19-33, 2011. Istanbul, Turkey;

4. **E. Markovic**, B. Glisic, I. Scepan, N. Stefanovic. Cephalometric Analysis of Growth Pattern and Incisor Position in Patients with A Class II Division 2 Malocclusion. 85th Congress of the European Orthodontic Society, June 10–14, 2009. Helsinki, Finland;
5. J. Pajevic, J. Juloski, N. Stefanovic, **E. Markovic**, I. Scepan. Is Perfection Overrated? 85th Congress of the European Orthodontic Society, June 10–14, 2009. Helsinki, Finland;
6. B. Glisic, **E.Stamenic**, A. Dozic, N. Jaksic. Sagittal jaws relationships in skull remains from Vinca (XIIct.). 71th Congress of the European Orthodontic Society, 71st Congress of the German Orthodontic Society, Mainz, June 1998;
7. **E. Stamenic**, N. Jaksic, G. Gemaljevic, Z. Stamenkovic. Type of Mandibular and Maxilllary rotation.rd Congress of the Balkan Stomatological Society, Sofia, April 1998;
8. Z. Stamenkovic, **E. Stamenic**, M. Obradovic, B. Glisic. Analysis of mandibular rotation according to Bjork and Jarabak. 3rd Congress of the Balkan Stomatological Society, Sofia, April 1998;
9. **E. Stamenic**, N. Jaksic, B. Glisic, Z. Stamenkovic. Cleft lip and palate: Distribution by sex, type and side of cleft. 71th Congress of the European Orthodontic Society, 71st Congress of the German Orthodontic Society, Mainz, June 1998;
10. B. Glisic, A. Dozic, **E. Stamenic**, I. Scepan, N. Jaksic. Comparison of Skeletal Changes from the 13th century to present day. 73rd Congress of the European Orthodontic Society, Valencia, June 1997;

Saopštenje sa skupa od nacionalnog značaja štampano u izvodu M64

1. Lj. Pašagić, I. Ilić, M. Anđelić, **E. Marković.** Terapija dentoalveolarnog otvorenog zagrižaja usled loše navike. 1st Congress of Serbian orthodontic Society. Knjiga abstrakata. April, 05-06.2013. Beograd;
2. Lj. Vučić, M. Bugurendić, **E. Marković**. Različiti načini rešavanja dubokog preklopa sekutića-prikaz slučaja. 1st Congress of Serbian orthodontic Society. Knjiga abstrakata. April, 05-06.2013. Beograd;
3. T. Pajević, **E. Marković**, N. Nedeljković, T. Vuličević. Primena twin-blok-a u terapiji malokluzija II klase 2 odelenja. Zbornik sažetaka. Simpozijum stomatologa i saradnika. 27-29.5.2010. str.86. Novi Sad;
4. B. Glisic, **E. Stamenic**, A. Dozic. The sagittal, transversal and vertical occlusal relationships in scull remains from Vinca(XIIIct.). 5th Panhelenic Orthodontic Congress. September 1998, Athens;
5. B. Glisic, A. Dozic, **E. Stamenic**, N. Jaksic. Os Inca-Finding on skull from XIII ct. Folia Anatomica (Official Journal of the Yugoslav Association of Anatomists and the Anatomical Society of Serbia), Vol.26, 1998;

Predavanje po pozivu

1. **E. Marković**, I. Šćepan, N. Nedeljković. Dijastema medijana kao estetski problem. Simpozijum Stomatologa i Saradnika, 01-02.06.2012.Novi Sad.
2. **E. Markovic**. Sastanak Udruženja ortodonata Srbije: Idealan ortodontski lepak: o čemu treba voditi računa prilikom izbora lepka u ortodonciji; 07.05.2011. Beograd;

PREGLED DOKTORSKE DISERTACIJE

Doktorska disertacije pod nazivom "Uticaj strukture ortodontskih žica na biokompatibilnost i percepciju bola tokom početne faze lečenja fiksnim aparatima" predstavljena je na 181 stranici teksta koji je podeljen u 9 poglavlja: Uvod; Pregled literature; Ciljevi; Učesnici u studiji, material i metod; Rezultati; Diskusija; Zaključci; Literatura i Prilozi. Prikazano je ukupno 31 slika, 60 tabela i 11 grafikona. U literaturi su navedeni podaci iz 291 bibliografske jedinice.

UVOD u disertaciju upoznaje čitaoca sa osnovama biološkog pomeranja zuba tokom ortodontske terapije i o težnjama ka idealnom materijalu koji bi zadovoljio sve aspekte ortodontske terapije.

PREGLED LITERATURE podeljen je na dve oblasti, u okviru kojih je 11 odeljaka. Prva oblast obradjuje podatke iz radova koji su se bavili ortodontskim žicama od legure nikla i titana (NiTi). Oblast *ORTODONTSKE ŽICE OD NITI LEGURE (2.1)* prikazuje istoriju razvitka legure od nikla i titana, kao i njenu strukturu i izgled. Odeljak *Memorija oblika (2.1.1) i Superelastičnost (2.1.2)* tumači važne karakteristike NiTi legura da se nakon prestanka dejstva sile ili pri promeni temperature, legura vraća u prvobitni, fabrički zadati oblik. Sledeći odeljak *Klasifikacija NiTI žica (2.1.3)* osvrće se na savremenu podelu žica u zavisnosti od njihove strukture i karakteristika koje zavise od procesa proizvodnje. Glavne faze u procesu proizvodnje žice, kao što su: topljenje i izlivanje; oblikovanje, formiranje i finiširanje opisane su u odeljku *Proizvodnja žice od NiTi legure (2.1.4).* Promenom hemijskog sastava legure omogućava se menjanje karakteristika same žice. Moguće kombinacije odnosa nikla, titanijuma i ostalih elemenata, kao i promene osobina žice koje nastaju promenom u sadržaja nikla i titana prikazani su u odeljku *Hemijski sastav legure (2.1.5).* Osim superelastičnosti i memorije oblika, ortodontska NiTi žica treba da se odlikuje i biokompatibilnošću da bi bila primenjljiva u uslovima usne duplje. Pregledom literature navedena su savremena shvatanja biokompatibilnosti biomaterijala.

Korozivni procesi koji mogu da dovedu do narušavanja površinskog sloja legure od koje je žica napravljena i time ugroze biokompatibilnost žice opisani su u odeljku *Biokompatibilnost (2.1.6).*

Mogućnosti ispitivanja biokompatibilnosti biomaterijala, kao i ortodontskih žica prikazani su u naredna dva odeljka (*2.1.7 i 2.1.8*). Nakon opisa ortodontskih žica kroz savremenu literaturu, razmatrani su biološki aspekti, mehanizam nastanka bola, kao i percepcija i njegova karakterizacija okviru oblasti *BOL* (*2.2*).

CILJEVI istraživanju su jasno definisani i odnose se na kategorizaciju bola, strukturu ortodontske NiTi žice i njihovu zavisnost.

U poglavlju UČESNICI U STUDIJI, MATERIAL I METODE prikazan je način ispitivanja osoba koje su bile uključene u istraživanje, kao i metode ispitivanja strukture novih žica i žica koje su bile u ustima ispitanika mesec dana. Laboratorijskim ispitivanjem pomoću Analize disperzijom X zraka -Energy Dispersive X-ray Analysis (Spectroscopy) (EDX ili EDS) koje je sprovedeno na Mašinskom fakultetu u Mariboru utvrđena je struktura novih, kao i korišćenih (iz usta izvađenih) NiTi žica. Ispitivan je sadržaj nikla i titana, njihov odnos, kao i promena u sadržaju pre i posle korišćenja. U kliničkom delu studije učestvovalo je 200 osoba kod kojih je započeta terapija fiksnim ortodontskim aparatima (*4.1 i 4.2*). Ispitanici su bili ortodontski pacijenti na Klinici za ortopediju vilica u Beogradu i privatnoj praksi, kojima su, u sklopu terapije fiksnim aparatima, ligirane žice 6 različitih proizvođača istog prečnika od 0.014" (0.35 mm). Učesnici u studiji su popunjavali specijalno formulisan modifikovani McGill upitnik za bol (*Prilog 3*).

REZULTATI laboratorijskog i kliničkog dela studije koji su statistički obrađeni, prikazani su pregledno na 12 slika u 59 tabela i 11 grafikona uz detaljan opis. Prikazan je hemijski sastav žica i sadržaj nikla i titana pre i posle korišćenja, struktura i izgled površine žica, kao i statistički obrađeni rezultati kliničkog dela studije koji se bavio karakterom i intenzitetom bola (*5.1-5.3*).

DISKUSIJOM, koje je izuzetno bogata i opširna tumačeni se dobijeni rezultati u svetlu dosadašnjih saznanja iz oblasti fiziologije bola, biomaterijala i biokompatibilnosti ortodonstkih žica, što doprinosi još boljem razumevanju dobijenih rezultata.

ZAKLJUČCI su navedeni jasno u skladu sa ciljevima disertacije dajući doprinos ne samo napredku naučno-istraživačkog radu iz oblasti ortodoncije i biomaterijala nego i unapređenju ortodontske kliničke prakse.

RADOVI I SAOPŠTENJA SA SKUPOVA IZ OBLASTI KOJOM SE BAVI DOKTORSKA DISERTACIJA:

1. J. Ferčec, B Glišić, I Šćepan, **E Marković**, D Stamenković, I Anžel, J Flašker, R Rudolf. Determination of stresses and forces on the orthodontic system by using numerical simulation of the Finite Elements Method. Acta Physica Polonica A 2012; Oct vol.122:pp. 659-665. **M23**
2. R. Rudolf, M. Anžel, **E. Marković,** M. Čolic, D. Stamenković: Gold in the past, today and future. Metalurgija 51 (2012) 2, 261-264. **M23**
3. J. Ferčec, R. Rudolf, I. Anžel, I. Pulko, **E. Marković**, D. Stamenković, B. Glišić· Methods of investigation of the stress-induced martensite in the orthodontic wire from shape memory alloy niti under different stress states. 1st Metallurgical and Materials Enginering Congress of South East Europe. Proceedings and book of abstracts. 147-153. May 23-25, 2013. Belgrade, Srebia; **M34**
4. R. Rudolf, J. Ferčec, S. Tomić, D. Stamenković, B. Glišić **E. Marković**,· New approach to determination of NiTi orthodontic archwires charac-teristic properties. 18th Congress of the Balkan Stomatological Society (BaSS). April 25-28, 2013 Skopje. **M34**

KONAČNA OCENA DOKTORSKE DISERTACIJE

Doktorska disertacija mr. sc. dr Evgenije Marković pruža originalni naučni doprinos u oblasti ortodoncije i nauke o biomaterijalima. Struktura NiTi žica i njen uticaj na percepciju bola kod ortodontskih pacijenata, iako ispitivana kroz dosadašnje publikacije, ipak nije rasvetljena u potpunosti. Rezultati doktorske disertacije umnogome pomažu razumevanju složenih mehanizama razmene nikla i titana kako unutar žice tako i između žice i medijuma, tj. pljuvačke. Procena biokompatibilnosti žice na osnovu promena u njihovom sadržaju pre i posle korišćenja ortodonstke žice je relativno malo eksploatisana metodologija koja je uspešno sprovedena u disertaciji. Podaci o karakteru bola, njegovom intenzitetu, kao i dužini trajanja u zavisnosti od vrste žice koja se koristi tokom terapije fiksnim aparatima pružaju mogućnost ne samo daljeg unapređenja karakteristika ortodonstkih žica nego i boljem razumevanje potreba pacijenata.

ZAKLJUČAK I PREDLOG KOMISIJE

Komisija je jednoglasno donela odluku da je doktorska disertacije mr. sc. dr Evgenije Marković pod nazivom "UTICAJ STRUKTURE ORTODONTSKIH ŽICA NA BIOKOMPATIBILNOST I PERCEPCIJU BOLA TOKOM POČETNE FAZE LEČENJA FIKSNIM APARATIMA" originalan i samostalan istraživački rad, sproveden u saglasnosti sa predlogom teme koju je Univerzitet odobrio. Doktorska disertacija u potpunosti ispunjava kriterijume koji su propisani Zakonom o Univerzitetu i statutom Univerziteta i Stomatološkog fakulteta u Beogradu. Komisija predlaže Naučno-nastavnom veću Stomatološkog fakulteta Univerziteta u Beogradu da prihvati pozitivan izveštaj i kandidatu mr. sc. dr Evgeniji Marković odobri javnu odbranu doktorske disertacije pod nazivom "UTICAJ STRUKTURE ORTODONTSKIH ŽICA NA BIOKOMPATIBILNOST I PERCEPCIJU BOLA TOKOM POČETNE FAZE LEČENJA FIKSNIM APARATIMA".

- Prof. Dr Ivana Šćepan, Klinika za ortopediju vilica, Stomatološki fakultet u Beogradu;

- Prof. Dr Dragoslav Stamenković, Klinika za stomatološku protetiku, Stomatološki fakultet u Beogradu;

- Doc. Dr Predrag Vučinić, Odsek za stomatologiju, Medicinski fakultet u Novom Sadu

Na osnovu člana 49. Statuta Stomatološkog fakulteta Univerziteta u Beogradu, Nastavno naučno veće Stomatološkog fakulteta, na VII redovnoj sednici u školskoj 2012/2013. godini, održanoj 12.07.2013. godine, donelo je sledeću

O D L U K U

Usvaja se pozitivan izveštaj Komisije za ocenu završene doktorske disertacije **dr Evgenije Marković**, pod nazivom „UTICAJ STRUKTURE ORTODONTSKIH ŽICA NA BIOKOMPATIBILNOST I PERCEPCIJU BOLA TOKOM POČETNE FAZE LEČENJA FIKSNIM APARATIMA“.

Imenovani/a će javno braniti doktorsku disertaciju, ukoliko dobije pozitivno mišljenje Veća naučnih oblasti medicinskih nauka Univerziteta u Beogradu, pred komisijom u sastavu:

1. prof. dr Ivana Šćepan
2. prof. dr Dragoslav Stamenković
3. doc. dr Predrag Vučinić, Medicinski fakultet u Novom Sadu.

O b r a z l o ž e nj e

Veće naučnih oblasti medicinskih nauka, na sednici od 10.07.2012. godine, dalo je saglasnost na predlog teme doktorske disertacije dr Evgenije Marković, pod nazivom „UTICAJ STRUKTURE ORTODONTSKIH ŽICA NA BIOKOMPATIBILNOST I PERCEPCIJU BOLA TOKOM POČETNE FAZE LEČENJA FIKSNIM APARATIMA“.

Imenovani/a je u časopisu Acta Physica Polonica, objavio/la rad pod nazivom: „Determination of stresses and forces on the orthodontic system by using numerical simulation of the Finite Elements Method (2012) i u časopisu Metalurgija, objavio/la je rad pod nazivom „Gold in the past, today and future“ (2012).

Imajući u vidu napred navedeno, Nastavno naučno veće Stomatološkog fakulteta Univerziteta u Beogradu, rešilo je kao u dispozitivu.

Odluku dostaviti: Imenovanom/oj, Univerzitetu u Beogradu, Odseku za nastavu, Veću, Komisiji (3) i Pisarnici.

Referent kadrovskog odseka
Violeta Rastović

Dekan
Stomatološkog fakulteta

Prof. dr Miroslav Vukadinović

Determination of Stresses and Forces on the Orthodontic System by Using Numerical Simulation of the Finite Elements Method

J. Ferčec[a], B. Glišić[b], I. Šćepan[b], E. Marković[b], D. Stamenković[b], I. Anžel[a], J. Flašker[a] and R. Rudolf[a,c]

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(Received January 17, 2012; revised version April 20, 2012; in final form July 30, 2012)

This study was addressed to use knowledge about the orthodontic system with numerical simulation of the finite elements method. For the first time we simulated the stresses on the orthodontic system and, in this manner, calculated the orthodontic force on the tooth. A 3D orthodontic model or orthodontic system was designed resembling moderate crowding in the dental arch with all supporting structures. CATIA V5 computer software was used to set up a model for the orthodontic system and ABAQUS was used for simulation of the stresses on the orthodontic system. Our attention was focused on the stresses on the tooth lateral incisor and its periodontal ligament. The results of the numerical simulation showed complex stresses on the tooth lateral incisor and its periodontal ligament. In this paper there is presented a calculation of the orthodontic force acting on the tooth lateral incisor due to the orthodontic wire. This orthodontic force was calculated from the stresses on the bracket. The calculated orthodontic force was in the area which is considered as the optimal orthodontic force for movement of the tooth.

PACS: 02.70.Dh, 81.40.Jj, 87.10.Kn, 87.19.Rr

1. Introduction

Malocclusion is the misalignment of teeth, or when the relationship between the upper and lower dental arches is incorrect. Malocclusions occur in all three planes of space and can affect each tooth in all three planes. Total malocclusion frequency varies with a mean of 46% [1]. Of all malocclusions, crowding is the predominant intra-arch problem in patients seeking orthodontic treatment in the United States and Western Europe [2, 3].

In order to correct malocclusions orthodontic treatment is needed. The preferred treatment option in the correction of malocclusions is the utilization of fixed orthodontic appliances. Contemporary orthodontics relies on the use of fixed orthodontic appliances to solve the misalignment of teeth and bite problems by moving the teeth gradually into the normal position in the dental arch. The fixed orthodontic appliance consists of brackets that are bonded to the teeth, as well as orthodontic wires. When the wire is engaged in the slot of the brackets it generates the forces necessary for orthodontic tooth movement [4–6].

Each tooth is attached to the alveolar bone by a strong network of parallel collagen fibres: the periodontal ligament (PDL) is remodelled and renewed constantly during normal function. PDL has two major components: (1) cellular elements, and (2) the tissue fluid. Both components play an important role in normal function and allow the orthodontic movements of teeth [7]. The sequence of events carried out by applying forces within the limits of physiological tolerance begins with the decreased blood flow through the PDL, followed by the resorption and apposition of the bone. A periodontal ligament placed under pressure will result in bone resorption, whereas a periodontal ligament under tension results in bone formation. Within a few hours of applying a light force, a series of chemical changes in the PDL begins stimulating the cells to differentiate into osteoclasts (responsible for bone resorption) and osteoblasts (responsible for bone apposition). The bone that opposes the motion undergoes frontal resorption to allow for dental displacement, whereas on the opposite side, the stress of the periodontal fibres results in the deposition and production of a new bone. If orthodontic forces stay light, frontal resorption on one side and apposition on the other will occur at the same rate. When a force of great intensity is applied on the tooth, it causes a vascular occlusion and cuts the blood supply to the PDL. In this case, aseptic necrosis occurs, resulting in an undermining bone resorption that does not start from the dental side, but comes from the alveolar region, causing the tissue damage, hyalinization and pain. The process of underlying resorption is faster and more damaging compared to frontal resorption [8–12].

In order to prevent undermining resorption light forces should be used during orthodontic treatment. The optimum force used in orthodontic treatment should be enough to produce tooth movement without tissue damage and with maximum comfort for the patient. Excessive forces can lead to severe pain, damage of the periodontal ligament and root resorption [13]. Insufficient forces extend the duration of the treatment. Delivering optimal force levels for controlled tooth movement remains of the *utmost importance* during *orthodontic treatment*. Light continuous orthodontic forces are preferred. The force needed to move the tooth is different for each tooth and depends on the kind of movement that is required during orthodontic treatment [14]. For example; the force of 10–20 g/cm^2 is needed for intrusion, and 70–100 g/cm^2 is the desirable force for translation [6]. Optimum force level for tooth movement usually varies in the range of 0.09 to 0.98 N (9–100 g/cm^2).

A variety of wires are used to generate the necessary biomechanical forces associated with tooth movement, such as: stainless steel; nickel–titanium (NiTi); beta--titanium; and cobalt–chromium. Once the wire is activated or bent, it is the unloading or deactivating forces that produce the orthodontic tooth movement. With current orthodontic treatment nickel–titanium wires are often used due to their superior mechanical properties, biocompatibility, ductility, resistance to corrosion, lower elastic modulus, and special characteristics such as superelasticity and shape memory effect. The effect that the wire produces is a summary of properties of the wire itself and geometrical factors. Geometrical factors such as: the cross-section of the wire (round, rectangular) and the distance between the brackets, have a great impact on the force level [9]. All of these factors should be addressed when the magnitude of orthodontic force is measured. There is still insufficient knowledge of the direction, magnitude and distribution of the forces applied in orthodontic therapy, as well as their effect on the tooth and surrounding supportive structures. Until recently, much of the orthodontic biomechanics literature was restricted to 2-dimensional experimental studies of the biomechanical aspects of orthodontic force systems and, more recently, to 3-dimensional (3D) computer modelling.

There is little evidence regarding 3D experimental measurements and analysis of orthodontic force systems [15–17]. Solutions using numerical methods began after 1970, leading to the development of specific software packages. Research conducted by the finite element method (FEM) in dental practice has been related mainly to dental implants, stress in periodontal ligaments and displacements of teeth under the influence of external forces [7, 18, 19]. The FEM enables the investigation of the biomechanical issues involved in orthodontic treatment. In addition, it stimulates currently increasing scientific interest in tooth movement [20]. The development of a numerical model makes it possible to quantify and evaluate the effects of orthodontic loads applied in order to achieve tooth movement. One of the main features of the FEM lies in its potential to analyse complex structures. In the case of tooth movement, the numerical model should resemble the clinical setting, including the type of malocclusion and choice of brackets, as well as arch wires.

Simulation of orthodontic tooth movement with a fixed orthodontic appliance using FEM can help in the determination of the forces produced by the orthodontic wire.

The purpose of this article was to simulate the stresses on the orthodontic system in the case of moderately crowded frontal teeth in the upper dental arch and to quantify the forces applied to teeth when different NiTi wires were engaged in fixed orthodontic appliances.

2. Materials and methods model

The orthodontic 3D model for this study was built using CATIA V5 software. A 3D model of a crowded central incisor, lateral incisor and canine in the upper dental arch simulated real malocclusion (Fig. 1).

Fig. 1. Model of moderate crowding in the upper dental arch.

A fixed orthodontic appliance was used to simulate the orthodontic treatment in a case with moderate crowding. Metal brackets were bonded to the teeth and wire inserted into the slots. Data for tooth dimensions were obtained from the dental anatomy literature [21]. The teeth were modelled using the orthographic views (top, front and side view) of the tooth. The teeth crowns in the model had the following heights and mesio-distal widths respectively: 11.2 mm and 8.6 mm for the central incisor, 9.8 mm and 6.6 mm for the lateral incisor and 10.6 mm and 7.6 mm for the canine. The root lengths were: 13 mm for the central incisor, 13.4 mm for the lateral incisor and 16.5 mm for the canine. The position of the teeth in the model resembled moderate crowding in the upper dental arch. The lateral incisor was moved 4 mm lingually and 3 mm gingivally from its normal position in the dental arch in order to present moderate crowding.

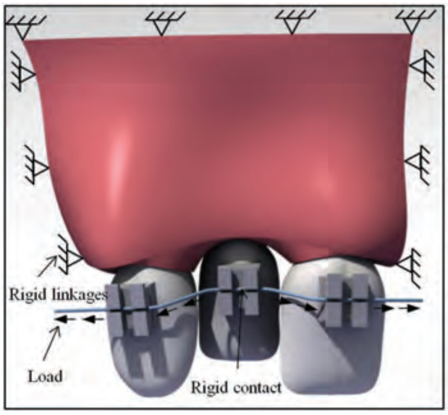

Fig. 2. CAD model of tooth position with boundary conditions.

A 3D model of the upper frontal teeth was obtained, with the periodontal ligament modelled for the length of the whole root (0.25 mm in width) (Fig. 2). Supportive bone was modelled in a 2 mm thick layer, with underlying cortical bone. The orthodontic NiTi wire was inserted into the bracket slot of each tooth in the model. For the model a wire of a diameter of 0.012″ (0.305 mm) was taken into consideration.

2.1. Material properties

The 3D model was based on the thesis that all materials are isotropic materials, which means that there are two independent material constants. In order to simplify the model, materials were considered to be homogeneous, meaning that linear and elastic material behaviour included two constants: Young's modulus and Poisson's ratio. The value of Young's modulus and Poisson's ratio for the alveolar bone, periodontal ligament, tooth and bracket were taken from literature (Table I) [22].

TABLE I

Young's modulus and Poisson's ratio on separate segments of the orthodontic system.

Linear-elastic material parameters used for:	Young's modulus of elasticity, E [MPa]	Poisson's ratio
alveolar bone	13800 [18]	0.30 [18]
teeth	20000 [18]	0.30 [18]
periodontal ligament	1 [22]	0.45 [22]
bracket (stainless steel)	180000	0.3

In the numerical simulation that was performed, three different NiTi orthodontic wires with various modulus of elasticity (Table II) were used. The purpose of the numerical simulation was to determine the initial stresses

TABLE II

Material parameter of wires for ABAQUS model.

Wire	Young's modulus of austenite, E [MPa]
1.	50000
2.	54000
3.	58000

and, consequently, the force when the wire was inserted into the slot of the brackets and ligated. Although the behaviour of NiTi wires in terms of superelasticity is complex, we simplified the material properties and the Young modulus of austenite for numerical analysis was taken [23]. However, this theory says that when, under certain stresses austenitic structures change in the martensitic structure, we can suppose, as in our case, that the stresses on the wire are in the elastic region of austenite. Data for Young's modulus of austenite for NiTi for various wires are presented in Table II [24]. In all three wires Poisson's ratio was 0.3 [24].

2.2. Finite element model generation

The constructed model was transferred into the ABAQUS/CAE 6.10-1 software for the numerical simulation by the FEM. In our model we performed a static analysis. The boundary conditions in our model are shown in Fig. 2. Our model is a fixed one mounted in the alveolar bone. To simplify the numerical calculation we fixed the orthodontic wire rigidly in the bracket of the lateral incisor. Loads were placed on both ends of the wire with the tension load as shown in Fig. 2. With this kind of load we are closer to the real case. The numerical model consists of 86315 finite elements.

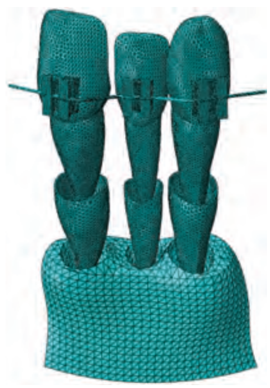

Fig. 3. The finite-element mesh of the model.

With the automatic mesh generation of parts by tetrahedral element, the following parts were meshed: alveolar bone, PDLs and teeth. The brackets and wire were meshed by hexahedral finite elements (Fig. 3). In real orthodontic treatment, especially in the levelling stage, it is desirable for the wire to slide through the slot of the bracket as freely as possible having the least friction [25]. In order to choose orthodontic wire wisely it is important to know the friction properties between the wire and the bracket. Information about these properties in the literature has not been consistent. It is very difficult to determine accurately the friction characteristics between the wire and the bracket because the contact conditions between them vary widely. For the friction coefficient between wire (NiTi) and bracket (stainless steel) a value of 0.3 [26] was taken from the literature. Other contacts between segments: alveolar bone-PDL, PDL-tooth, tooth-bracket were rigid.

2.3. Calculation of the force

The tooth was moved through the use of force applied by the wire inserted into the slot of the bracket. By using the FEM the stresses were converted into force.

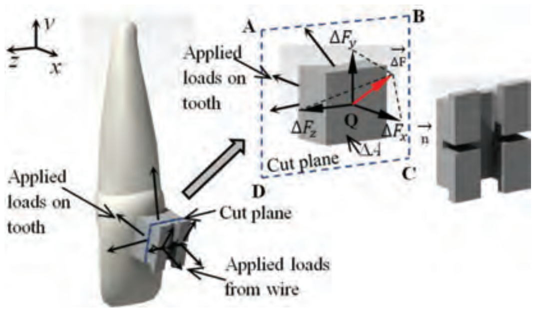

Fig. 4. Cutting a bracket of the lateral incisor, projecting the internal resultant force onto normal and tangential components.

To calculate the forces on the lateral incisor we used the stresses which act on the bracket of the lateral incisors. For the stresses which act on the cut plane $ABCD$ (Fig. 4) bracket of the lateral incisor we used Eqs. (1.1)–(1.3) to calculate the forces on the tooth

$$\sigma_{xx} \stackrel{\text{def}}{=} \lim_{\Delta A \to 0} \frac{\Delta F_x}{\Delta A}, \tag{1.1}$$

$$\tau_{xy} \stackrel{\text{def}}{=} \lim_{\Delta A \to 0} \frac{\Delta F_y}{\Delta A}, \tag{1.2}$$

$$\tau_{xz} \stackrel{\text{def}}{=} \lim_{\Delta A \to 0} \frac{\Delta F_z}{\Delta A}. \tag{1.3}$$

The cut plane $ABCD$ is oriented by its unit normal direction vector $\boldsymbol{n}$ or normal. Normal $\boldsymbol{n}$ has been chosen to be parallel to the x-axis. At the point Q we refer to a rectangular Cartesian coordinate system of axes $\{x, y, z\}$. To the cut portion of the bracket we applied a system of internal forces that restores static equilibrium. $\Delta \boldsymbol{F}$ are the resultant of internal forces acting on the ΔA. The component ΔF_x is aligned with the cut-plane normal and is called the normal internal force component or normal force. Components ΔF_y and ΔF_z which lie on the cut plane are called the tangential internal forces components or tangential forces. We defined the stress components at point Q by taking the limits of internal force over elemental-area rations, as that area shrinks to zero (see Eqs. (1.1)–(1.3)). σ_{xx} is called a normal stress, whereas τ_{xy} and τ_{xz} are tangential stresses [27].

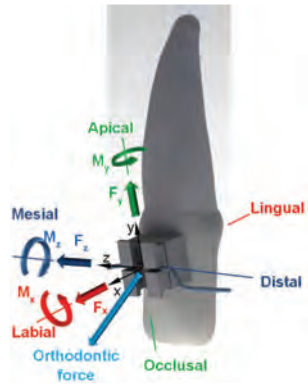

Fig. 5. Reference coordinate system in the tooth with showing the forces and moments.

The reference coordinate system was defined and presented in Fig. 5.

3. Results

By using ABAQUS software for numerical simulation a model with three different orthodontic wires was presented. The values of the stress on the lateral incisor, PDL and the bracket itself produced by different types of wires are shown in Figs. 6 and 7. It can be seen that by increasing the elastic modulus of the wire, the stresses on the bracket, PDL and tooth became more intense.

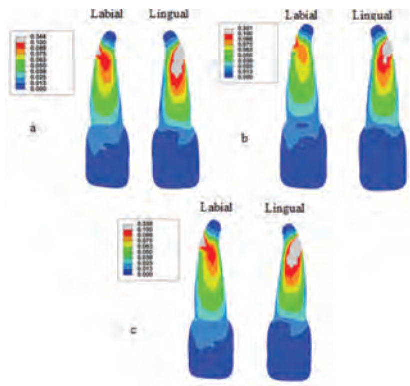

Fig. 6. Von Mises stresses on the tooth lateral incisor: (a) $E = 50000$ MPa; (b) $E = 54000$ MPa; (c) $E = 58000$ MPa.

Due to the action of several components of stresses on the tooth lateral incisor and PDL stresses are shown with *equivalent* or the *Von Mises* stresses. The units in the figures are shown in MPa.

Figure 6 shows the Von Mises stresses on the upper lateral incisor. From the figure it could be seen that the

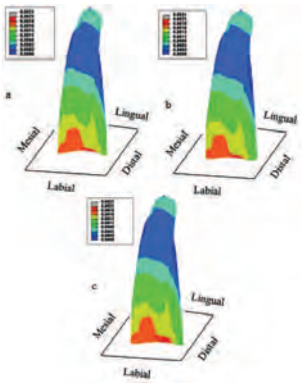

Fig. 7. Von Mises stresses on the periodontal ligament: (a) $E = 50000$ MPa; (b) $E = 55000$ MPa; (c) $E = 58000$ MPa.

stress state generated on the tooth complex was caused by a single component of force. The maximum Von Mises stresses occurred on the bottom of the root of the tooth. The maximal values of the Von Mises stress on the lateral incisor tooth for the separate wires are: wire 1: 0.344 MPa, wire 2: 0.301 MPa, wire 3: 0.338 MPa.

Maximum Von Mises stress on the lateral incisor tooth did not depend on the increasing modulus of elasticity of the wire. This means that the components of normal and tangential stresses on the tooth are different. But the surfaces with the highest stresses increased with the increase in Young's modulus of the wire. The highest stresses were caused on the lower side of the lingual side.

Figure 7 shows the Von Mises stresses on the PDL of the lateral incisor. The maximal Von Mises stress on the PDL of the lateral incisor is caused on the circumference of the PDL by the contact with the tooth crown (Fig. 7).

The maximal Von Mises stresses for separate wires are very similar: wire 1: 0.00211434 MPa, wire 2: 0.00213878 MPa, wire 3: 0.00214612 MPa.

On the PDL the highest stresses occur on the lingual side of the tooth. This is due to the fact that, on this side, the tension stresses on the PDL. The difference comes between the mesial and the distal sides. As we can see in Fig. 7 the highest stresses are on the distal side. This is due to the smaller distance between the teeth or brackets.

Different stresses are caused in different directions (normal and tangential) on the tooth and PDL due to the various components of forces. Each component of force has a different influence on the stresses in the root of the tooth and PDL. The force F_x caused compressive and tension stresses on the labial and lingual side on the tooth and PDL. This force is mainly for moving the tooth into the correct position; it moves the tooth in a lingual or labial direction. The force F_y caused compression and tension stresses on the tooth and PDL in both the apical and occlusal direction. This force wants to move the tooth in an apical or occlusal direction. The force F_z caused compression and tension stresses in both the distal and mesial directions on the tooth and PDL. This

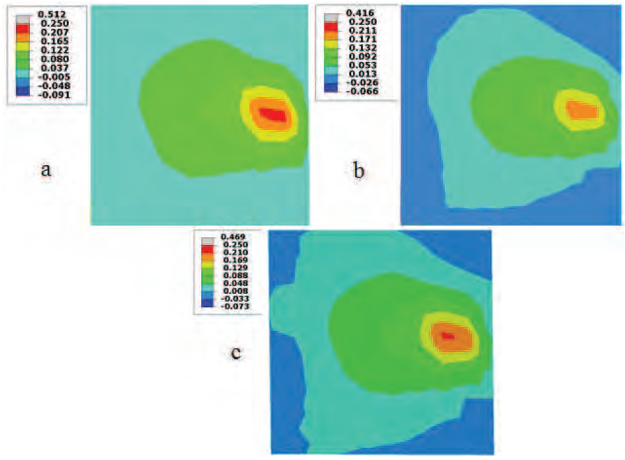

Fig. 8. Normal stresses σ_{xx} on the cut-plane of the bracket: (a) $E = 50000$ MPa; (b) $E = 54000$ MPa; (c) $E = 58000$ MPa.

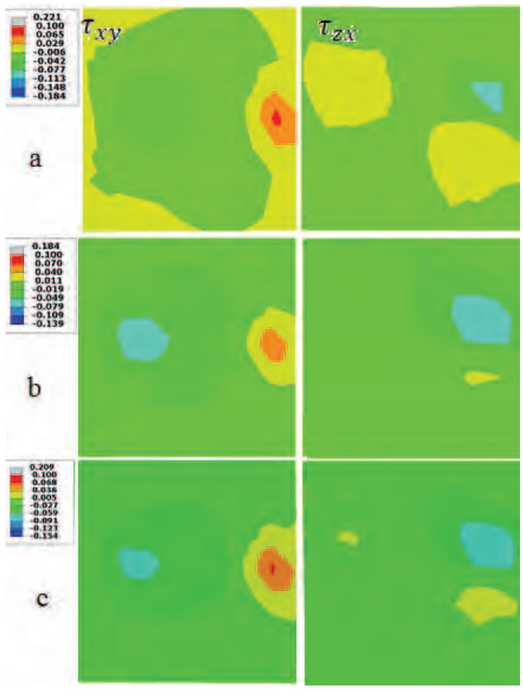

Fig. 9. Tangential stresses τ_{xy} and τ_{zx} on the cut--plane of the bracket: (a) $E = 50000$ MPa; (b) $E = 54000$ MPa; (c) $E = 58000$ MPa.

force is usually due to friction between the bracket and the wire. Due to the simultaneous activity of individual components of force a complex stress state was caused in both the tooth and PDL. All components of the forces acting on the tooth were dependent on the stiffness of the wire, for which we will also show the calculation of the forces in the following way.

The force caused on the bracket by the wire with given modulus was calculated using the stresses at the cut--plane (Fig. 4) of the bracket. Figure 8 shows the normal stresses on the cut-plane of the bracket for all three different wires. Maximum normal stress on the cut-plane of each wire was as follows: wire 1: 0.219192 MPa, wire 2: 0.219465 MPa, wire 3: 0.219735 MPa.

Figure 9 shows the tangential stress at the cut-plane. Maximum tangential stress τ_{xy} on the cut-plane of each wire was as follows: wire 1: 0.07475 MPa, wire 2: 0.07493 MPa, wire 3: 0.08011 MPa.

Maximum tangential stress τ_{zx} on the cut-plane of each wire was as follows: wire 1: 0.0311 MPa, wire 2: 0.0320 MPa, wire 3: 0.0329 MPa.

To calculate the forces we used Eqs. (1.1)–(1.3). We first calculated the separate force in all axes, and then we calculated the resultant force acting on the tooth. We calculated separate forces from the average value of the average normal stress and two average tangential stresses from the cut-plane.

TABLE III

The average stresses in separate axes and calculated components of internal force with resultant force.

Wire	Average stresses [MPa]			Components of internal forces [N]			Orthodontic force [N]
	σ_{xx}	τ_{xy}	τ_{xz}	F_x	F_y	F_z	F
1	0.0341	−0.012	−0.0015	0.35	−0.12	−0.016	0.37
2	0.0346	−0.0121	−0.00152	0.354	−0.124	−0.0156	0.375
3	0.035	−0.0124	−0.00161	0.358	−0.127	−0.017	0.38

In Table III we can see the results of the components of internal forces and resultant force or orthodontic force. The components of internal forces F_y and F_z have negative values, which means that they act in a reverse direction as supposed in Fig. 5. The direction act of orthodontic force is shown in Fig. 5. From wire 1 we got the minimum orthodontic force 0.37 N and from wire 3 the maximum orthodontic force 0.38 N. In our model of the orthodontic system we can see that a higher stiffness of wire gives a higher level of orthodontic force on the tooth.

4. Discussions

FEM is a powerful tool for the analysis of complex structures, but the outcome is dependent on the formulation of the problem [28]. The acting forces in the beginning stage of orthodontic treatment in the case with moderate crowding were presented using FEM. This was an attempt to quantify and evaluate the effects of orthodontic loads applied to the bracket and teeth in order to achieve initial tooth movement. With the intention of simplifying the procedure the moment of force was not taken into account. The emphasis was put on the level of force produced by the NiTi wire. It was determined that, by the smallest elastic modulus of 50000 MPa, the calculated force on the lateral incisor was approximately 0.37 N. The bigger force was produced by wires with a higher value of elastic modulus. The force level was in area that is supposed to be optimal for orthodontic tooth movement (0.09–0.98 N) [6].

Different structures and materials used in orthodontics have had their properties identified, such as bones, teeth and stainless steel. When a numerical model is used choosing the right material properties, such as elastic modulus and Poisson's ratio, as well as presenting the characteristics of the alveolar bone, tooth and PDLs are the most important factors in obtaining precise results. Also, the reliability of FEM cannot be checked directly, due to the fact that the model of crowded teeth was made only as a replica of a real life problem.

The wide range of boundary conditions, contact definitions, material property definitions etc., used in current FEM analyses creates a genuine need for consistency [29]. Since the introduction of FEM into dental biomechanical research in 1973, the stress and strain fields in the alveolar support structures during orthodontic tooth movement have been analysed extensively [30–37]. Not much research has been done in simulating the orthodontic movement focusing on the properties of the orthodontic wire and its effect on supporting structures. In order to do that, the properties of wires made by different manufacturers should be available to enable simulation of the real life problem. The further simulations must be more accurate. Consequently, research work in the future should focus on the determination of the elastic modulus of different commercially available orthodontic wires, and friction coefficients between wires and brackets, as well as other properties that define orthodontic movement of the teeth. Contact points between single elements, especially between wire and bracket, should be constructed precisely. Contact points between wire and bracket are places of higher stress concentration and should be taken into consideration in determining the friction. Additionally, the force level produced by the fixed orthodontic appliance in different orthodontic cases of dental malposition should be measured and compared. With results obtained in such a manner, simulation would be more precise and efficient.

5. Conclusions

A 3D model can be used successfully for numerical simulation of modern orthodontic mechano-therapy. The initial orthodontic force produced by three different orthodontic wires at the beginning of the orthodontic treatment were quantified and qualified. Introduction of more variables into the future simulation of orthodontic treatment using FEM is needed for obtaining more accurate results.

Acknowledgments

This article has been supported by EUREKA Programme Orto-NiTi within the framework of the Ministry of Higher Education, Science and Technology of the Republic of Slovenia and Programme for Young Researcher within the framework of the Slovenian Research Agency. The authors thank Zlatarna Celje d.d., Slovenia, for working on the development of the new Ni–Ti alloy.

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ISSN 0543-5846
METABK 51(2) 261-264 (2012)
UDC – UDK 669.14.018.298:669.18=111

GOLD IN THE PAST, TODAY AND FUTURE

Received – Prispjelo: 2011-05-27
Accepted – Prihvaćeno: 2011-07-10
Review paper – Pregledni rad

This paper deals with gold, which is described as a chemical element. Special attention is paid to its physical-chemical properties and, furthermore, where or in what form it can be found in nature. We discuss the role it has played through history and we inform how gold has been developed to the level it has reached today's value. Still more, when gold is broken into nanoparticles, this form could be highly useful for a wide range of processes, including general nanotechnology, electronics manufacturing and the synthesizing of different functional materials. It is important that we know that gold is also used in industry in many engineering applications (contacts in micro-electronics) and medicine (dental alloys, implants).

Key words: gold, physical-chemical properties, nano-particles, applications

Zlato u prošlosti, sadašnjosti i budućnosti. Ovaj članak govori o zlatu kao kemijskom elementu. Posebna pažnja posvećena je njegovim fizikalno-kemijskim svojstvima i gdje i u kojem obliku se može pronaći u prirodi. Razmatra se uloga koju je zlato odigralo u povijesti i donosi se informacije o tome kako je doseglo razinu vrijednosti koju ima danas. Zlato razlomljeno na nanočestice upotrebljivo je u širem spektru procesuiranja, uključujući opću nanotehnologiju, elektroničku prizvodnju i spajanju materijala raznih funkcionalnosti. Važno je znati da se zlato koristi i u industriji, mnogim inženjerskim procesima (kontakti u mikro-elektronici) i medicini (dentalne slitine, implatanti).

Ključne riječi: zlato, fizikalno-kemijska svojstva, nanočestice, primjene

INTRODUCTION

Gold is a chemical element with the atomic number 79 and the symbol Au, which is derived from the Latin name "aurum" and means the morning dawn [1]. By coagulation it crystallizes in a centred cubic grid and in the periodic table it is located between the transition metals. The relative atomic mass of gold is 196,97, the density is 19,32 g/cm³, the melting temperature is 1063 °C, the elastic modulus is 77 MPa and the coefficient temperature of elongation (WAK) is 14,1 µm/m · K [1]. Gold is a very dispersed and rare element in the Earth's crust. In the wild it is located in its native form or (less frequently) in the form of telluride, which contains the only Golden minerals (kalaverit, sylvanite, petcit) [2]. Native gold is located primarily in the veins of silica (SiO_2), in the ores of other materials, or in deposits and is not clean; it contains 1–50 % mercury. The largest deposits of gold are in South Africa, the USA, Canada, Australia, Mexico and Russia. Approximately 20 % of world production is used commercially, while the rest is in gold reserves (the gold basis of paper money).

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PHYSICAL-CHEMICAL PROPERTIES

Gold has its own unique yellow colour. Its appearance is also influenced by its brilliance and reflective ability. Because of these properties gold cannot be confused with any other metal. If gold contains an admixture of other elements it changes colour. Due to the admixture of silver in gold (up to 30 % by weight) it turns silver-white [3]. If the surface is polished the sharp metallic shine is stressed. Gold products are usually made of an alloy in which you can find behind the gold other alloying elements such as silver, copper, platinum, palladium etc. in many cases where products contain copper, so-called oxidation zones are visible, which is the reason for the dark, unpolished look of the surface [4]. Gold has almost twice the density of lead and 19,3 times greater than that of water. The admixture of other metals also has an effect on the density. For example, if the mass fraction of silver in gold alloy is between 2 and 20 %, then consequently the alloy density is between 15,5 and 19,3 g/cm³ [1]. Other contaminants which may affect the density are copper, platinum, palladium, rhodium, iridium and bismuth.

In the chemical sense gold is the least active metal, since it burns in air, is not oxidized in water, does not change colour, does not react with strong alkaline solutions and all the pure acids (except for selenium acid). Gold dissolved in a solution which is a mixture of chlorine and nitric acid ($HCl: HNO_3 = 3:1$); it dissolves in a cyanide solution [5]. Gold dissolves in mercury to form amalgam. The gold compounds have one (+1) or three (+3) valence and they are not very persistent. Colloids are formed by adding a solution of formaldehyde or phenylhydrazine to gold. Gold is a soft and very dense metal with a strong yellow colour and has a high degree of cleavage.

GOLD IN THE BANKING BUSINESS

In the fourth millennium (before Christ) the Egyptian workers found their first silver and gold. This discovery formed the natural exchange system of the economy at that time. Minted as indestructible silver and gold coins and precious metals they began to be used as currency. For security reasons, they began to be stored by the Goldsmith, and these in turn issued a Certificate of Safekeeping (CS), which was redeemable for silver and gold, and which later became the paper money used instead of silver and gold. On this basis they began subsequently to establish a private bank, and soon it was found to be in circulation longer than the CS as it was available in silver and gold. Later other currencies were developed which were also based on silver and gold, which corresponded to the supply of these precious metals as they were stable and not subject to inflation.

During the First World War huge financial resources were required to finance military operations. Because the war lasted a full four years, they violated the gold standard and printed more money than they had gold and silver. As a result, the uncovered amount of money has increased and inflation has started to show. In the fifties of the last century they tried to get back the gold standard, so all currencies were tied to the dollar, and this contains an ounce of gold, which at the time was 35 dollars. Today, gold stocks are at an end, the money in circulation is growing and is us only on the trust of its users.

GOLD IN NANOTECHNOLOGY

Nanoparticles lie between bulk and atomic dimensions and are therefore endowed with special properties, thereby making them starting material for many futuristic applications. The properties of nanoparticles depend on their crystallite sizes [6]. Therefore, control over the particle sizes and particle distributions (PSDs), is highly desirable. Of the different classes of organic and inorganic (metal, dielectric, and semiconductor) nanoparticles, noble metal nanoparticles have fascinated scientists' from historic times because of their unique size- and shape-dependent optical properties [7].

Today the potential of Au nano- particles is recognised to derive from the addressability of their interesting optical properties via spectroscopic and photonic techniques [8]. For those spherical nanoparticles much smaller than the wavelength of light (diameter $d \ll \lambda$), an electromagnetic field at a certain frequency (ν) induces a

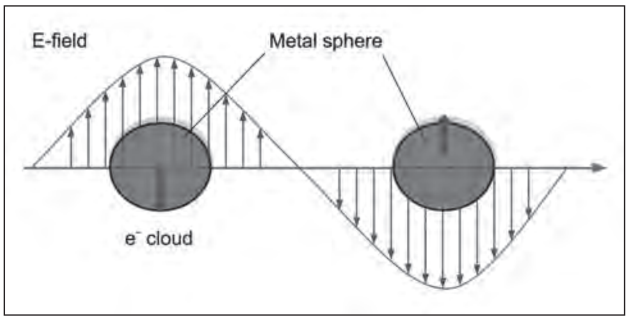

Figure 1 Schematic presentation of the interaction of a metal nano-sphere with light

resonant, coherent oscillation of the metal free electrons across the nano-particle (Figure 1). This oscillation is known as the surface Plasmon resonance [7,8].

The resonance lies at visible frequencies for Au metal. The surface Plasmon oscillation of the metal electrons results in a strong enhancement of absorption and scattering of electromagnetic radiation in resonance with the surface Plasmon resonance (SPR) frequency of the Au nanoparticles, giving them intense colours and interesting optical properties. The frequency and cross section of SPR absorption and scattering is dependent on the metal composition, nanoparticle size and shape, dielectric properties of surrounding medium/substrate and presence of inter-particle interactions. Au is the plasmonic metal of choice because of its much higher stability as compared to Cu and other metals. In addition, spherical Au colloids can easily be made in a wide range of sizes (4-80 nm) by facile chemistry involving the reductions of Au ions in solution [9]. Other interesting Au nanostructures (Figure 2) with modified optical properties e.g. nanorods, nanoprisms, triangular nanoparticles, nanocubes, and composite silica core Au-shell particles, can be fabricated via different techniques, such as: wet synthesis techniques, electrochemistry, photochemical techniques, nano-lithography, ultrasonic pyrolysis, etc.

Due to the phenomenon of SPR, the absorption and scattering cross-section of Au nanoparticles are signifi-

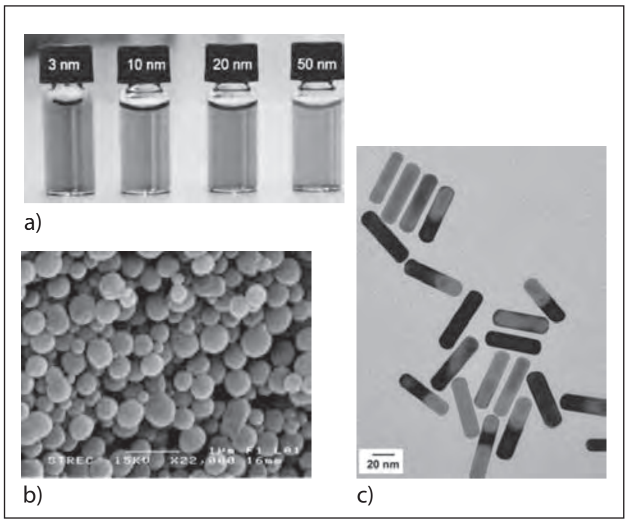

Figure 2 a) Photographs of colloidal dispersions of Au nanoparticles with increasing sizes, b) Au nanospheres, c) Au nanorods

cantly superior to the absorbing and fluorescing dyes used conventionally in biological and biomedical imaging [10]. Researchers demonstrated that the optical cross-sections of the Au-nanospheres are typically four to five orders of magnitude higher than those of conventional dyes. Current diagnostics and investigational techniques in molecular biology and biomedicine rely heavily on chemical contrast agents to stain/label specific cells and tissues of interest [11] in order to overcome the problem of weak signals of endogenous chromospheres and the subtle spectral differences between normal and diseased cells and tissues. Colloidal Au nanoparticles with strong SPR enhanced absorption and scattering are an important addition to the toolbox of imaging labels and contrast agents. Au nanoparticles are not susceptible to photo-bleaching and they appear to be biocompatible and non-cytotoxic, as supported by recent experiments on cells [11].

Another factor motivating the use of Au nanoparticles is their facile bio conjugation and bio modification [12]. The surface of Au nanoparticles has a strong binding affinity towards thiols, disulphides, and amines. In particular, the simple Au-thiol chemistry allows the surface conjugation of various peptides, proteins, and DNA. The electrostatic adsorption of biomolecules such as vitamin C and or large protein/enzyme molecules, to the nanoparticles` surface is a simple and commonly used technique for Au nanoparticles capped with citrate or similar carboxylic acid derivate.

GOLD IN DENTISTRY

Gold is the oldest dental restorative material, having been used for dental repairs for more than 4 000 years. These early dental applications were based on aesthetics rather than masticatory ability. The use of gold in dentistry remains significant today, with typical annual consumption estimated to be approximately - 70 - tonnes - worldwide. However, with an increasingly wide range of alternative materials available for dental repairs, it is considered appropriate to review the current gold based technology available today and thereby highlight the exceptional performance that competing materials must demonstrate if they are to displace gold from current usage.

In conservative and restorative dentistry, as well as in orthodontics, gold is used either as a pure metal, or alloyed together with noble metals and base metals. This use of pure gold is limited to direct filling of small occlusive cavities and no standard exists for the application and properties of direct filling with gold. However, pure gold used in this application is very soft (HV 25), has a very low 0,2 % proof stress (30 MPa), and a large elongation (45 %). As a result it can be cold worked very easily, a necessary requirement for filling a cavity precisely. Since gold fillings do not have high mechanical resistance against masticatory forces, they are only suitable for very small cavities. In recent years, pure gold has also been used through the electroforming process. Electroformed inlays and onlays are suitable to be cemented into cavities after they have been veneered with porcelain. Tooth restorations such as porcelain veneered copings for crowns and bridgework can be electroformed with pure gold. Unfortunately, no standard yet exists for this process, which is rapidly becoming an established mainstream technique in modern dentistry. A more common technique in conservative dentistry is cementing investment cast gold alloy inlays and onlays into cavities.

Gold alloys are used in dentistry, not only for their preferred golden colour [13], but also because they maintain an extremely high chemical stability in the mouth. They also possess several desirable mechanical properties such as high strength, ductility and elasticity [14]. From among the various types of alloys used for porcelain fused to metal (PFM) restorations, Au-Pt based high noble alloys have had the advantage of being around for some considerable time. They are part of clinical experience and are extremely successful [13]. High Au-content dental alloys, including Au-Pt alloys, show good biocompatibility due to the corrosion resistance of high noble elements [13]. Besides functional performance and aesthetics, biocompatibility is a third important requirement for dental restorative materials. Where dental restorations are based on the use of different alloys, there is the obvious potential for oral polymetallism. Indeed, two alloys of different composition have different electrochemical potentials and inevitably induce corrosion, with the subsequent release of metal ions into the tissue. The ion release from metallic prostheses and implants is the main cause of any unwanted primary and secondary reactions in the human body. This phenomenon may lead to the deterioration of dental devices and, in the worst case, may cause prosthesis failure or fracture.

CONCLUSIONS

The Future of Gold is in the Biomedical Industry and Dentistry and is connected to the historical development work concerning the properties of gold. If longevity, functionality, aesthetics and biocompatibility, together with ease of manufacture, are considered as the most important requirements, the optimum material for biomedical applications and dental restorations is still a well-approved high gold alloy.

On the other hand there is the application of gold in nano-technology. Gold nanoparticles in the 1-10 nm size range have special physic-chemical properties that are useful in a wide variety of applications such as cancer diagnostics, catalysis, Raman and fluorescence spectroscopy selective, ionisation of biomolecules, and single electronics. In the future commercial realisation of such applications relies on economical synthesis of size-controlled nanoparticles, which requires the development of continuous-flow versions of lab-scale processes.

ACKNOWLEDGEMENTS

This paper is part of a Slovenian Research Programme No. P2-0120, Bilateral Project SLO/SR BI-SR/10-10-022, and EUREKA Programme E!4213 NANO-FOILS. The authors thank Zlatarna Celje d.d., Celje, Slovenia, working on the Au-development.

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Note: The responsible translator for English language is mag. Shelagh Hedges Baker, Faculty of Mechanical Engineering, University of Maribor, Slovenia.

Орг. јед.	Број	Прилог	Вредност
03	958/2		

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Београд, 10.7.2012. год.
02 Број: 06 - 19091/68-12
БТ

На основу чл. 123. став 4 Закона о високом образовању ("Службени гласник РС", број 76/05, 100/07-аутентично тумачење, 97/08 и 44/10), чл. 46. ст. 5. тач. 3. Статута Универзитета у Београду - пречишћен текст ("Гласник Универзитета у Београду", број 162/11) и чл. 14. – 21. Правилника о већима научних области на Универзитету у Београду ("Гласник Универзитета у Београду", број 134/07, 150/9 и 158/11, а на захтев Стоматолошког факултета, број 958/1од 25.06.2012. године,

Веће научних области медицинских наука, на XIV седници одржаној дана 10. јула 2012. године, донело је

ОДЛУКУ

ДАЈЕ СЕ сагласност на предлог теме докторске дисертације:

Кандидат
Евгеније Марковић

Назив теме:„Утицај структуре ортодонтских жица на биокомпатибилност и перцепцију бола током почетне фазе лечења фиксним апаратима".

ПРЕДСЕДНИК ВЕЋА
Проф. др Нада Ковачевић

Доставити:
- Факултету
- секретару Већа
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Obrazac 1.

Fakultet STOMATOLOŠKI

Broj zahteva

16.08.2013.god.

(Datum)

UNIVERZITET U BEOGRADU

Stručno veće za medicinske nauke

(naziv stručnog veća kome se zahtev upućuje , shodno čl.6 Statuta Univerziteta u Beogradu i čl. 7. st.1 ovog pravilnika)

ZAHTEV

za davanje saglasnosti na izveštaj o urađenoj doktorskoj disertaciji

Molimo da, shodno članu 68. st.3. Zakona o univerzitetu ("Službeni glasnik RS" br. 20/98), date saglasnost na izveštaj o urađenoj doktorskoj disertaciji kandidata EVGENIJE SELIMIR MARKOVIĆ

(ime, ime jednog od roditelja i prezime)

KANDIDAT EVGENIJA SELIMIR MARKOVIĆ prijavila je doktorsku disertaciju pod nazivom

(ime, ime jednog od roditelja i prezime)

„UTICAJ STRUKTURE ORTODONTSKIH ŽICA NA BIOKOMPATIBILNOST I PERCEPCIJU BOLA TOKOM POČETNE FAZE LEČENJA FIKSNIM APARATIMA“

Univerzitet je dana 10.07.2012 svojim aktom pod br. 06-19091/68-12 dao saglasnost na predlog teme doktorske disertacije koja je glasila

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Komisija za ocenu i odbranu doktorske disertacije kandidata EVGENIJE SELIMIR MARKOVIĆ

(ime, ime jednog od roditelja i prezime)

obrazovana je na sednici održanoj 05.06.2013. odlukom fakulteta pod br. 3/52

u sastavu:

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DRAGOSLAV STAMENKOVIĆ	PROFESOR	STOM. PROTETIKA
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DEKAN FAKULTETA

Prof. dr Miroslav Vukadinović

Prilog:
1. **Izveštaj komisije sa predlogom**
2. **Akt Nastavno-naučnog veća fakulteta o usvajanju izveštaja**
3. **Primedbe date u toku stavljanja izveštaja na uvid javnosti, ukoliko je takvih primedbi bilo.**