ROMANIAN ACADEMY

STOMATOLOGY EDU JOURNAL

2018 VOLUME 5 ISSUE 4

# stomedu

A WORLD OF EDUCATIONAL RESOURCES FOR EACH PRACTICE

PUBLISHING HOUSE
OF THE ROMANIAN ACADEMY

4
2018

CE PROGRAM FAQs

HOFIGAL®

# Hofident Q10


**Product presentation:** Solution for oral hygiene.

**Composition (INCI):** aqua/water, alcohol, *Capsella Bursa Pastoris* extract, *Plantago Lanceolata* extract, *Chamomilla Recutita* extract, *Achillea Millefolium* extract, *Aesculus Hippocastanum* extract, *Mentha Piperita* extract, Ubiquinone.

**Action:** The product has antiseptic, healing, hemostatic, anti-inflammatory action, it acts as a antioxidant, detoxifier, deodorant. It is strongly recommended in gingivitis, stomatitis, thrush, compression pain causedby dental prostheses, after tooth extraction, in case of nipple lesion, bleeding gums, mouth and gum ulcers.

**Recommendations:** It delays dental plaque formation, it prevents bad odour and provides daily mouth hygiene.

# HofImun® FORTE


**Product presentation:**
Chewable tablets to stimulate the immune system

**Composition:** Each chewable tablet contains raspberry fruit extract *(Rubii idaei fructus)*, Echinacea extract *(Echinacea purpurea)*, concentrated extract of licorice root *(Glycyrrhiza radix)*, magnesium ascorbate and excipients.

**Action:** It stimulates the immune system, it is antiinflammatory, antiviral, antiseptic, it fluidifies the bronchial and pharyngeal secretions, antioxidant, cardioprotective, vasoprotective, it has antineoplastic antileukimic action, (due to the ellagic acid), it contributes to wound healing, fortifies and remineralizes (it regulates the potassium balance), it has antiulcer effects and is an overall body tonic.

**Recommendations:** to supplement the diet with nutrients and bioactive substances in: acute and chronic infections of the upper airways (angina, pharyngitis, laryngitis, bronchitis), prophylactic during periods with increased risk of infection with influenza viruses, it has sweating effects in fever, in recurrent herpes episodes of mucocutaneous rash, frequent urinary tract infections, inflammatory urogenital processes; immunodepression after radiotherapy or chemotherapy, bacterial skin infections, psoriasis, neurodermitis, chronic cardiovascular diseases associated with hypercholesterolemia, adjuvant in the diet indicated in the treatment of gastroduodenal ulcers, tonic during periods of physical and mental strain, exhaustion.


# Bucoprotect gel

**Product presentation:** Gel for oral hygiene.

**Composition (INCI):** aqua, *capsella bursa pastoris, calendula officinalis, achillea milefolium, hippophae rhamnoides, olea europea, hypericum perforatum,* carbomer, triethanolamine, collagen, *foeniculum vulgare, mentha piperita, citrus amara.*

**Action:** Antiseptic, anti-inflammatory, healing, stimulates the inside lining of the mouth and gums trophicity, reduces pain caused by specific oral diseases (gingivitis, stomatitis, lesions of the prosthesis, thrush, periodontitis).

**Recommendations:** Fights against bad breath (halitosis).

2 Intrarea Serelor Str., Sector 4,
042124, Bucharest, ROMANIA
Tel./Fax: +4021-334.59.05;
+4021-334.74.86;
+4021-492.00.69.
e-mail: office@hofigal.eu,
marketing@hofigal.eu
exportimport@hofigal.eu
web: www.hofigal.eu
www.revistahofigal.ro

stomaeduj

**2018 Volume 5 Issue 4**
**Pages 199-278**

**EDITOR OFFICE:**
Stomatology Edu Journal
102-104 Mihai Eminescu st., 2nd District
RO-020082 Bucharest, ROMANIA
Tel/Fax: +40314 327 930
e-mail: stomatology.edu@gmail.com
www.stomaeduj.com
**EDITORS:**
Jean-François ROULET
Rolf EWERS
Marian-Vladimir CONSTANTINESCU
**MANAGING EDITOR:**
Florin-Eugen CONSTANTINESCU
ROPOSTURO
Romanian Association of Oral Rehabilitation and Posturotherapy
10, Ionel Perlea St., 1st District
RO-010209 Bucharest, Romania
Tel: +4021 314 1062
Fax: +4021 312 1357
e-mail: roposturo@gmail.com
www.roposturo.stomaeduj.com
**TECHNICAL EDITOR:**
Gabriel Octavian LAZAR
Edgar MORARU
**PROJECT EDITOR:**
Irina-Adriana BEURAN
**DESIGN EDITOR:**
Dragoș Georgian GUȚOI
**COVER BY:**
Arch. Florin ADAMESCU

**PUBLISHER OFFICE:**
Romanian Academy Publishing House
13, Calea 13 Septembrie, 5th District
RO-050711 Bucharest, Romania
Tel: +4021 318 81 46, 4021 318 81 06
Fax: +4021 318 24 44
e-mail: edacad@ear.ro
www.ear.ro
**TECHNICAL EDITOR:**
Doina ARGEȘANU
**EDITORIAL ASSISTANT:**
Monica STANCIU
**COMPUTER EDITING:**
Iolanda POVARĂ

**SUBSCRIPTIONS**
S.C. MANPRES DISTRIBUTION S.R.L.
1, Piața Presei Libere, Corp B
3rd floor, room 301–302, 1st District
RO-013701 Bucharest, Romania
Tel/Fax: +4021 314 63 39
e-mail: abonamente@manpres.ro
www.manpres.ro

ISSN 2360 – 2406 (Print)
ISSN 2502 – 0285 (Online)
ISSN – L 2360 – 2406



# Contents

# EDITORIAL BOARD

# The Value of Consensus Conferences: Peer review by 50 key opinion leaders!

Richard Bengt PRICE
BDS, DDS, MS. PhD
FDS RCS (Edin), FRCD(C), Professor

Jean-François ROULET
DDS, Habil, Prof hc, Dr hc, Professor
Editor-in-Chief

Dear readers,

Fifty years ago, for the most part, all the dentist had to know about direct restorative materials was how to use dental amalgam and silicate cement. The preparation design for amalgams was well understood, and mechanical retention was a fundamental requirement. Reliable adhesion to both dentin and enamel was utopian, metal free ceramics were not durable, and light-cured resins had yet to be developed. Today, we have a multitude of materials and techniques that enable the dentist to produce direct and indirect restorations that are practically undetectable for both the dentist and the patient. However, there are tremendous consequences from having so many restorative materials and techniques available, and it has become more and more difficult for both practitioners and university professors to find their way through what is now considered a restorative jungle. On the one side, the internet offers in milliseconds a vast amount of information, which often sounds interesting and authoritative but, unfortunately, it is not always correct. Most dental schools claim to teach evidence-based dentistry and focus on providing treatment recommendations that are free from bias and based on prospective randomized double-blinded clinical trials. This approach should ascertain the truth, but has some severe disadvantages. Firstly, it requires a long time for valid results to be produced; secondly, patients cannot be standardized; thirdly, there is often an element of bias in that the exclusion criteria for the very studies that we rely on often eliminate some significant parts of populations that are candidates for the treatment being evaluated. Finally, ethical considerations often limit the questions that can be asked from a prospective randomized, double-blinded clinical trial. This is further compounded by the fact that it has been estimated that more than 95% of recent prosthodontic and implant review articles failed to use search strategies that were systematic, thus undermining the conclusions upon which treatment decisions are based [1].

One solution to the problems described above is a consensus conference. The principle is the following: experts, key opinion leaders, who represent the profession and industry come prepared to discuss a well-defined topic. Based on all their combined scientific, clinical and epidemiologic knowledge, together with presentations, a structured discussion occurs, in which proven, accepted information is sorted out from less valid information. In essence, this is now peer review by some 50 key opinion leaders instead of peer review by 2 or 3 selected reviewers for a 'peer reviewed' journal publication. At the end of such a conference, a draft consensus paper is formulated, which is subsequently reviewed, edited and approved by those key opinion leaders.

The Northern Light conferences at Dalhousie University in Halifax (Canada) have produced such recommendations for the light curing of direct restorations (2014) [2-4], dental light-curing units (2015) [5], bulk-fill restorations (2016)

[6], and light-curing adhesives (2017) [7,8]. In July 2018, 50 dentists, scientists, clinicians, teachers, manufacturers, editors, and key opinion leaders met in Oslo for 3 days to discuss two topics, the light curing of indirect restorations and what exactly is meant by the term 'bioactive' in the context of restorative materials. The complexity of the latter topic made for spirited discussions, however, after several rounds of refinement, we are proud to present the following consensus statements as part of this editorial. We hope that this information will help dentists provide restorations that exhibit excellent longevity. The information will also help the reader understand what a bioactive restorative material should do.

Sincerely yours,
R. Price and J.-F. Roulet

References


1. Layton D. A critical review of search strategies used in recent systematic reviews published in selected prosthodontic and implant-related journals: are systematic reviews actually systematic? Int J Prosthodont. 2017;30(1):13-21.
[PubMed] Google Scholar(5) Scopus(5)
2. Roulet JF, Price R. Light curing - guidelines for practitioners - a consensus statement from the 2014 symposium on light curing in dentistry held at Dalhousie University, Halifax, Canada. J Adhes Dent. 2014;16(4):303-304.
[Full text links] [PubMed] Google Scholar(13) Scopus(6)
3. Watts DC. Let there be More Light! Dent Mater. 2015;31(4):315-316.
[Pub Med] Google Scholar(4) Scopus(2)
4. Platt JA, Price RB. Light curing explored in Halifax. Oper Dent. 2014;39(6):561-563.
[Full text links] [PubMed] Google Scholar(7) Scopus(4)
5. Strassler H, Oxman J, Rueggeberg F. Light Curing- Tips on Choosing Your Next Curing Light. CDA Essentials 2016;3:30-33.
http://www.cda-adc.ca/en/services/essentials/2016/issue6/#1
6. Price R. Consesnsus Statements on Bulk Fill Composites. Canada Dental Assoc.
http://oasisdiscussions.ca/2017/06/07/csbf/
7. Gianinni M. Diretrices para obter sucesso clinico na adesão as estruturas dental. THE International Journal Of Esthetic Dentistry, v. 3, n. 2, 2018 (218-221).
8. Strassler HE, Alkhuabizi Q, Ganesh N. Reimaginng Dental Bonding: Predictable Restorations for Patients. Compendium of Continuing Education eBook, Nov 2018.
https://www.aegisdentalnetwork.com/media/71589; https://www.aegisdentalnetwork.com/cced/ebooks/reimagining-dental-bonding-predictable-restorations-for-patients/?hq_e=el&hq_m=5472145&hq_l=10&hq_v=b02f196240


## Light Transmission through Indirect Restorative Materials

a) There is an exponential decline in the amount of light that reaches the bottom of the restoration as its thickness increases.
b) There are considerable differences in the amount of light that is transmitted through the various types and shades of restorative material.
c) The shorter wavelengths (violet, ~ 410 nm) do not pass through materials as well as longer wavelengths (blue, ~ 460 nm) of light.
d) Future studies should account for external and internal reflection, refraction, and absorption due to variation in the surface finish and the incident angle of the light.

At the meeting, it was agreed that, when luting indirect restorations, dentists should:

- use the recommended adhesive - cement combinations, particularly when using self-etching universal adhesives together with dual-cure" resin cements;
- recognize that resins that are solely light-cured must receive sufficient light, check the thickness of the restoration, and stay within the cement manufacturer's instructions for use;
- recognize that most "dual curing" resin materials benefit from receiving additional light exposure;
- recognize that doubling the exposure time will not compensate for the reduction in transmitted light if the thickness of the restorative material thickness has doubled (e.g., from 1.0 to 2.0 mm);
- use "self-curing" or "dark-curing" resin cement systems that do not require any additional light when they are concerned that insufficient light will be delivered to the resin cement.

**Bioactive Restorative Materials (filling materials, adhesives, and cements)**

"Bioactivity" applied to a dental restorative material should describe an active beneficial biological process. It is suggested that dental restorative materials may be called "bioactive" if, in addition to their primary function of restoring or replacing missing tooth structure, they actively stimulate or direct specific cellular or tissue responses, or both, or they can control interactions with microbiological species. Such effects should be characterized by the field of application, the effect, and how the effect was scientifically proven.

The term "bioactive" may also be found in a wider sense to describe restorative materials that have one or more of the following:

- a character that causes the formation of reparative tissue;
- component(s) that dissolve that can be identified with normal physiological species that are involved in a biological process;
- component(s) that dissolve and happen to have antimicrobial activity (this includes high-pH materials);
- a surface conducive to cell attachment;
- a surface that may nucleate the formation of biological-like calcium phosphates, including bioapatite-like material, when in contact with saliva or tissue fluids;
- component(s) that dissolve and thereby cause local precipitation of biological-like calcium phosphates, including bioapatite-like materials, in a purely passive chemical process.

The Northern Light conferences at Dalhousie University in Halifax (Canada) have produced such recommendations for the light curing of direct restorations (2014) [2-4], dental light-curing units (2015) [5], bulk-fill restorations

References:


1. Hench LL. Bioactive ceramics. Ann N Y Acad Sci. 1988;523(1):54-71.
   [PubMed] Google Scholar(554) Scopus(265)
2. Hench LL. The story of Bioglass. J Mater Sci Mater Med. 2006;17(11):967-978
   [PubMed] Google Scholar(1479) Scopus(1031)
3. ADA. ACE Panel Report Bioactive Materials. ADA; 2018.
   https://www.ada.org/~/media/ADA/Science%20and%20Research/Files/ACE_Panel_Report_Bioactive_Materials_Q2_2018.pdf?la=en
4. Vallittu PK, Boccaccini AR, Hupa L, Watts DC. Bioactive dental materials-Do they exist and what does bioactivity mean? Dent Mater. 2018;34(5):693-694.
   [PubMed] Google Scholar(6) Scopus(4)
5. ISO 23317. Implants for surgery - In vitro evaluation for apatite-forming ability of implant materials. Geneva: International Organization for Standardization;2014.
6. Goldberg M, Schmalz G. Toward a strategic plan for pulp healing: from repair to regeneration. Clin Oral Investig. 2011;15(1):1-2.
   [PubMed] Google Scholar(8) Scopus(5)


**DOI: https://doi.org/10.25241/stomaeduj.2018.5(4).edit.1**

# Prerequisites to improve the quality of the editorial management system of the journal

Marian-Vladimir CONSTANTINESCU
DDS, MSc, PhD, Professor
Editor-in-Chief

Dear readers,

This fourth issue of the Stomatology Edu Journal (Stoma Edu J) closes a stage, namely the first five years in the existence of the journal. Together with the other two Editors-in-Chief, Prof. Jean-François Roulet (University of Florida) and Professor Rolf Ewers (Medical University of Vienna), we have tried to promote it in the academic and editorial space on all possible communication channels. I am deeply satisfied to tell you that through its important research, educational and specialty work, your Stomatology Edu Journal (Stoma Edu J) has managed to overcome the critical target mass of potential readers, the over 85,000 dentists in Central and Eastern European. Of course, if the 2013 census indicated there were 85,000 dentists, even though their number, with all the constant migration to the Western European countries, has increased by several thousand, the journal has been accessed by December 2018 by more than 190,000 readers, the difference being provided by readers in the United States, Great Britain, China, South Korea, India, Germany, Morocco, France, Seychelles, Greece, Turkey, Brazil, Austria, Honduras, Italy, Canada, Belize, Malaysia, the United Arab Emirates and others[1].

Upon its online appearance, the Stomatology Edu Journal (Stoma Edu J), in its first year of publication and after the second issue, in December 2014, had 190 unique visitors who made 534 visits to 1730 pages. There were 522 from Romania, 362 from France, 348 from Ukraine, 291 from USA, 56 from Germany, 18 from the UK, 16 from Austria, 14 from the Russian Federation, 12 from Japan, and 10 from Vietnam, Lebanon and Sweden. Now after 5 years, after the publication of 15 issues at the beginning of December, we present the readers with the following significant data: over 190,000 unique visitors they made 418,458 visits to 1,901,772 pages, 589,857, from Romania, 521,351 from USA, 177,888 from China, 164,851 from the Russian Federation, 60,674 from France, 52,791 from Ukraine, 22,552 from Germany, 13,602 from Canada, 12,346 from the United Kingdom, 12,019 from India, 8,024 from the Seychelles, 7,794 from Poland, 4.927 from South Korea, 4.191 from Brazil, 3.027 from Estonia, 2.518 from Italy, 1.913 from Moldova, 1.795 from Austria, 1.614 from the United Arab Emirates, and 1.350 from Israel. Exceeding the critical addressability number is due to several achievements accumulated during the five years of sustained activity that have increased the visibility of the Stomatology Edu Journal (Stoma Edu J), namely:

- constantly increasing the quality of the articles published due to the demanding work of the team of reviewers coordinated by Professor Emeritus, Stephen F. Rosenstiel, from The Ohio State University, Columbus, USA, Reviewer-in-Chief, to which there have been a series of prestigious Academic Editors associated since 2017;
- the scientific quality of the articles published has been consistently supported by the consistent language supervision permanently provided by the English Language Editor-in-Chief, Roxana-Cristina Petcu, Phil, PhD, Professor, University of Bucharest, Bucharest, Romania;
- access granted by the American Dental Association, ADA, to our readers from the first 2017 issue for each of the Stoma Edu J issues to an article with CE Program FAQs courtesy of Professor Michael Glick, American Dental Association Journal Editor, JADA, Mr. Michael Springer, Publisher, JADA, Mr. Nawin Gupta, Director of Business Operations, ADA and Mrs Stefanie K. Jewell-Thomas, Elsevier;
- the Crossref allocation of a unique alphanumeric string, namely a Digital Object Identifier (DOI) as of 2017 and the DOI identification will be retrospectively attributed to all articles published starting with the first number;

• adding, as of 2017, to all references mentioned in the articles published alongside the Digital Object Identifier (DOI), active links from PubMed, Google Scholar and Scopus to join the quoted publications circuit;
• positioning the journal in significant databases such as: Academia.edu[2]; InfoBase Index[3]; Google Scholar[4]; SHERPA / RoMEO[5]; National Library of Medicine (NLM)[6]; International Committee of Medical Journal Editors (ICMJE)[7].
• the evaluation and indexing by the Directory of Open Access Journals (DOAJ) in 2018 as a certification of the quality of the published articles. DOAJ posted on its website 40 articles, Abstract and Full Text[8].
In the coming months, we look forward to the scientific quality review and the technical evaluation from PubMed Central (PMC) and Clarivate Analytics. The PubMed Central (PMC) assessment consists in the mandatory compliance with the minimum technical publishing standards (PDF and XML) and the quality of the articles. The obligatory technical condition of the XML format has put us in a position to look for a language-savvy collaborator. Our new collaborator, Dr. Simon Cleemput, a dental student at the University of Leuven, Belgium, has offered to support the unanimous desire of the editors and many other authors so that the Stomatology Edu Journal (Stoma Edu J) could be registered in MEDLINE.
Professor J.-F. Roulet, guided by John Calvin Maxwell's quote, an American author focusing on leadership, "You can not solve tomorrow's problems with today's solutions." has decided to introduce an editorial management software https://manuscriptmanager.com. The software has been successfully used by Prof. J.-F. Roulet as editor of The Journal of Adhesive Dentistry, a journal rated IF: 1.691 (2017) and Oral Health & Preventive Dentistry for many years. This editorial software is a gift offered to me by Prof J-F Roulet on my 70th birthday . The benefits of this software that simplifies the peer review process will be enjoyed by all authors of the Stomatology Edu Journal (Stoma Edu J) starting with the first issue in 2019. Beginning on January 1st 2019, authors can log in to www.manuscriptmanager.net/stom[9], create a user name and password as an author and from then on the fully blinded peer review process will be accomplished in a hopefully fast and efficient way. The submitted manuscript will then be sent to reviewers by the click of a button by the editor and reviewers will be reminded automatically if they did not meet the deadlines. In order to respond to the invitation of the Romanian Academy to stimulate the international circulation of scientific information through the electronic archive - "Academica Romanian Index", I renew my request to every Editor who wishes to bring his scientific contribution to the Stomatology Edu Journal (Stoma Edu J) that, by March 1st, they should send a CV of maximum 250 words regarding their contribution in the field, surname, names, scientific titles, current administrative titles, the institution's logo and a recent 3.5 x 4.5 cm color photograph .
In line with the management software introduced to make the publishing team more accountable, to increase the quality of the published articles and the number of readers since 2019, the editorial board will be restructured and will be organized by topics. Allow me to thank you for your five-year presence in the Editorial Board and please do not forget the over 190,000 readers of the Stomatology Edu Journal (Stoma Edu J) who are waiting to read an article written by you and your colleagues as soon as possible.
On behalf of the Executive Editorial Board, I wish you and your loved ones a Blessed Christmas, a Happy New Year, and may your home be full of peace, health, well-being and joy.

Sincerely yours,
M-V Constantinescu
Editor-in-Chief

References


1. https://server4.megahost.net:2083/cpsess2757419012/awstats.pl?config=stomaeduj.com&ssl=&lang=en&login=1&post_login=902619333584140
2. http://independent.academia.edu/StomatologyEduJournal
3. http://www.infobaseindex.com/journal-accepted.php
4. https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=%22stomatology+edu+journal%22&oq=
5. http://www.sherpa.ac.uk/romeo/search.php?issn=2360-2406
6. https://www.ncbi.nlm.nih.gov/nlmcatalog/101699548
7. http://www.icmje.org/search/?q=stomatology+edu+journal
8. https://doaj.org/toc/2502-0285
9. https://www.manuscriptmanager.net/sLib/v4/login.php?paramScreen=jHJY/hWDHe9191l3TUyKW8TMk207pdjyWotrYzpoeRI=


**DOI: https://doi.org/10.25241/stomaeduj.2018.5(4).edit.2**

# Laudatio in Celebration of Professor Rolf Ewers on his 75th birthday

Together with the readers and the editors at the Stomatology Edu Journal we would very much like to congratulate Professor Rolf Ewers on his 75th birthday. Throughout his academic career he has shown visionary leadership in clinical commitment, clinical expertise, innovation and research creating a brand name at the Vienna University. His department was known for its excellence at the top of cranio-maxillo-facial surgery. During and after his academic career he has been the figurehead for many of us and serves as a living example of what can be achieved with intelligence, manual dexterity, perseverance, organisational and political talent, open mindedness and above all a profound understanding of patient care and commitment to each patient. He was born on 01.12.1943 in Litzmannstadt, Poland and attended school in Germany. Thereafter he spent one year as an exchange student in the United States. He graduated from the medical school and the dentistry one at Freiburg (Germany). Again he chose the United States for a surgical assistantship at the Downstate University Medical Center, Brooklyn – New York. His time in the US proved to be an excellent investment. Then he rose to academic prominence to the position of Professor Ordinarius and Chairman of the Department of Oral and Cranio-Maxillofacial Surgery at the University of Vienna, in November 1989, a position which he held till 2012. Being a savvy, hardworking and skillful surgeon with an excellent team around him, he came to be in the limelight of craniomaxillofacial surgery performing the first tongue transplantation in the world in 2003. He was granted German–Austrian dual nationality. Together with his wife Hildegund they raised 3 children: Josefine, Stephanie and Elisa. Hildegund is the most underestimated part of his biography. To channel such an academic storm of talent and keep a balance between career and family life takes both IQ and EQ and she perfectly knows how to be the Neck in this succesful Head and Neck combination. It is impossible for the Head not to turn in the same direction as Hildegund. Pursuing an academic career requires great sacrifices to meet the expectations of a University: research, articles, PhD, lectures, teaching, resident training programs, clinical excellence, clinical output and active participation in national and international meetings, boards and journals. All of these tasks to be fulfilled at a fixed and modest wage! Professor Rolf Ewers faced all these challanges without hesitation as if nature had gifted him with a constant stream of creativity and energy. He has written over 600 publications in the fields of cranio-maxillo-facial surgery either as author, senior author or co-author, as well as more than 20 chapters in books. He held more than 760 scientific lectures worldwide, more than 800 student lectures; he is a member of 29 professional associations, of 11 editoral boards of national and international peer reviewed journals. His scientific success is based on medical research. He devoted much of his time and interest in bone replacement materials with porous hydroxyapatite, bone inductive proteins and bioengineered bone production. He was a leader in the development of 3D-reconstruction techniques and computer-assisted intra-operative navigation, augmented virtual reality, and telesurgery.

He has been rightfully and frequently decorated with national and international prizes and awards.

We know he loves reading, bicycling, art, music and the State Opera in Vienna. We wish you and your family the very best in the future: enjoy life!

Constantinus Politis, MD, DDS, MHA, MM, PhD
Professor and Chairperson
Department of Oral and Maxillofacial Surgery
University Hospitals Leuven, Leuven, Belgium
Co-Editors-in-Chief (Europe) of Stomatology Edu Journal

DOI: https://doi.org/10.25241/stomaeduj.2018.5(4).letter.1

# 22nd of International Congress of Esthetic Dentistry, Istanbul, Turkey

Between 19th – 21st October, 2018, the Turkish Academy of Esthetic Dentistry (EDAD) held its 22nd edition of the International Congress of Esthetic Dentistry. An outstanding event, with over 600 participants, held in the beautiful city of Istanbul, where history and science perfectly combined together.

The congress lasts for 3 full days of an intensive training program with theoretical presentations in one main hall as well as workshops and practical courses in parallel side halls. In addition, Poster and Oral Presentations brought about one other element that colored the congress, along with a very interesting exhibition area where the most important companies in the dental market presented their latest novelties.

This year EDAD gathered the most significant speakers in the field of dentistry: Dr. Stavros Pelekanos from Greece, Dr. Gaetano Paolone from Italy, Dr. Florin Cofar from Romania, Dr. Mirela Feraru from Israel, Dr. Marcelo Calamita from Brazil, Dr. Florin Lazarescu from Romania, Dr. Dan Herschbach from Germany, Dr. Andrea Fabianelli from Italy, and many more. Among the highlights of the scientific program were the topics surrounding aesthetic dentistry, digital dentistry, concepts of full mouth rehabilitation, restorative dentistry, soft tissue management, etc.

The EDAD Foundation celebrating its 22nd anniversary this year, was spearheaded by Galip Gürel, Selim Pamuk, Ata Anıl, Gazanfer Gür, Hasan Alkumru, Ahmet Kurtaran, Mete Fanuscu and Engin Taviloğlu.

EDAD has brought Turkish dentists together with respected scientists' high-quality presentation techniques and intense case study-based seminars. EDAD has set its mission to become the primary channel to keep its members up-to-date with the advancements and changes in aesthetic dentistry in a quickly evolving technological environment, and has been successful in fulfilling its mission.

One of the most important advantages EDAD provides its members with is to show them that knowledge can be implemented in their practices without making concessions with respect to their academic knowledge. The EDAD congresses have been of utmost importance in teaching our dentists how to apply academic research to practical instruments rather than simply teach them the raw results of academic studies.

Furthermore, EDAD showed that a congress is not just a mere exchange of scientific information, but an opportunity for our colleagues to socialize and have fun in a common environment with scientists and their colleagues from different parts of the world.

Florin Lăzărescu, DDS
President, ESCD

**DOI: https://doi.org/10.25241/stomaeduj.2018.5(4).news.1**

Stoma Edu J. 2018;5(4):209

From The Journal of the American Dental Association

**JADA ONLINE CE EXAMS**
http://jada.ada.org/ce/home
http://jada.ada.org/ceworksheets

October 2018

Rebecca L. Slayton, DDS, PhD, Olivia Urquhart, MPH, Marcelo W.B. Araujo, DDS, MS, PhD, Margherita Fontana, DDS, PhD, Sandra Guzmán-Armstrong, DDS, MS, Marcelle M. Nascimento, DDS, MS, PhD, Brian B. Nový, DDS, Norman Tinanoff, DDS, MS, Robert J. Weyant, DMD, DrPH, Mark S. Wolff, DDS, PhD, Douglas A. Young, DDS, EdD, MS, MBA, Domenick T. Zero, DDS, MS, Malavika P. Tampi, MPH, Lauren Pilcher, MSPH, Laura Banfield, MLIS, MHSc, Alonso Carrasco-Labra, DDS, MSc

**EVIDENCE-BASED CLINICAL PRACTICE GUIDELINE ON NONRESTORATIVE TREATMENTS FOR CARIOUS LESIONS**

**A report from the American Dental Association**

J Am Dent Assoc. 2018 Jul;149(7):619–627.e1. doi: 10.1016/j.adaj.2018.02.025.

This article has an accompanying online continuing education activity available at: http://jada.ada.org/ce/home.

DOI: 10.1016/j.adaj.2018.07.002.


https://doi.org/10.1016/j.adaj.2018.07.002
https://jada.ada.org/article/S0002-8177(18)30469-0/fulltext

Continuing Education Online

Original Article

# INFLUENCE OF CHEWING LOAD ON WEAR RATE OF POLYMETHYL METHACRYLATE DOUBLE CROSS-LINKED DENTURE TEETH IN VITRO

**Jean-François Roulet[1a*], Abdullah Al-Naser[2b], William Martin[3c], Nader Abdulhameed[1d], Chiayi Shen[1e]**

[1] Department of Restorative Dental Sciences, College of Dentistry, University of Florida, Gainesville, FL, USA
[2] Department of Restorative Dental Sciences, Graduate Prosthodontics, College of Dentistry, University of Florida, Gainesville, FL, USA
[3] Center for Implant Dentistry, College of Dentistry, University of Florida, Gainesville, FL, USA

[a] DDS, PhD
[b] DDS, MS
[c] DMD, MS, FACP
[d] BDS, MS
[e] PhD

**ABSTRACT**

**DOI: 10.25241/stomaeduj.2018.5(4).art.1**

**Purpose of the Study**: Compare occlusal wear of PMMA DCL denture teeth under two different loads in vitro.

**Materials & Methods**: Sixteen mandibular second premolars (SR Orthoplane DCL) with a flat occlusal surface (specimens) were worn by sixteen maxillary second premolar-antagonists (Ortholingual DCL). These teeth were subjected in a chewing simulator (CS-4, SD Mechatronik) up to 240,000 loading cylces at 19.6N (LL ≈ full denture) and 68.6N (HL ≈ implant-overdenture) and TC (2,222 x 5 °C - 55 °C). Replicas of mandibular teeth were obtained at 0, 10,000; 20,000; 40,000; up to 240,000 cycles with polyvinyl-siloxane impressions and dental stone. Antagonist-replicas were made at baseline and at 240,000 cycles. The volumetric wear was determined with Geomagic after scanning replicas with a laser scanner. Linear regressions and ANOVA were used for statistical analysis.

**Results**: The wear rate of the HL-specimens was significantly higher than that of the LL-group ($p < 0.0001$). The LL-wear rate became linear after 60,000 cycles and was calculated to be $0.182 \times 10^{-6}$ mm$^3$/stroke. The HL-wear rate was linear from 20,000 to 140,000 cycles and was $1.056 \times 10^{-6}$ mm$^3$/stroke, then up to 240,000 cycles $0.656 \times 10^{-6}$ mm$^3$/stroke. At 240,000 cycles the HL-group showed significantly higher antagonist-wear ($p < 0.0001$). The antagonists in both groups demonstrated higher wear than their opposing specimens ($p < 0.08$).

**Conclusions**: HL generated significantly higher wear of both the specimens and the antagonists. The antagonists showed higher wear than the specimens. As a clinical consequence one may expect more wear of denture teeth in implant supported overdentures than in full dentures.

**Keywords**: wear, denture, PMMA, cross linked, in vitro.



**Peer-Reviewed Article**

**Citation:** Roulet J-F, Al-Naser A, Martin W, Abdulhameed N, Shen C. Influence of chewing load on wear rate of polymethyl methacrylate double cross-linked denture teeth in vitro. Stoma Edu J. 2018;5(4):210-219

**Academic Editor:** David Christopher Watts, BSc, PhD, DSc, Professor, The University of Manchester, Manchester, United Kingdom

Received: November 10, 2018
Revised: November 20, 2018
Acccepted: November 30, 2018
Published: December 04, 2018

***Corresponding author:** Professor Jean-François Roulet, DDS, PhD, Prof hc, Director of Center for Dental Biomaterials Department of Restorative Dental Sciences, College of Dentistry, University of Florida, 1395 Center Drive, Room D9-6, PO Box 100415, Gainesville FL 32610-0415, USA Tel: +1 352 273 5850; Fax: +1 352 846 1643, e-mail: jroulet@dental.ufl.edu



## 1. Introduction

Estimates show that in the US the adult population in need of one or two complete dentures will increase from 35.4 million adults in the year 2000 to 37.9 million adults in 2020 [1]. Despite the fact that prevention is able to avoid tooth loss [2,3] these numbers are very high. There are basically two reasons for this. First, the population demographics have changed dramatically. Based on US census statistics, there are substantial trends observed for the time period 1991 – 2020. The total adult population will increase significantly from 187 million to 245 million; adults aged 55 to 74 years will increase by 86% from 39,280,000 to 73,099,000 and senior adults 75 years and older will increase by 61%, from 13,489,000 to 21,835,000 [4,5]. Second, the population older than 55 did not profit much from the benefits of prevention [1], and finally the social structure [6,7] combined with health care insurance being not mandatory has favored tooth extractions vs restorative dentistry. Thus, the aging population will bring with it an increase in the number of teeth lost [8]; projections for 2050 predict the number of edentulous people in the US at 8.6 million [6]. Life expectancy will continue to increase due to advances in the medical fields.

For over 100 years, complete maxillary and mandibular dentures have been the traditional standard of care for edentulous patients [9], in which patients still perceive improved treatment success in terms of increased prosthesis retention and stability in this treatment method [10]. However, many patients have limitations with stability and retention; over 50% of mandibular prostheses had such problems [11]. Edentulous patients have prosthodontic and physiologic limitations. With respect to physiology, significant amount of mechanoreception is compromised after teeth loss due to absence of the periodontal ligament, which contains sensory fibers. It leads to abnormal changes in magnitude, precision, and direction of occlusal load application [12]. Awad et al [13] reported that incorporating new dentures may result in improvements of overall satisfaction

reported by patients, regarding aesthetics, comfort, and speech. On the other hand, for some patients, the incorporation of new dentures may not improve their function [13]. This confirms that there is a wide variety in the ability of edentulous patients to tolerate complete dentures [13,14]. Among elderly denture patients, 25 % experienced pain when chewing and 41 % needed more time for chewing. This can be explained with age related physiological changes, decreased motor control of the tongue, decreased biting force, and medication induced xerostomia [15]. People wearing full dentures have less than 20% of the masticatory performance of those with a natural dentition [16,17]. If a few teeth, preferably canines, are left and usable in the mandible, teeth supported overdentures can be incorporated, which means that complete dentures are supported by both edentulous ridges and the retained natural roots. This solution shows increased retention, stability, and comfort for the patients with increased quality of life [18]. With the introduction of titanium implants that osseointegrate in the 1970s [19-21] the way was open for implant supported overdentures with higher probability of success in the mandible when overdentures are supported by implants rather than tooth roots [22]. In the year 2002, the McGill consensus statement on overdentures declared that "Mandibular two-implant overdentures as first choice standard of care for edentulous patients [9] are based on an overwhelming evidence" [8]. This decision has been supported and the superiority of implant supported overdentures has been confirmed with systematic reviews [23,24].

Removable complete dentures consist of denture bases, which contain mostly polymethyl methacrylate [25]. Their designs are patient-specific, made during the prostheses processing in dental laboratories. Denture teeth are the other component of complete dentures, in general, there are three different materials used to fabricate teeth by dental manufacturers. The ceramic type was first introduced in Europe in 1789, its use is limited nowadays due to difficulty in adjustment and potential fracture from the denture base [26], although they have favorable esthetics and wear resistance. Acrylic resin denture teeth were introduced in the 1940s, and they contain mostly polymethyl methacrylate (PMMA). They are more frequently used than ceramic teeth in removable prosthodontics [27], due to some advantages such as excellent fracture toughness, easy occlusal adjustment and high bond strength to the denture base [28]. Their previous generations showed problematic wear resistance [29]. There are four subgroups under PMMA teeth; a) conventional unfilled, b) inorganically filled, c) highly cross-linked, and d) double cross-linked (DCL), which has improved mechanical and physical properties [30]. Composite resin denture teeth were introduced in the 1980s. It is claimed that they have more favorable esthetics and wear resistance [30].

Some studies showed an increase in motor control and perception in removable implant-retained prostheses [31]. In patients with complete dentures, a mean chewing force was reported in one study to be approximately 20 Newton [32], another study reported a mean chewing force of nearly 70 Newton in the mandibular implant-retained overdentures [33], indicating an overall increase of load on denture teeth within the studies' limitations.

**Table 1.** Ingredients of PMMA DCL denture teeth [60].

| Ingredients | Weight % |
|---|---|
| Polymethyl methacrylate | 33 - 35 |
| Dimethylacrylate | 5 - 7 |
| Cross-linked PMMA | 59 |
| UDMA/PMMA fillers | 0 |
| Pigments | < 0.5 |
| Initiators & stabilizers | < 0.5 |

Wear of acrylic resin teeth was reported in the literature. Wear is a phenomenon that occurs when two surfaces undergo a slipping movement under an applied load [34]. It is a complex, multifactorial process [35]. Abrasive wear occurs in natural and artificial teeth, it is the removal of material by the act of rubbing, cutting, or scraping [36]. Two-body abrasive wear occurs between denture teeth [37,38], which is friction between two surfaces without an abrasive agent or medium present. The attritional wear resistance of restorative materials limits the service time of the restorations [39].

Nowadays, many edentulous patients are treated using removable complete dentures with PMMA DCL denture teeth as a common choice, because of their better wear resistance [40]. In addition, there is an increased trend in patient acceptance of implant-retained overdentures. With a potential increase in motor control after implant treatment, it might be beneficial to know if the difference in chewing force will accelerate the wear of this type of popular artificial teeth. Therefore, the objective of this in vitro study was to compare the occlusal wear rate of the modern PMMA DCL denture teeth under two different loads. A low load simulated a mean chewing force in conventional complete dentures and a high load simulated a mean chewing force in implant-retained overdentures.

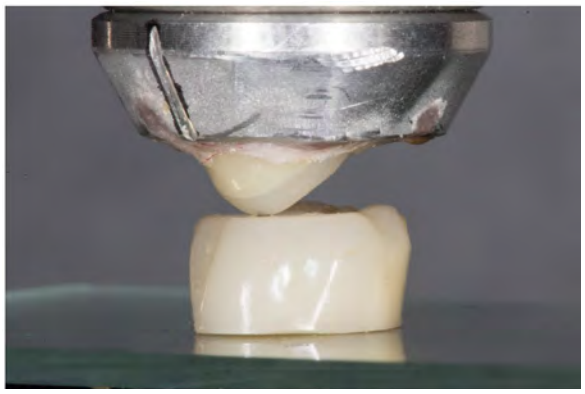
Null hypotheses:

- The in vitro wear of DCL PMMA denture teeth is independent of the chewing load;
- The in vitro wear of DCL PMMA denture teeth increases linearly with the number of chewing cycles.

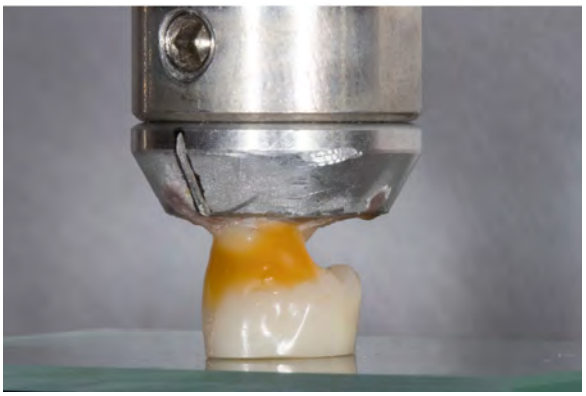
## 2. Materials and Methods

DCL PMMA denture teeth (Ivoclar Vivadent, Schaan, Liechtenstein) were selected. Sixteen mandibular second premolars (SR Orthoplane DCL ML6, REF 565849, LOT UP0794) were used as specimens and sixteen maxillary second premolars (Ortholingual DCL LU6, REF 565736, LOT UP2255) were used as antagonists. The composition of these denture teeth is shown on Table 1. These teeth were placed

**Figure 1.** Use of a polyvinyl siloxane putty jig to achieve consistent relationship between the antagonist teeth to their holders. Note the mechanical retention on the antagonist holder to obtain a rotation lock.



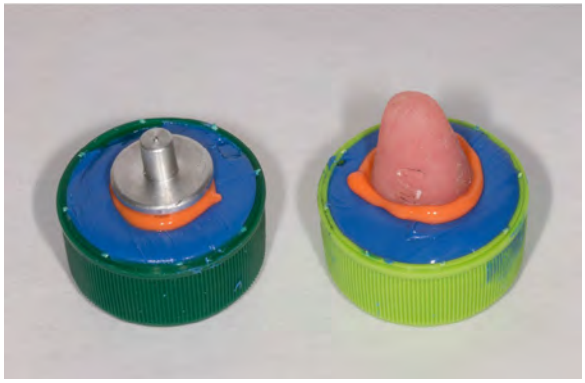
(a) A mounted antagonist tooth with its palatal cusp in contact with the center of a flat occlusal surface on a specimen tooth.



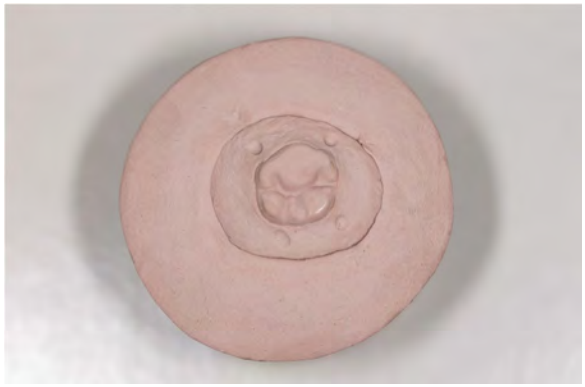
(b) A specimen tooth was stabilized onto its antagonist tooth using a dental stick wax.

(c) Lowering the mouting jig arm to position specimen teeth into cold-curing acrylic resin.

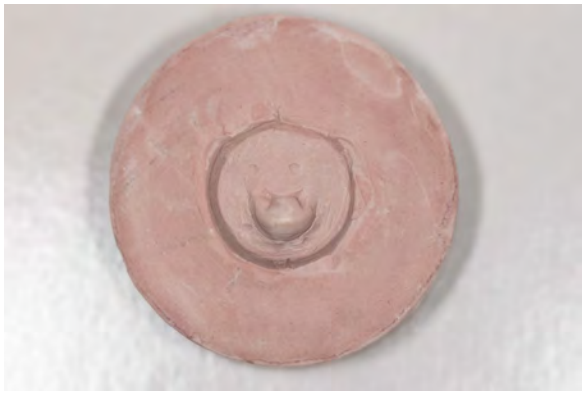
**Figure 2.** Mounting of specimen teeth (a, b, c).



(a) Impression making of an antagonist tooth (left) and a specimen tooth (right).



(b) A stone replica of a specimen tooth.



(c) A stone replica of an antagonist tooth.

**Figure 3.** Impression making of specimens and antagonists (a, b, c).

in a chewing simulator (CS-4, SD Mechatronik, Feldkirchen-Westerham, Germany) at two different loads:

1. 19.6 Newton (low-load group): 8 specimens and 8 antagonists
2. 68.6 Newton (high-load group): 8 specimens and 8 antagonists

The maxillary premolars (antagonists) were mounted with cold-curing acrylic resin (Pro Base Cold, Ivoclar Vivadent) onto antagonist metal holders, modified with a rotary instrument to achieve extra retention, air-abraded with aluminum oxide particles and conditioned with Monobond Plus (Ivoclar Vivadent). A polyvinyl siloxane putty jig (Virtual® XD Putty, Ivoclar Vivadent, Amherst, NY) was made after mounting the first antagonist in order to get consistent relationship between the antagonist teeth to their holders (Fig. 1). The antagonists were slightly tipped to position their palatal cusps at the highest point to be in contact with the specimens, their buccal cusps were shortened to

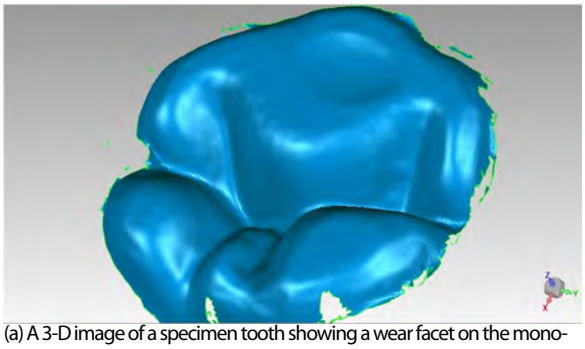
be in level with the embedding medium. A mounting jig system was used to conveniently achieve specific occlusal relationship between those prepared antagonists and their opposing specimens outside the chewing simulator machine. It was aimed to have each palatal cusp in contact with the center of the monoplane mandibular premolar's buccal cusp. Every mandibular premolar was stabilized using a small amount of dental sticky wax to a mounted antagonist in the defined position, and then the assembly was lowered into an individualized specimen holder, loaded with cold-curing acrylic resin for embedding (Fig. 2). These metal holders had irregular designs, in order to prevent positional errors. When the setting became fully completed, a polyvinyl siloxane putty jig was made to securely support the assembly's upper and lower components, which contained a pair of denture teeth, and then they were moved into the chewing simulator. The occlusal relationship in each pair of teeth was verified before having definitive positioning inside the machine.

The specimens were mounted randomly into the 8 chambers of the chewing simulator and stressed mechanically and thermally at 1.2 Hz with horizontal movement of 0.7 mm. Mechanical stresses were low-load (19.6 N) and high-load (68.6 N). Thermal stresses were introduced by cycling between 5 °C and 55 °C, dwell time was 30 s at each temperature with 15 s changing times for a total of 90 s per cycle. For 240,000 chewing strokes, there were 2,222 thermal cycles.

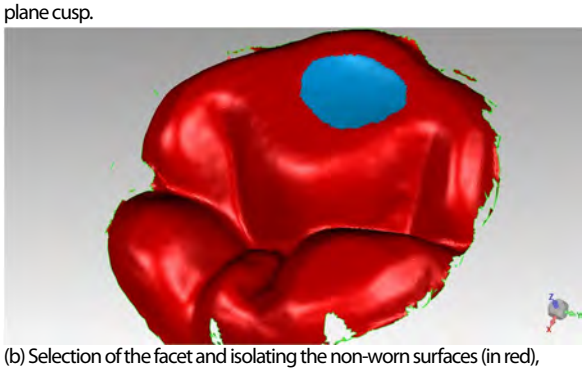
Impressions of mandibular teeth were obtained before starting the experiment and after 10,000; 20,000; 40,000; 60;000; 80,000; 100,000; 120,000, 140,000, 160,000, 180,000, 200,000, 220,000, and 240,000 chewing strokes using polyvinyl siloxane impression materials (Virtual® XD Extra-Light Body and Virtual® XD Heavy Body, Ivoclar Vivadent). Impressions of antagonist teeth were made at baseline and after the end of the experiment only. The following impression technique was used: one step heavy body/wash using small plastic containers (plastic bottle caps) as impressions trays (Fig. 3). The impressions were poured using type IV dental stone (Silky-Rock, Whip Mix, Louisville, U.S.) after being boxed (Fig. 3).

### 2.1. Quantification of wear

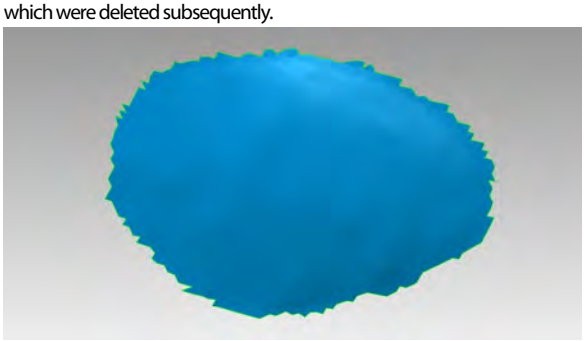
Stone models of both specimens and antagonists were scanned using a laser scanner (Laserscanner LAS-20, SD Mechatronik). The amount of wear was calculated using a 3-D software (Geomagic Control, 3Dsystems, Rock Hill, SC, USA). With respect to the specimens, the periphery of each worn area (facet) on the flat buccal cusp surface was selected first to be used as a reference. Then all the surrounding data (non-worn surfaces) were deleted, the depression inside the facet was filled using the "fill command", generating a flat surface coronally at the same level with the non-worn borders, the last step was to volumetrically measure the space within the worn area, which represented the amount material loss in cubic millimeter (Fig. 4). As for the antagonists, 3-D images of both the baseline and the final wear were superimposed using four reference points. Circular trimming was done for the superimposed models to delete all data that did not have any changes in the final wear image inferior to the worn cusp's borders. After isolating the superimposed worn and non-worn cusp tips the non-worn periphery was used as a reference to fill the space inside the cusp tip, volumetric measurements were taken in each model. The last step was to calculate the difference between them to yield in the material loss in cubic millimeter.



(a) A 3-D image of a specimen tooth showing a wear facet on the monoplane cusp.



(b) Selection of the facet and isolating the non-worn surfaces (in red), which were deleted subsequently.



(c) Close-up view: the facet area with its non-worn periphery after deleting the surrounding surfaces.

(d) Lateral view: the space within the facet was filled in creating a flat surface above in level with the non-worn periphery; it resembled the surface before starting wear simulation.

**Figure 4.** Quantification of wear in the specimen teeth (a-d).

### 2.2. Evaluation of wear pattern

Surface details of the wear areas of both selected specimens and antagonists were inspected after completion of chewing rounds using digital microscopy (VH-1000 series, KEYENCE, Itasca, IL, U.S.) at 100x magnification, in order to evaluate the wear pattern.

### 2.3. Statistical analysis

Linear regression (SAS 9.4) of the amount of wear in volume against the number of chewing cycles was used to determine the wear rate of each specimen tested. The statistical difference between the mean wear rates of the two loading groups was determined by linear regression, ANOVA, and Tukey test. The statistical differences of the mean of total volume of wear of antagonists and the specimens as influenced by the loading were determined with the T-tests.

## 3. Results

The experimental data show that there is a linear relationship between the cumulative wear volume and the number of cycles ($R^2$ > 95% for all specimens), excluding the first reading of the high-load group and the first two readings of the low-load group (Fig. 5). In addition, the high-load group appears to have two segments with distinct linear relation intersecting at 140,000 cycles. ANOVA and Tukey test showed significant differences ($p < 0.0001$) between the two segments (68.6N-1 and 68.6N-2) of the high load group and between the high load group and the low load group (Fig. 5, Tab. 2). For the high load group two separate wear rates were calculated: from 20,000 to 140,000 cycles it was 1.056 x $10^{-6}$ $mm^3$/stroke, then up to 240,000 cycles 0.656 x $10^{-6}$ $mm^3$/stroke. The wear rate of the low load group was 0.182 x $10^{-6}$ $mm^3$/stroke (Tab. 2).

The wear of the antagonists at the end of the experiment (240.000 cycles) is shown in Fig. 6. As for the sample teeth, there is a significant difference between the high load and the low load group. Comparing the sample wear with the antagonist wear at 240.000 cycles T-tests revealed statistical differences ($p < 0.001$) between low-load group and either segment of high-load group, and between the two segments of the high-load group (Tab. 3).

The microscopic images showed comparable wear patterns among the two groups' specimens, unlike that of the antagonists, which showed coarse and irregular surface texture in the low-load group as compared to the high-load group (Figs. 7 & 8).

## 4. Discussion

PMMA denture teeth have been used more frequently than other types due to favorable procedural and chemical properties [41]. Greater significance is added in studies when a commonly used material is selected for testing. The occlusal surface wear is a result of the combination of impact wear and sliding wear during process of mastication [42,43]. Progressive denture teeth wear results in insufficient posterior teeth support and consequently may lead to changes in the vertical and horizontal yaw relations and may cause functional and aesthetical impairments [44,45]. In order to assess the wear of a dental material such as denture teeth, it is advised to use impact and sliding as both occur on teeth surfaces during mastication. Denture teeth are used for edentulous patients, who have a reported mean chewing force of nearly 20 N wearing full dentures [32], and a mean chewing force of nearly 70 N with overdentures [33]. We assume that these values may reflect most clinical subjects, and can be used in chewing simulation studies.

A large number of chewing simulators have been used to determine in vitro wear of acrylic resin denture teeth [46-49]. In the present study the denture teeth were subjected to two-body wear, as it was reported in the literature [50-52]; it simulates the type of wear that occurs in full dentures with bilaterally balanced occlusion [51]. With respect to the selection of chewing cycles number, a wear simulation study

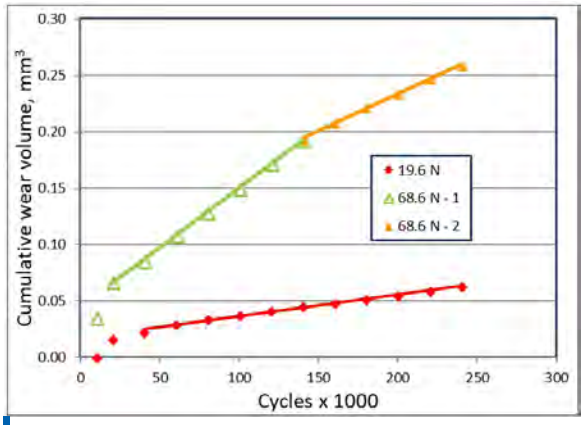



**Figure 5.** Mean wear volume as function of loading cycles. The high load group exhibits two segments (1 & 2) linear relationship and the straight line represents the best fit curve of the linear regression. ($p < 0.0001$).

**Table 2.** ANOVA and Tukey test for both segments of high load wear and the low load wear of the specimens. Dependent Variable: wear rate.

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 3.05751734 | 1.52875867 | 116.84 | <.0001 |
| Error | 21 | 0.27476608 | 0.01308410 | | |
| Corrected Total | 23 | 3.33228342 | | | |

| | R-Square | Coeff Var | Root MSE | CYCLE Mean |
|---|---|---|---|---|
| | 0.917544 | 18.10987 | 0.114386 | 0.631621 |

| Source | DF | Anova SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| LOAD | 2 | 3.05751734 | 1.52875867 | 116.84 | <.0001 |

| Tukey Grouping | Mean | N | LOAD (N) |
|---|---|---|---|
| A | 1.05603 | 8 | 68.6 |
| B | 0.65607 | 8 | 68.6 |
| C | 0.18277 | 8 | 19.6 |

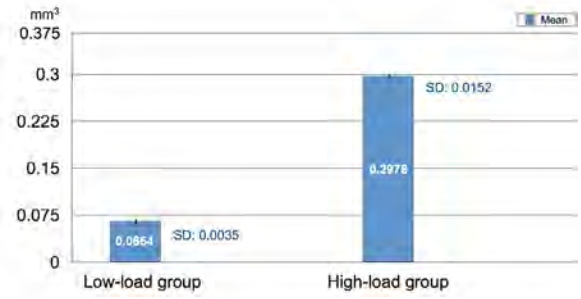
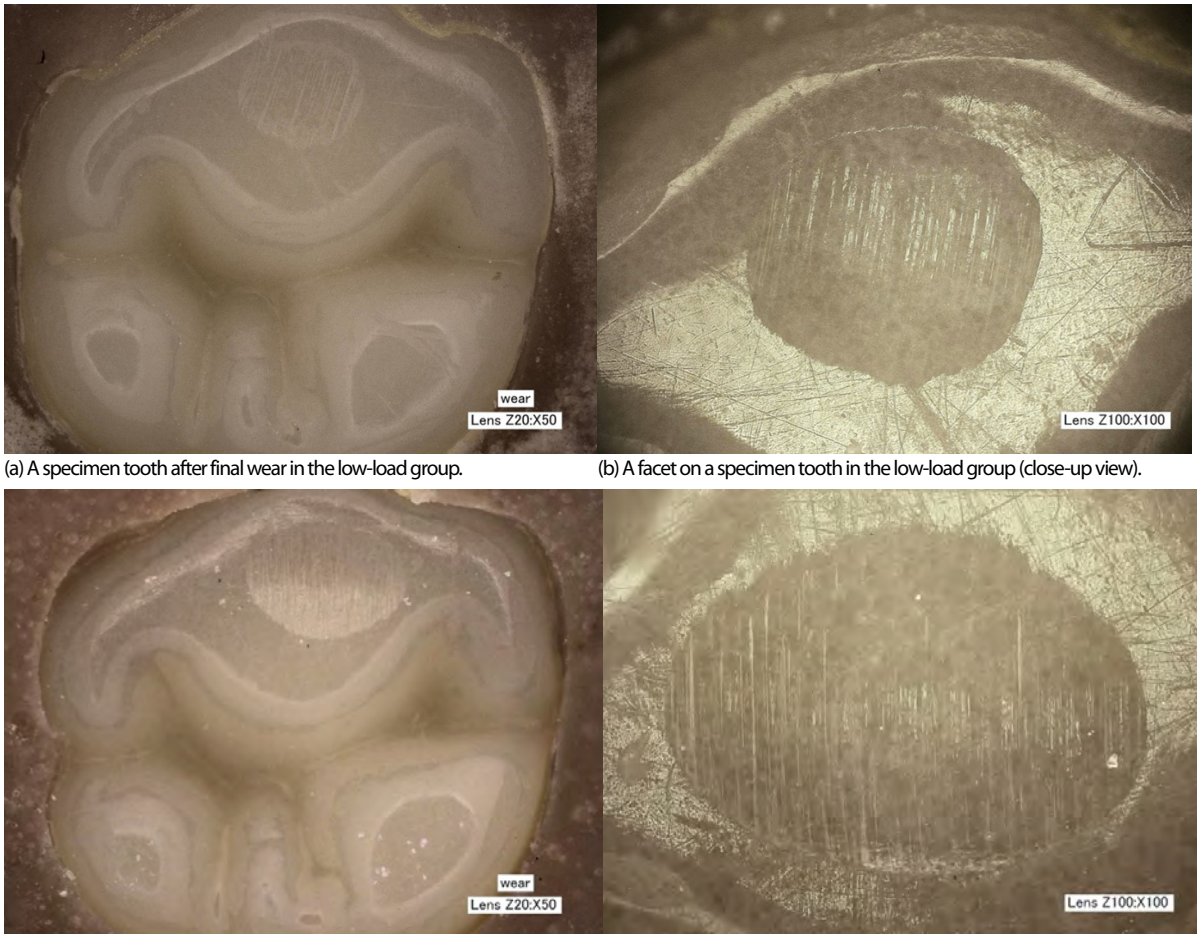



**Figure 6.** Wear of the antagonists in both groups (Mean ± SD), $p < 0.001$.

**Table 3.** Total wear volume (mean ± SD; in $mm^3$) at the end of the experiment. Different capital superscript letters show significant differences for columns and different low letters show significant differences for rows ($p < 0.001$).

| Type of surface | Loading cycle | |
|---|---|---|
| | 19.6 N | 68.6 N |
| Antagonist | $0.065 \pm 0.004^{Aa}$ | $0.298 \pm 0.015^{Ab}$ |
| Specimen | $0.063 \pm 0.002^{Ba}$ | $0.259 \pm 0.090^{Bb}$ |




(a) A specimen tooth after final wear in the low-load group.

(b) A facet on a specimen tooth in the low-load group (close-up view).

(c) A specimen tooth after final wear in the high-load group.

(d) A facet on a specimen tooth in the high-load group (close-up view).

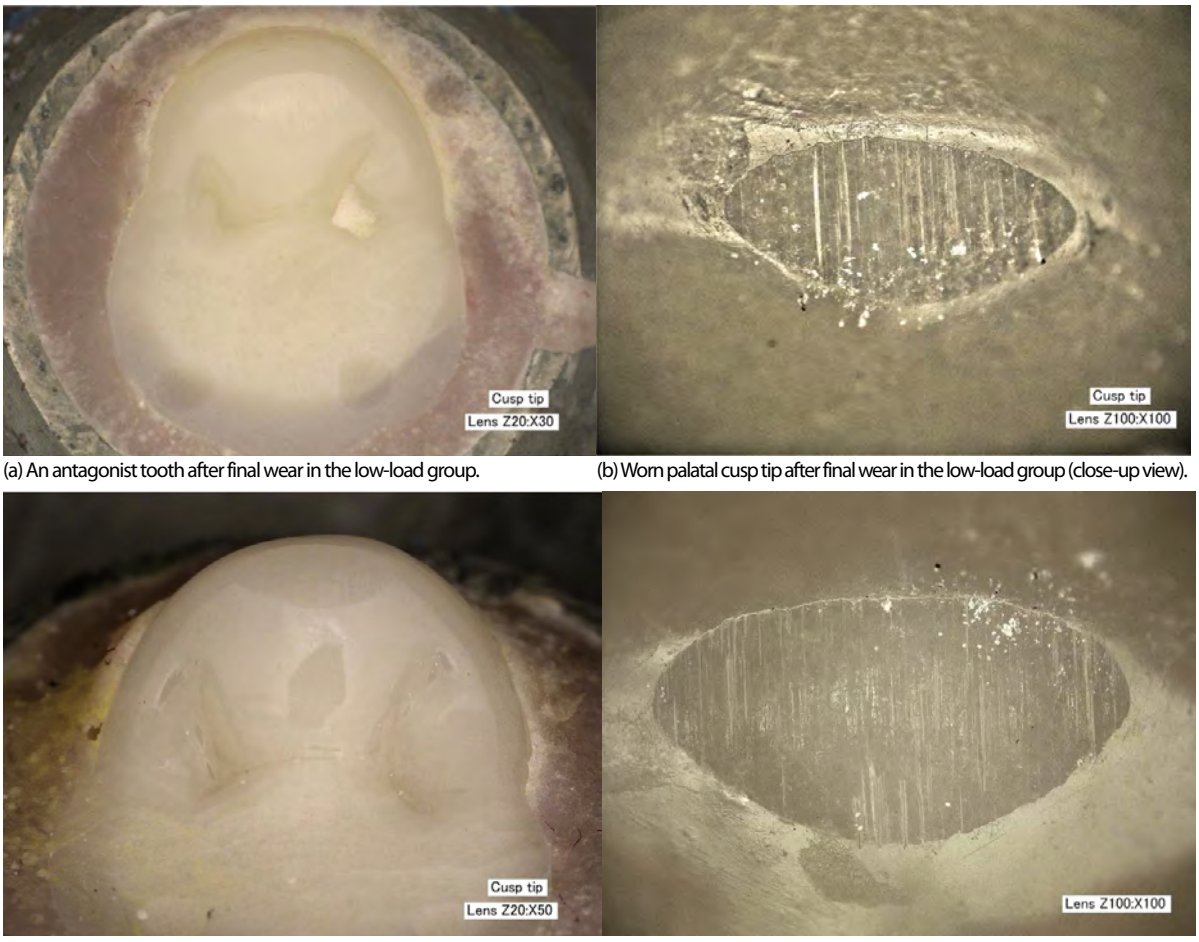
**Figure 7.** Microscopic digital images of specimen teeth in both groups a, b, c & d).

of IPN PMMA denture teeth had wear results after 200,000 chewing cycles [53] comparable to 1-year clinic follow-up results with the same material in two in vivo studies [54,55]. Thus, Coffey et al [53] assumed that the amount of wear occurring at 200,000 cycles would correspond to approximately 1 year of clinical function. Regarding the selection of fluid, distilled water was proved as a suitable intermediate medium, it did not have a significant difference with respect to mechanical properties of enamel and denture-base materials when compared to human saliva [56,57].

The selection of both specimens and antagonists denture teeth from the same material was done to simulate clinical conditions. The antagonist's material substantially influenced the wear rates in two-body wear [58]. In the present study, denture teeth with flat occlusal surfaces were used to simplify the wear analysis process. Measuring and interpreting the wear facet on a flat surface is more predictable than determining the wear on a complex occlusal surface with possibly more than one wear facet. Furthermore, it allowed comparisons with other studies using a similar approach [51]. When specimens with flat surfaces were exposed to antagonists from the same material, wear results were close to that of denture teeth's clinical wear [59]. Type IV low expansion dental stone replicas of denture teeth were produced after making polyvinyl siloxane impressions to investigate wear using a laser scanner, this method was considered accurate and reliable in other studies [59-61]. Furthermore, we had experienced distortions of the flat surface from wear facets scanned directly from ceramic discs [62]. The interpretation was that the laser beam, slightly entering a translucent surface was interacting with the material differently at an edge than on a regular surface. Therefore, for the present study the replica technique was preferred, where this phenomenon cannot happen with a stone surface.

The results of the present study showed significant differences in the wear rate between the low-load and the high-load groups for the specimens (Fig. 5) and the antagonists as well (Fig. 6). Mean wear rate of the high-load group specimens was 5.8 times greater before 140,000 cycles and 3.6 times greater after that turning point than the other group. As for their antagonists' mean wear rate, it was also greater by factor of 4.6. The linear regression analysis of the specimens wear rate showed an overall straight-line data in both groups, indicating approximately consistent relationship between number of cycles and amount of wear. No wear was detected in the low-load group until 10,000 chewing strokes, which might either show the lower limit of wear detection of this method or demonstrate favorable short-term wear resistance.

There are some possible explanations for the shift in the high-load group's specimens wear rate after




(a) An antagonist tooth after final wear in the low-load group.

(b) Worn palatal cusp tip after final wear in the low-load group (close-up view).

(c) An antagonist tooth after final wear in the high-load group.

(d) Worn palatal cusp tip after final wear in the low-load group (close-up view).

**Figure 8.** Microscopic digital images of antagonist teeth in both groups (a, b, c & d).

140,000 chewing strokes. Upon removal of fillers in the specimens due to the fatigue process of the filler/matrix during lateral movement, the antagonists became rough, causing accelerated wear [59]. The enamel layer's ingredients of the PMMA denture teeth might have different mechanical properties than that of dentin layer [25], it is possible that dentin layers of specimens and/or antagonists were exposed at around 140,000 strokes. The influence of the antagonist shape on wear rate of their opposing surfaces was reported, a ball-shape stylus generated significantly less wear on PMMA denture teeth than a conical ceramic stylus as it created less fatigue stress [59,63,64]. In the present study, more flattened antagonist's cusps appeared in the high-load group. We recommend using high-resolution microscopy to assess the ultrastructure of the specimens after each chewing round, which might help to detect possible differences in wear pattern. The difference may be due to the measuring technique as well. In the high load group some of the wear facets were extended slightly beyond the flat surface with the result that some of the volume was missing due to the fact that the flat surface was used as a reference.

The specimens' wear results were compared to previously reported data. One in vitro study showed significantly greater wear rate after 100,000 strokes [51] as compared to the low-load group in the present study, it might be caused by the abrasive nature of aluminum oxide antagonists and the greater chewing load they used (40 N) [51]. A 1-year clinical study showed a comparable result to the high-load group of the present study after 240,000 strokes, assuming the average number of annual chewing strokes is close to the suggested rate [65]. The results of the present study also support those from an in vitro study, which had steatite balls as antagonists, the researchers used 49 N chewing load [52], and their reported values were in between those of our low-load group and high-load group at both 120,000 and 240,000 strokes. Wear resistance is an important physical property of removable denture teeth [48,66]. Clinical problems were detected such as loss of vertical dimension, loss of masticatory efficiency, faulty teeth relationship that could affect patients and dental practice [11,44,67]. The previous generations of PMMA denture teeth had poor wear performance, as was detected in an in vitro three-body wear assessment for non-DCL PMMA teeth [29]. On the contrary, PMMA DCL denture teeth showed higher in vitro wear resistance than the conventional type [30,68]. With respect to the clinical wear assessment, patient-related factors should be considered, since there are differences among individuals in muscle activity, duration of dentures wear, presence or absence of para-functional habits and abrasiveness of food [65]. According to a clinical study, higher wear was detected in the implant-retained overdentures [33], this finding is in

agreement with the present study, since the high-load group had greater wear.

There are only a few data about wear patterns of denture teeth. One in vitro study that had scanning electron microscopy (SEM) evaluation for PMMA DCL teeth opposed by the same tooth type using 30 N load after 100,000 cycles [59]. A direct comparison with these data is difficult, we used digital light microscopy vs SEM being used by Heintze et al 2012 [59]. In one group Heitze et al [59] used antagonists of the same material as the worn surface, however different diameters, different load (30 N) and 3 mm sliding distance vs 0.7 mm in the present study. The wear pattern of the DCL specimens in both studies seems to be comparable, showing uniformity with parallel fine grooves.

## 5. Conclusion

Modern PMMA DCL denture monoplane mandibular premolars were used as specimens opposed by semi-anatomic maxillary premolars as antagonists in a wear simulation experiment, with the chewing load as a variable factor.

Within the limitations of this study:

• Significantly greater wear of both the specimens and the antagonists was detected when a chewing load of 68.6 N (high-load group) was used as compared to a load of 19.6 N (low-load group);

• Higher wear rate of the antagonists was detected as compared to the specimens in both groups;

• In the high-load group, higher wear rate of the specimens was detected in the first 140,000 chewing cycles as compared to the subsequent 140,000 cycles. As a clinical consequence one may expect more wear of denture teeth in implant supported overdentures than in full dentures.

## Author Contributions

JFR: Idea, experimental design, wrote final manuscript. AAN: Performed the experiment as part of the MS requirements, wrote initial manuscript. WM: experimental design, proofread manuscript. NA: supported experimental phase and data production. CS: statistical analysis, proofread manuscript.

## Acknowledgement

The authors thank Ivoclar Vivadent for donating the materials.

## References

1. Turkilmaz I, Company AM, McGlumphy EA. Should edentulous patients be constrained to removable complete dentures? The use of dental implants to improve the quality of life for edentulous patients. *Gerodontology*. 2010;27(1): 3-10. [Full text links] [PubMed] Google Scholar (120)
2. Roulet J-F, Zimmer S. *Prophylaxe und Präventivzahnmedizin*. Stuttgart, Germany: Georg Thieme Verlag, 2003. Google Scholar (21)
3. Axelsson P, Nyström B, Lindhe J. The long term effect of a plaque controlprogram on tooth mortality, caries and periodontal disease in adults. *J Clin Periodontol*. 2004;31(9): 749-757. [Full text links] [PubMed] Google Scholar (803) Scopus (404)
4. U.S. Bureau of Census. *Statistical Abstract of the United States: 1996*. 116th edition. Washington DCUS. Bureau of Census 1996. p 15, Tab. II, No 14.
5. U.S. Bureau of Census. *Statistical Abstract of the United States: 1996*. 116th edition. Washington DCUS. Bureau of Census 1996. p 17, Tab II No 17.
6. Slade GD, Akinkugbe AA, Sanders AE. Projections of US Edentulism prevalence following 5 decades of decline. *J Dent Res*. 2014;93(10): 959-965. [Full text links] [Free PMC Article] [PubMed] Google Scholar (106) Scopus (61)
7. Dye BA, Thornton-Evans G, Li X, Iafolla TJ. *Dental caries and tooth loss in adults in the United States, 2011-2012*. NCHS Data Brief No. 197, 2015. [Full text links] [PubMed] Google Scholar (75) Scopus (42)
8. Feine JS, Carlsson GE, editors. *Implant overdentures. The standard of care for edentulous patients*. Chicago, IL: Quintessence; 2003. Google Scholar (27)
9. Feine JS, Carlsson GE, Awad MA, et al. The McGill consensus statement on overdentures. Mandibular two-implant overdentures as first choice standard of care for edentulous patients. *Gerodontology*. 2002;19(1): 3-4. [Full text links] [PubMed] Google Scholar (379) Scopus (140)
10. Burns DR, Unger JW, Elswick RK Jr, Beck DA. Prospective clinical evaluation of mandibular implant overdentures: Part I - Retention, stability, and tissue response. *J. Prosthet. Dent*.1995;73(4): 354-363. [Full text links] [PubMed] Google Scholar (230) Scopus (102)
11. Redford M, Drury TF, Kingman A, Brown LJ. Denture use and the technical quality of dental prostheses among persons 18-74 years of age: United States, 1988-1991. *J Dent Res*. 1996;75 Spec No: 714-725. [Full text links] [PubMed] Google Scholar (152) Scopus (69)
12. Klineberg I, Murray G. Osseoperception: sensory function and proprioception. *Adv Dent Res*. 1999;13: 120-129. [Full text links] [PubMed] Google Scholar (103) Scopus (30)
13. Awad MA, Lund JP, Dufresne E, Feine JS. Comparing the efficacy of mandibular implant-retained overdentures and conventional dentures among middle-aged edentulous patients: satisfaction and functional assessment. *Int J Prosthodont*. 2003;16(2): 117-122. [PubMed] Google Scholar (309) Scopus (164)
14. Boerrigter EM, Stegenga B, Raghoebar GM, Boering G. Patient satisfaction and chewing ability with implant-retained mandibular overdentures: a comparison with new complete dentures with or without preprosthetic surgery. *J Oral Maxillofac Surg*. 1995;53(10): 1167-1173. [Pub Med] Google Scholar (145) Scopus (84)
15. Smith JM, Sheiham A. How dental conditions handicap the elderly. *Community Dent Oral Epidemiol*. 1979;7(6): 305-310. [Full text links] [PubMed] Google Scholar (193)
16. Kapur KK, Soman SD. Masticatory performance and efficiency in denture weares. *J Prosthet Dent*. 1964;14(4): 687-694. [PubMed] Google Scholar (210)
17. Heath MR. The effect of maximum biting force and bone loss upon masticatory function and dietary selection of the elderly. *Int Dent J*. 1982;32(4): 345-356. [PubMed] Google Scholar (225) Scopus (121)
18. Dodge CA. Prevention of complete denture problems by use of "overdentures". *J Prosthet Dent*. 1973;30(4 Pt 1): 403-411. [PubMed] Google Scholar (58) Scopus (24)
19. Brånemark PI, Hansson BO, Adell R, et al. Osseointegrated implants in the treatment of the edentulous jaw. Experience from a 10-year period. *Scand J Plast Reconstr Surg*. 1977;16: 1-132. [PubMed] Google Scholar (2751) Scopus (1927)
20. Schroeder A, Pohler O, Sutter F. [Tissue reaction to an implant of a titanium hollow cylinder with a titanium surface spray layer]. [Article in German]. *Schweiz Mschr Zahnheilk*. 1976;86(7): 713-727. [PubMed] Google Scholar (134) Scopus (0)
21. Schroeder A, Sutter F, Ledermann PD, Stich H. [Current experience with the ITI double hollow cylinder implant type K. Internationales Team für orale Implantologie].[Article in German]. *Schweiz Mschr Zahnheilk*. 1984;94(6):503-510. [PubMed] Google Scholar (3) Scopus (0)
22. Mericske-Stern R, Steinlin Schaffner T, Marti P, Geering AH. Peri-implant mucosal aspects of ITI implants supporting overdentures. A five-year longitudinal study. *Clin Oral Implants Res*. 1994;5(1): 9-18. [Full text links] [PubMed] Google Scholar (370) Scopus (157)
23. Thomason JM, Kelly SA, Bendkowski A, Ellis JS. Two implant retained overdentures--a review of the literature supporting the McGill and York consensus statements. *J Dent*. 2012;40(1): 22-34. [Full text links] [PubMed] Google Scholar (175) Scopus (102)
24. Boven GC, Raghoebar GM, Vissink A, Meijer HJ. Improving masticatory performance, bite force, nutritional state and patient's satisfaction with implant overdentures: a systematic

review of the literature. *J Oral Rehab*. 2015;42(3): 220-233. [Full text links] [PubMed] Google Scholar (76) Scopus (42)
25. Heintze SD, Monreal D, Rousson V. Fatigue resistance of denture teeth. *J Mech Behav Biomed Mater*. 2016;53: 373-383. [Full text links] [PubMed] Google Scholar (10)
26. Marchack BW, Yu Z, Zhao XY, White SN. Adhesion of denture tooth porcelain to heat-polymerized denture resin. *J Prosthet Dent.* 1995;74(3): 242-249. [Full text links] [PubMed] Google Scholar (30) Scopus (16)
27. Ghazal M, Kern M. Wear of denture teeth and their human enamel antagonists. *Quintessence Int.* 2010;41(2): 157-163. [Full text links] [PubMed] Google Scholar (22) Scopus (10)
28. Ekfeldt A, Oilo G. Wear mechanisms of resin and porcelain denture teeth. *Acta Odontol Scand.* 1989;47(6): 391-399. [PubMed] Google Scholar(36) Scopus(29)
29. Winkler S, Monasky GE, Kwok J. Laboratory wear investigation of resin posterior denture teeth. *J Prosthet Dent*. 1992;67(6): 812-814. [Full text links] [PubMed] Google Scholar (53) Scopus (24)
30. Suzuki S. In vitro wear of nano-composite denture teeth. *J Prosthodont.* 2004;13(4): 238-243. [Full text links] [PubMed] Google Scholar (102) Scopus (53)
31. Abarca M, van Steenberghe D, Malevez C, et al. Neurosensory disturbances after immediate loading of implants in the anterior mandible: an initial questionnaire approach followed by a psychophysical assessment. *Clin Oral Investig.* 2006;10(4): 269-277. [Full text links] [Free PMC Article] [PubMed] Google Scholar (73) Scopus (40)
32. Michael CG, Javid NS, Colaizzi FA, Gibbs CH. Biting strength and chewing forces in complete denture wearers. *J Prosthet Dent.* 1990;63(5): 549-553. [Full text links] [PubMed] Google Scholar (118) Scopus (67)
33. Fontijn-Tekamp FA, Slagter AP, Van Der Bilt A, et al. Biting and chewing in overdentures, full dentures, and natural dentitions. *J Dent Res.* 2000;79(7): 1519-1524. [Full text links] [PubMed] Google Scholar (638) Scopus (366)
34. Sulong MZ, Aziz RA. Wear of materials used in dentistry: a review of the literature. *J Prosthet Dent.* 1990;63(3): 342-349. [Full text links] [PubMed] Google Scholar (151) Scopus (70)
35. Burwell JR. Survey of possible wear mechanisms. *Wear.* 1957;1(2): 119-141. Google Scholar (389) Scopus (168)
36. Ferracane JL. *Materials in dentistry: principle and application.* Philadelphia: J.B. Lippincott, 1995; 293-311. Google Scholar (318)
37. Harrison A, Lewis TT. The development of an abrasion testing machine for dental materials. *J Biomed Mater Res.* 1975;9(3): 341-353. [PubMed] Google Scholar (118)
38. Harrison A, Huggett R. Measuring the rate of wear of artificial teeth in complete dentures. *J Prosthet Dent.* 1975;33(6): 615-619. [Full text links] [PubMed] Google Scholar (14) Scopus (8)
39. Kern M, Strub JR, Lü XY. Wear of composite resin veneering materials in a dual-axis chewing simulator. *J Oral Rehabil.* 1999;26(5): 372-378. [Full text links] [PubMed] Google Scholar (205) Scopus (138)
40. Reis KR, Bonfante G, Pegoraro LF, et al. In vitro wear resistance of three types of polymethyl methacrylate denture teeth. *J Appl Oral Sci*. 2008;16(3): 176-180. [Full text links] [Free PMC Article] [PubMed] Google Scholar (31) Scopus (18)
41. Stober T, Henninger M, Schmitter M, et al. Three-body wear of resin denture teeth with and without nanofillers. *J Prosthet Dent.* 2010;103(2): 108-117. [Full text links] [PubMed] Google Scholar (34) Scopus (14)
42. Kim SK, Kim KN, Chang IT, Heo SJ. A study of the effects of chewing patterns on occlusal wear. *J Oral Rehabil.* 2001;28(11): 1048-1055. [Full text links] [PubMed] Google Scholar (73) Scopus (46)
43. Mair LH, Strlarski TA, Vowles RW, Loyd CH. Wear: mechanisms, manifestations and measurement. Report of a workshop. *J Dent.* 1996;24(1-2): 141-148. [Full text links] [PubMed] Google Scholar (386) Scopus (209)
44. Rammelberg P, Pospiech P, Gernet W, et al. [Etiologic factors of disk displacement in the TMJ]. [Article in German]. *Dtsch Zahnärztl Z.* 1996;21: 211-218. Google Scholar (365)
45. Yip KH, Smales RJ, Kaidonis JA. Differential wear of teeth and restorative materials: clinical implications. I*nt J Prosthodond.* 2004;17(3): 350-356. [PubMed] Google Scholar (115) Scopus (57)
46. Cornell JA, Jordan JS, Ellis S, Rose EE. A method of comparing the wear resistance of various materials used for artificial teeth. *J Am Dent Assoc.* 1957;54(5): 608-614. [Full text links] [PubMed] Google Scholar (56) Scopus (19)
47. Satoh Y, Nagai E, Maejima K, et al. Wear of denture teeth by use of metal plates. Part 2: Abrasive wear of posterior teeth. *J Nihon Univ Sch Dent.* 1992;34(1): 16-27. [PubMed] Google Scholar (0) Scopus (9)
48. Zeng J, Sato Y, Ohkubo C, Hosoi T. In vitro wear resistance of three types of composite resin denture teeth. *J Prosthet Dent.* 2005;94(5): 453-457. [Full text links] [PubMed] Google Scholar (79) Scopus (42)
49. ISO/TS 14569-2: 2001 (en). *Dental materials-Guidance on testing or wear-part 2. Wear by two- and three body contact.* https://www.iso.org/obp/ui/#iso:std:iso:ts:14569:-2:ed-1:v1:en
50. Kunzelmann KH1, Bürkle V, Bauer C. Two-body and three-body wear of glass ionomer cements. *Int J Paediatr Dent.* 2003;13(6): 434-440. PMID: [Full text links] [PubMed] Google Scholar (24) Scopus (8)
51. Stober T, Lutz T, Gilde H, Rammelsberg P. Wear of resin denture teeth by two-body contact. *Dent Mater.* 2006;22(3): 243-249. [Full text links] [PubMed] Google Scholar (90) Scopus (51)
52. Ghazal M, Steiner M, Kern M. Wear resistance of artificial denture teeth. *Int J Prosthodont.* 2008;21(2): 166-168. [PubMed] Google Scholar (25) Scopus (60)
53. Coffey JP, Goodkind RJ, DeLong R, Douglas WH. In vitro study of the wear characteristics of natural and artificial teeth. *J Prosthet Dent.* 1985;54(2): 273-280. [Full text links] [PubMed] Google Scholar (85) Scopus (41)
54. Harrison A. Clinical results of the measurement of occlusal wear of complete dentures. *J Prosthet Dent.* 1976;35(5): 504-511. [Full text links] [PubMed] Google Scholar (34) Scopus (23)
55. 55.Ogle RE, David LJ, Ortman HR. Clinical wear study of a new tooth material: Part II. *J Prosthet Dent. 1*985;54(1): 67-75. [Full text links] [PubMed] Google Scholar (48) Scopus (27)
56. Douglas WH, Sakaguchi RL, DeLong R. Frictional effects between natural teeth in an artificial mouth. *Dent Mater.* 1985;1(3): 115-119. [Full text links] [PubMed] Google Scholar (46) Scopus (31)
57. Al-Mulla MA, Murphy WM, Huggett R, Brooks SC. Effect of water and artificial saliva on mechanical properties of some denture-base materials. *Dent Mater.* 1989;5(6): 399-402. [Full text links] [PubMed] Google Scholar (27) Scopus (17)
58. Abe Y, Sato Y, Akagawa Y, Ohkawa S. An in vitro study of high-strength resin posterior denture tooth wear. *Int J Prosthodont.* 1997;10(1): 28-34. [PubMed] Google Scholar (34) Scopus (15)
59. Heintze SD, Zellweger G, Grunert I, et al. Laboratory methods for evaluating the wear of denture teeth and their correlation with clinical results. *Dent Mater.* 2012;28(3): 261-272. D [Full text links] [PubMed] Google Scholar (23) Scopus (14)
60. Heintze SD, Zellweger G, Sbicego S, et al. Wear of two denture teeth materials in vivo-2-year results. *Dent Mater.* 2013;29(9): e191-e204. [Full text links] [PubMed] Google Scholar (13) Scopus (10)
61. Mehl A, Gloger W, Kunzelmann KH, Hickel R. A new optical 3-D device for the detection of wear. *J Dent Res.* 1997;76(11): 1799-807. [Full text links] [PubMed] Google Scholar (279) Scopus (173)
62. Esquivel-Upshaw J, Hsu S, Abdulhameed N, et al. *Volume loss and depth analysis using stylus profiler and laser scanner.* Poster No 0668 presented at: IADR/AADR/CADR General Session; March 23, 2017; San Francisco, CA, USA. https://iadr.abstractarchives.com/abstract/17iags-2638172/volume-loss-and-depth-analysis-using-stylus-profiler-and-laserscanner
63. Krejci I, Lutz F, Zedler C. Effect of contact area size on enamel and composite wear. *J Dent Res.* 1992;71(7): 1413-1416. [Full text links] [PubMed] Google Scholar (49) Scopus (30)
64. Condon JR, Ferracane JL. *Effect of antagonist diameter on in vitro wear of dental composite*. Poster No 954 presented at: AADR/CADR Annual Meeting; March 14, 2003; San Antonio, TX, USA. https://iadr.abstractarchives.com/abstract/2003SanAnton-27566/effect-of-antagonist-diameter-on-in-vitro-wear-of-dental-composite
65. Schmid-Schwap M, Rousson V, Vornwagner K, Heintze SD. Wear of two artificial tooth materials in vivo: a 12-month pilot study. *J Prosthet Dent.* 2009;102(2): 104-114. [Full text links] [PubMed] Google Scholar (26) Scopus (12)
66. Ogle RE, Davis EL. Clinical wear study of three commercially available artificial tooth materials: Thirty-six month results. *J Prosthet Dent.* 1998;79(2): 145-151. [Full text links] [PubMed] Google Scholar (64) Scopus (36)
67. Lindquist TJ, Ogle RE, Davis EL. Twelve-month results of a clinical wear study of three artificial tooth materials. *J Prosthet Dent.* 1995;74(2): 156-161. [Full text links] [PubMed] Google Scholar (33) Scopus (16)
68. Douglas WH, Delong R, Pintado MR, Latta MA. Wear rates of artificial denture teeth opposed by natural dentition. *J Clin Dent.* 1993;4(2): 43-47. [PubMed] Google Scholar (28) Scopus (18)

**Jean-François ROULET**

DDS, DMD, PhD, Dr hc, Prof hc, Professor, Chair
Department of Restorative Dental Sciences, Center for Dental Biomaterials
College of Dentistry, University of Florida
Gainesville, FL, USA

## CV

Jean-François Roulet, DDS, Dr med dent, PhD, is the former chair and current professor of the Department of Restorative Dental Sciences at the University of Florida. Professor Roulet is author/coauthor of more than 180 papers, edited/contributed to 27 textbooks and mentored more than 150 theses. He is a renowned international lecturer with over 800 appearances to date. Dr. Roulet is a member of many professional organizations, has won numerous awards, and holds four patents. He is editor of Prophylaxe Impuls and Stomatology Edu Journal. His areas of interest include minimally invasive dentistry, dental materials (ie, composites and ceramics), adhesive dentistry, esthetic dentistry, and application concepts in preventive dentistry.

## Questions

### 1. Which teeth were worn?

❑a. Ceramic;
❑b. Double crosslinked PMMA;
❑c. PMMA;
❑d. Composite.

### 2. Which loads were used?

❑a. 50 and 100 N;
❑b. 20 and 80 N;
❑c. 19.6 and 68.6 N;
❑d. 20 and 50 N.

### 3. How many load cycles were performed?

❑a. 120,000;
❑b. 240,000;
❑c. 500,000;
❑d. 2,222.

### 4. Which result is correct?

❑a. The high load group showed significantly higher wear;
❑b. The samples showed more wear than the antagonists;
❑c. The antagonists showed equal wear in both load groups;
❑d. There were no statistically significant differences in wear of the samples.

Original Article

# EFFECT OF POWDERED GREEN TEA MATCHA ON BIOFILM FORMATION BY MUTANS STREPTOCOCCI

**Mochamad Fahlevi Rizal**[1,2a], **Noboru Kaneko**[1a*], **Hiroshi Ogawa**[1b]

[1]Division of Preventive Dentistry, Department of Oral Health Science, Graduate School of Medical and Dental Sciences, Niigata University, Japan
[2]Department of Pediatric Dentistry, Faculty of Dentistry, Universitas Indonesia, Indonesia

[a]DDS, PhD, Assistant Professor
[b]DDS, MDSc, PhD, Professor and Head

## ABSTRACT

**Introduction:** Antibacterial ingredients with high safety and mild taste that can be used for mouthwash for children are required. Matcha is one of the natural beverages that is made from the leaves of *Camellia sinensis* and widely consumed by Japanese and Asian people. This study aimed to evaluate the effectiveness of matcha in suppressing biofilm formation by mutans streptococci, typical cariogenic bacteria.

**Methodology:** Five laboratory strains of *Streptococcus mutans* (serotype c, e and f) and *Streptococcus sobrinus* (serotype d and g) were used to evaluate the antibacterial effect of matcha. Matcha extract was added to bacterial cells in Heart Infusion broth supplemented with 1% sucrose (HIS). After incubation for 24 hours, the formed biofilm was dyed by Crystal Violet, and optical density at 490 nm was determined as the amount of biofilm formation. The effect of 0.02% chlorhexidine in HIS and MilliQ in HIS were also measured as well.

**Results:** The amounts of biofilm formation by all serotypes of mutans streptococci in matcha + HIS were significantly lower than those in MilliQ + HIS as were chlorhexidine in HIS, except *S. sobrinus* serotype g. The differences of amounts biofilm formation by all *S. mutans* (serotype c, e and f) and *S. sobrinus* serotype d in matcha + HIS and in chlorhexidine + HIS were not significant statistically.

**Conclusion:** Matcha extract has an equivalent effectiveness of 0.02% chlorhexidine against most serotypes of mutans streptococci.

**Keywords:** *Streptococcus mutans, Streptococcus sobrinus*, chlorhexidine, green tea, mouthwash.

DOI: 10.25241/stomaeduj.2018.5(4).art.2



**Peer-Reviewed Article**

**Citation:** Rizal MF, Kaneko N, Ogawa H. Effect of powdered green tea matcha on biofilm formation by mutans Streptococci. Stoma Edu J. 2018;5(4):220-225.

**Academic Editor:** Mircea Ioan Popa MD, PhD, Professor, Head Microbiology Department II, "Carol Davila" University of Medicine and Pharmacy, Bucharest, Romania

Received: November 30, 2018
Revised: December 07, 2018
Accepted: December 17, 2018
Published: December 18, 2018

***Corresponding author:**
Assistant Professor Noboru Kaneko, DDS, PhD, Division of Preventive Dentistry, Department of Oral Health Science, Graduate School of Medical and Dental Sciences, Niigata University, 2-5274, Gakkocho-dori, Chuo-ku, Niigata City, Japan
Tel: +81 25 227 2857, Fax: +81 25 227 0807, e-mail: nkaneko@dent.niigata-u.ac.jp

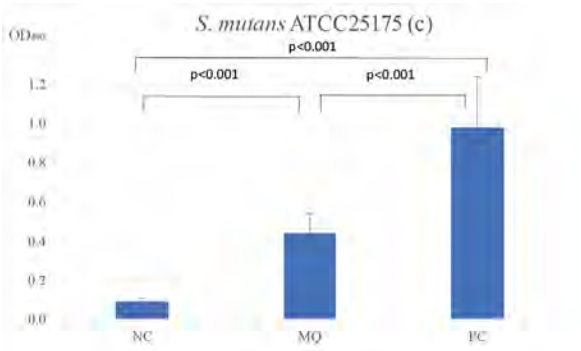


## 1. Introduction

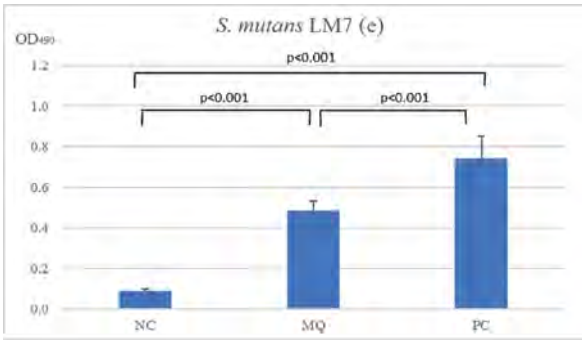
Efforts to obtain antibacterial ingredients that meet the criteria of comfort, especially taste, are needed to improve the quality of the oral cavity. Oral health is inseparable from the normal flora balance of the oral cavity in order to prevent the occurrence of caries and gingivitis. The use of natural ingredients that are commonly consumed by the wider community in a place needs to be expanded in the functions of maintaining public health, especially oral health [1]. The ease of getting it and the consumption habits of the community makes it easy for materials like this to be accepted by the community if proven to have good effects on oral health. Because caries and gingivitis are also a problem in children in many countries, especially with developmental disabilities, natural ingredients as an antibacterial for the oral cavity are urgently needed to be easily accepted by the child community, both in terms of safety and ease of use [2-4]. Each community has unique ingredients developed in its area, but has not been utilized optimally in addition to regular consumption of food and beverages [5].

Green tea (*Camellia sinensis*) is commercially available in the market in three forms: Loose leaf, bagged and powdered (matcha) [6]. Matcha is generally consumed in Japan as a beverage that has high anti-oxidants such as flavonoids [7]. Many natural foods and beverages that are commonly consumed by people in a region, such as honey in the tropical regions, olive oil, virgin coconut oil and others have been partially known to have antibacterial effects especially in the oral cavity [8]. With many natural sources like ginger and garlic that also have flavonoid and are commonly used in Asia one needs to observe the antibacterial effect on oral bacteria [9]. As a comparison, chlorhexidine has been used for many years as a strong antibacterial standard and is also used in dentistry for preventive measures and treatment but the taste becomes an issue especially for children [10].

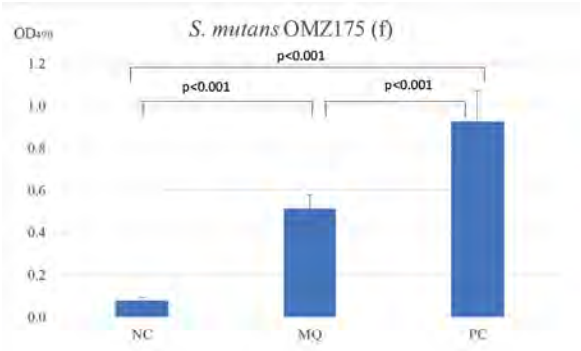
The streptococci that are commonly related to the human caries process are *Streptococcus mutans* and *Streptococcus sobrinus*. These cariogenic bacteria are divided into 5 serotypes (c, e, f, d and g) [11]. There has been no study on the antibacterial effects of matcha against each serotype of mutans streptococci. It is expected that the results of research related to antibacterial from natural sources can be used



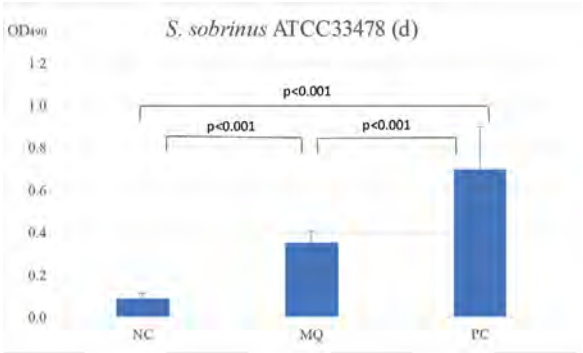

(a)



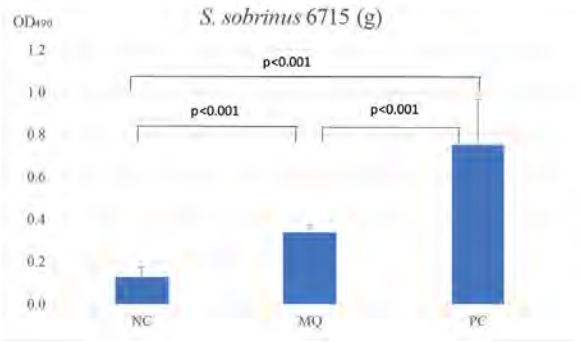

(b)




(c)




(d)




(e)

**Figure 1.** Biofilm formation in NC (MilliQ alone), MQ (MilliQ + bacterial cells in HIS) and PC (bacterial cells in HIS) by each strain of mutans streptococci:
(a) *S. mutans* ATCC25175 serotype c,
(b) *S. mutans* LM7 serotype e,
(c) *S. mutans* OMZ175 serotype f,
(d) *S. sobrinus* ATCC33478 serotype d,
(e) *S. sobrinus* 6715 serotype g.

to prevent infection in order to minimize chemical substances [12]. This study aimed to evaluate the effectiveness of matcha in suppressing biofilm formation by each serotype of mutans streptococci.

## 2. Material and Methods

### 2.1. Preparation of antibacterial solutions

As a matcha solution, 5 gram of powdered green tea matcha (Itoen, Tokyo, Japan) was added to 100 mL of water at 100˚C and boiled for 15 minutes to extract. Prior to use in the laboratory, the solution was filtered using 0.20 µm Minisart filter (Sartorius, Göttingen, Germany). The chlorhexidine solution used in this study was 0.02% and was prepared from 20% chlorhexidine gluconate (Wako Pure Chemical, Osaka, Japan).

### 2.2. Culture of mutans streptococci

As mutans streptococci, we used 3 laboratory strains of *S. mutans* (serotype c, e, f) and 2 laboratory strain of *S. sobrinus* (serotype d, g) (Table 1). Each strain from -80 ˚C stock was cultured in Brain Heart Infusion (BHI) broth (Becton Dickinson Maryland, USA) at 37 ˚C overnight and then also sub-cultured in BHI broth. The bacterial solution was centrifuged and dissolved in Heart Infusion broth (Becton Dickinson Maryland, USA) supplemented with 1% sucrose (HIS) until it reached 1 x $10^6$ CFU/ml which was then used for the biofilm assay as strain culture.

### 2.3. Biofilm assay

The biofilm formation of each strain was evaluated using a 96 well plate. Each plate was divided into 5 areas of 12 wells and labeled as MT for wells that were filled by matcha solution and strain culture, CHX for wells that were filled by 0.02% chlorhexidine and strain culture, MQ for wells that were filled by MilliQ and strain culture, NC for wells that were filled by milliQ alone as negative control and PC for wells that were filled by HIS and strain culture as positive control (Table 2).
After 24 hours of incubation, the culture supernatant was discarded, and each well was washed twice with 200 µL Phosphate Buffered Saline (PBS). A 200 µL volume of 0.5% crystal violet was then added and incubated at 37 ˚C for 15 minutes.
The remaining crystal violet solution was discarded, the

**Table 1.** Strains of mutans streptococci used in this study.

| Strain | Serotype | |
|---|---|---|
| *Streptococcus mutans* | | |
| ATCC25175 | c | (type strain) |
| LM7 | e | |
| OMZ175 | f | |
| *Streptococcus sobrinus* | | |
| ATCC33478 | d | (type strain) |
| 6715 | g | |

**Table 2.** Composition of cultures for biofilm assay.

| | Antibacterial solution | Bacterial cells in HIS | HIS | MilliQ | Total |
|---|---|---|---|---|---|
| PC | 0 µL | 100 µL | 100 µL | 0 µL | 200 µL |
| MT | 100 µL | 100 µL | 0 µL | 0 µL | 200 µL |
| CHX | 100 µL | 100 µL | 0 µL | 0 µL | 200 µL |
| MQ | 0 µL | 100 µL | 0 µL | 100 µL | 200 µL |
| NC | 0 µL | 0 µL | 0 µL | 200 µL | 200 µL |

PC: positive control; MT: matcha solution; CHX: 0.02% chlorhexidine gluconate; MQ: milliQ solution; NC: negative control

biofilm was washed once with 200 mL PBS, and then 200 µL of 96% ethanol was added to each well. The optical density of the biofilm formation was then measured at 490 nm ($OD_{490}$) using a microplate reader [13].

### 2.4. Statistical analysis

The $OD_{490}$ values evaluated as biofilm formation were compared between NC, MQ and PC to confirm the validity of the measurement. Then $OD_{490}$ values of MT, CHX, NC and MQ were compared to determine the differences in their effects on biofilm formation. In order to compare the differences, t-test and Bonferoni correction were used.

All statistical analyses were performed using SPSS statistics 19 (IBM, USA); p values of 0.05 or less were considered significant.

## 3. Results

Fig. 1 shows $OD_{490}$ values which mean amount of biofilm formation of NC (MilliQ alone), MQ (MilliQ + bacterial cells in HIS) and PC (bacterial cells in HIS) by *S. mutans* (serotype c, e and f) and *S. sobrinus* (serotype d and g), respectively. The $OD_{490}$ of PC showed significantly higher values than MQ, and those of MQ showed significantly higher values than NC in all strains (serotype c, e, f, d and g).

Fig. 2 shows $OD_{490}$ values which mean amount of biofilm formation of MT (matcha solution + bacterial cells in HIS), CHX (CHX solution + bacterial cells in HIS), NC (MilliQ alone) and MQ (MilliQ + bacterial cells in HIS), respectively. The $OD_{490}$ of MT, CHX and NC showed significantly lower values than MQ and no significant difference was found between MT, CHX and NC in all *S. mutans* (serotype c, e and f) and *S. sobrinus* (serotype d). In *S. sobrinus* serotype g, the $OD_{490}$ of MT showed lower value than MQ though the difference did not reach statistical significance. The $OD_{490}$ of CHX and NC showed significantly lower values than MQ and MT in *S. sobrinus* serotype g.

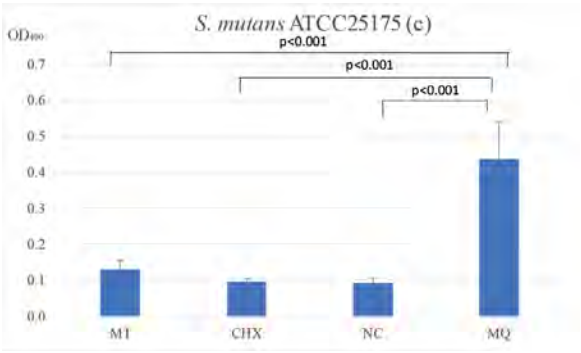
## 4. Discussion

The $OD_{490}$ of PC showed significantly higher values than MQ and those of MQ showed significantly higher values than NC in all strains, which indicated that the biofilm assay used in this study could evaluate the amount of biofilm formation adequately. The $OD_{490}$ of MT and CHX showed significantly lower values than MQ and the differences between MT, CHX and NC were not significant in all strains except *S. sobrinus* serotype g. This means that the antibacterial effect of matcha solution resemble CHX solution in most strains of mutans streptcocci.

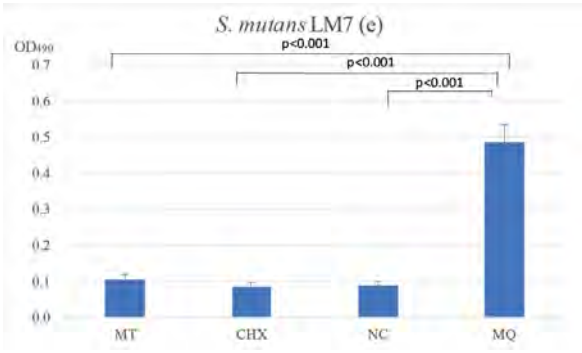
This in-vitro research provides an overview of the antibacterial effects of matcha on various strains of mutans streptococci. Mutans streptococci are considered as typical cariogenic bacteria [14,15]. Mutans streptococci can be classified into five serotypes, with dominant serotypes being slightly different locally. The effect of matcha against *S. sobrinus* serotype g was not significant among all mutans streptococci strains of serotype examined in this study. However, in oral cavity of humans worldwide, *S. sobrinus* serotype g is not a type that found dominantly [16-19]. In other study *S. sobrinus* serotype g more resistance to chlorhexidine than *S. mutans* and *S. sobrinus* serotype d [20]. Therefore, matcha is thought to have the effect of inhibiting biofilm formation for most of mutans streptococci in oral cavity. One of the cariogenic properties of these bacteria owes the high performance of glucan synthesis to sucrose, which contributes to the biofilm formation [21,22]. So, the effectiveness of matcha in suppressing the biofilm formation by mutans streptococci colonization was important to be evaluated in this study. The better antibacterial will suppress more types of strains, meanwhile caries are not only caused by a single bacterial but related to the biofilm activity involving many bacteria [23].

Chlorhexidine is a common ingredient as an antibacterial agent and is widely used for mouthwashes [24-28]. However, chlorhexidine has a taste issue, and it has problems such as side effects on the mucosa and tooth coloring, so it is not suitable for mouthwashes in children [29,30]. The concentration of chlorhexidine used clinically is 0.12% and 0.2%, while in this study using a concentration of 0.02%. It was proved that the concentration of 0.03% was as effective as 0.12% or 0.2% concentration clinically [31-33]. The result of this study revealed that the low concentration of 0.02% chlorhexidine can inhibit biofilm formation of mutans streptococci.

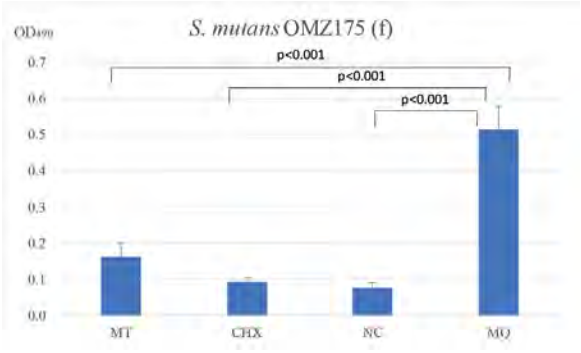
Matcha has long been used for drinking and the safety has been established. The requirements for mouthwash that can be used by children are related to safety issue [34,35]. It is also considered to have less problems with taste. Therefore, it is considered that matcha is suitable as an ingredient for mouthwash for children. The bacteria investigated this time are mutans streptococci and are strongly related to dental caries. However, there are many others bacteria in the oral cavity related to dental caries and other oral disease such as periodontitis. In this study, we did not consider the influence on other such cariogenic bacteria and periodontal disease related bacteria.



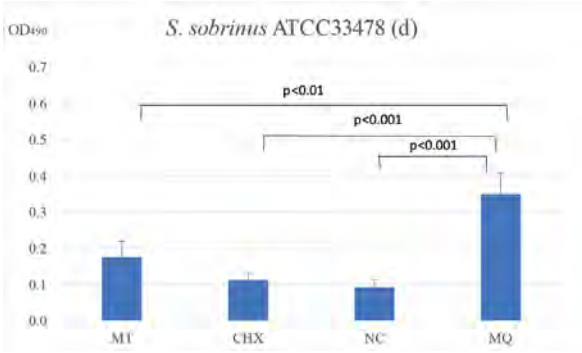

(a)



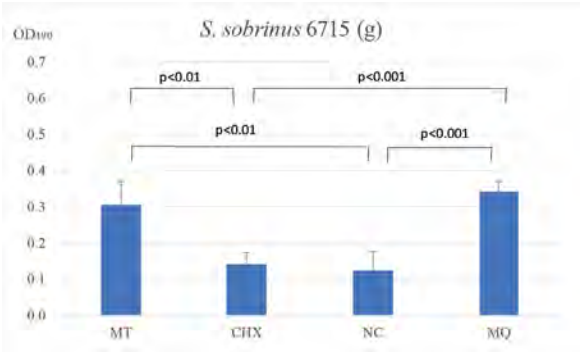

(b)




(c)




(d)




(e)

**Figure 2.** Effect of matcha extract and chlorhexidine on biofilm formation by each strain of mutans streptococci:
(a) *S. mutans* ATCC25175 serotype c,
(b) *S. mutans* LM7 serotype e,
(c) *S. mutans* OMZ175 serotype f, (
(d) *S. sobrinus* ATCC33478 serotype d,
(e) *S. sobrinus* 6715 serotype g.

Hereafter, it seemed necessary to investigate the antibacterial effect on those bacteria.

## 5. Conclusion

Matcha has the equivalent effectiveness of 0.02% chlorhexidine against most serotypes of mutans streptococci, namely S. mutans serotype c, e and f and S. sobrinus serotype d. It is suggested that matcha is a promising ingredient as a safe and effective for mouthwashes in children.

## Author Contributions

MFR: Idea, experimental design, data analysis, wrote the manuscript. NK: Performed biofilm and spectrophotometry assay, substantial contributed to writing manuscript. HO: Performed substantial contributed to writing manuscript.

## Acknowledgement

The authors have no conflict of interest. This research funding by Division of Preventive Dentistry, Department of Oral Health Science, Graduate School of Medical and Dental Sciences, Niigata University. The authors declare that the research was conducted in the absence of any commercial or financial relationship that could be construed as a potential conflict of interest.

## References

1. Jacob, PS. Editorial: Natural products in oral health. *The Open Dent J.* 2016;10(Suppl-1, M1): 158-159. [Full text links] [Free PMC Article] [PubMed] Google Scholar (0) Scopus (0)
2. Norwood KW, Slayton, RL. Oral health care for children with developmental disabilities. *Pediatrics*. 2013;131(3): 614-619. [Full text links] [PubMed] Google Scholar (53) Scopus (22)
3. Lachenmeier DW, Monokhova YB, Markova M, et al. What happens if people start drinking mouthwash as surrogate alcohol? A quantitative risk assessment. *Food Chem Toxicol*. 2013; 51: 173-178. [Full text links] [PubMed] Google Scholar (13) Scopus (8)
4. Werner CWdeA, Seymour RA. Are alcohol containing mouthwashes safe? *Br Dent J.* 2009;207(10): 488-489. [Full text links] [PubMed] Google Scholar (37) Scopus (16)
5. Palombo EA. Traditional medicinal plant extracts and natural products with activity against oral bacteria: potential application in the prevention and treatment of oral diseases. *Evid Based Complement Alternat Med.* 2011;2011: 680354. [Full text links] [Free PMC Article] [PubMed] Google Scholar

(381) Scopus (196)
6. Farooq S, Sehgal A. Antioxidant activity of different forms of green tea: loose leaf, bagged and matcha. *Curr Res Nutr Food Sci.* 2018;6(1): 35-40.
[Full text links] Google Scholar (1) Scopus (0)
7. Dietz C, Dekker M, Fiszman BP. An intervention study on the effect of matcha tea, in drink and snack bar formats, on mood and cognitive performance. *Food Res Int.* 2017; 99(Pt 1): 72-83.
[Full text links] [PubMed] Google Scholar (5) Scopus (3)
8. Lavine P, Fauziah E, Rizal MF, Budiardjo SB. Antibacterial effect of virgin coconut oil on (Actinomyces Sp.) that causes dental black stain in children. *Asian J Pharm Clin Res.* 2018;11(2): 333-335.
[Full text links] Google Scholar (0) Scopus (0)
9. Ali AMA, El-Nour MEM, Yagi SM. Total phenolic and flavonoid contents and antioxidant activity of ginger (Zingiber officinale Rosc.) rhizome, callus and callus treated with some elicitors. *J Genet Eng Biotechnol.* 2018.
[Full text links] Google Scholar (2) Scopus (1)
10. Calogiuri GF, Di Leo E, Trautmann A, et al. Chlorhexidine hypersensitivity: a critical and updated review. *J Allergy Ther.* 2013;4(4): 1-7.
[Full text links] Google Scholar (35) Scopus (0)
11. Coykendall AL, Bratthall D, O'Connor K, Dvarskas RA. Serological and genetic examination of some nontypical Streptococcus mutans strains. *Infect Immun.* 1976;14(3): 667-670.
[Full text links] [Free PMC Article] [PubMed] Google Scholar (48) Scopus (17)
12. Kiany F, Niknahad H, Niknahad M. Assessing the effect of pomegranate fruit seed extract mouthwash on dental plaque and gingival inflammation. *J Dent Res Rev.* 2016;3(4): 117-123.
[Full text links] Google Scholar (1) Scopus (0)
13. Linggriani A, Rizal MF, Fauziah E, Suharsini M. Differences in the effect of 0.05% and 0.1% propolis flavonoids on in vitro biofilm formation by Streptococcus mutans from children's dental plaque. *Asian J Pharm Clin Res.* 2018;11(2): 215-218.
[Full text links] Google Scholar (0) Scopus (0)
14. Sánchez-Acedo M, Montiel-Company JM, Dasí-Fernández F, Almerich-Silla JM. Streptococcus mutans and Streptococcus sobrinus detection by Polymerase Chain Reaction and their relation to dental caries in 12 and 15 year-old schoolchildren in Valencia (Spain). *Med Oral Patol Oral Cir Bucal*. 2013;18(6): e839-e845.
[Full text links] [Free PMC Article] [PubMed] Google Scholar (12) Scopus (12)
15. Okada M, Kawamura M, Oda Y, et al. Caries prevalence associated with Streptococcus mutans and Streptococcus sobrinus in Japanese schoolchildren. *Int J Paediatr Dent*. 2012;22(5): 342-348.
[Full text links] [PubMed] Google Scholar (31) Scopus (13)
16. Nakano K, Nemoto H, Nomura R, et al. Serotype distribution of Streptococcus mutans a pathogen of dental caries in cardiovascular specimens from Japanese patients. *J Med Microbiol.* 2007;56(Pt4): 551-556.
[Full text links] [PubMed] Google Scholar (59) Scopus (38)
17. Holbrook WP, Beighton D. Streptococcus mutans levels in saliva and distribution of serotypes among 9-year-old Icelandic children. *Scand J Dent Res.* 1987;95(1): 37-42.
[Full text links] [PubMed] Google Scholar (46) Scopus (0)
18. Fauziah E, Sutadi H, Bachtiar EW. Prediction of baby bottle tooth decay syndrome using the salivary mucin MG2. *Int J Clin Prev Dent.* 2013;9(4): 211-214.
[Full text links] Google Scholar (1) Scopus (0)
19. Kozai K, Nakayama R, Tedjosasongko U, et al. Intrafamilial distribution of mutans streptococci in Japanese families and possibility of father-to-child transmission. *Microbiol Immunol.* 1999;43(2): 99-106.
[Full text links] [PubMed] Google Scholar (131) Scopus (57)
20. Grönroos L, Mättö J, Saarela M, et al. Chlorhexidine susceptibilities of mutans streptococcal serotype and ribotypes. *Antimicrob Agents Chemother.* 1995;39(4): 894-898.
[Full text links] [Free PMC Article] [PubMed] Google Scholar (51) Scopus (33)
21. Hahnel S, Mühlbauer G, Hoffmann J, et al. Streptococcus mutans and Streptococcus sobrinus biofilm formation and metabolic activity on dental materials. *Acta Odontol Scand.* 2012;70(2): 114-121.
[Full text links] [PubMed] Google Scholar (13) Scopus (9)
22. Merritt J, Qi F. The mutacins of Streptococcus mutans: regulation and ecology. *Mol Oral Microbiol.* 2012;27(2): 57-69.
[Full text links] [Free PMC Article] [PubMed] Google Scholar (81) Scopus (59)
23. Sanz M, Beighton D, Curtis MA, et al. Role of microbial biofilms in the maintenance of oral health and in the development of dental caries and periodontal diseases. Consensus report of group 1 of the Joint EFP/ORCA workshop on the boundaries between caries and periodontal disease. *J Clin Periodontol*. 2017 Mar;44 Suppl 18: S5-S11.
[Full text links] Google Scholar (45) Scopus (27)
24. Kocak MM, Ozcan S, Kocak S, et al. Comparison of the efficacy of three different mouthrinse solutions in decreasing the level of streptococcus mutans in saliva. *Eur J Dent.* 2009;3(1): 57-61.
[Full text links] [Free PMC Article] [PubMed] Google Scholar (51) Scopus (0)
25. Simratvir M, Singh N, Chopra S, Thomas AM. Efficacy of 10% povidone iodine in children affected with early childhood caries: an in vivo study. *J Clin Pediatr Dent*. 2010;34(3): 233-238.
[Full text links] [PubMed] Google Scholar (30) Scopus (17)
26. Cieplik F, Kara E, Muehler D, et al. Antimicrobial efficacy of alternative compounds for use in oral care toward biofilms from caries-associated bacteria in vitro. *Microbiology Open*. 2018: e00695.
[Full text links] [PubMed] Google Scholar (0) Scopus (0)
27. Vinod KS, Sunil KS, Sethi P, et al. A novel herbal formulation versus chlorhexidine mouthwash in efficacy against oral microflora. *J Int Soc Prev Community Dent.* 2018;8(2): 184-190.
[Full text links] [Free PMC Article] [PubMed] Google Scholar (0) Scopus (0)
28. James P, Worthington HV, Parnell C, et al. Chlorhexidine mouthrinse as an adjunctive treatment for gingival health. *Cochrane Database Syst Rev.* 2017;3: CD008676.
[Full text links] [PubMed] Google Scholar (3) Scopus (23)
29. Gunasekaran G, Lakshmanan R. Effect of chlorhexidine mouthwash on taste alteration. *Asian J Pharm Clin Res*. 2016;9(13): 102-104.
[Full text links] Google Scholar (2) Scopus (0)
30. Bagis B, Baltacioglu E, Özcan M, Ustaomer S. Evaluation of chlorhexidine gluconate mouthrinse-induced staining using a digital colorimeter: an in vivo study. *Quintessence Int*. 2011;42(3): 213-223.
[Full text links] [PubMed] Google Scholar (36) Scopus (18)
31. Bonesvoll P. Oral pharmacology of chlorhexidine. *J Clin Periodontol.* 1977;4(5): 49-65.
[Free text links] [PubMed] Google Scholar (77) Scopus (46)
32. Dogan S, Günay H, Leyhausen G, Geurtsen W. Effects of low-concentrated chlorhexidine on growth of Streptococcus sobrinus and primary human gingival fibroblasts. *Clin Oral Investig.* 2003;7(4): 212-216.
[Free text links] [PubMed] Google Scholar (10) Scopus (8)
33. Sylvie S, Catherine F, Jean-Philippe G, Christine R. In vitro bactericidal assay under simulated practical conditions for comparison of chlorhexidine mouthrinses: chlorhexidine concentration isonly one of the in vitro activity criteria. *Oral Health Dentl Manag.* 2016;15(6): 1-6.
[Full text links] Google Scholar (0) Scopus (0)
34. Massey CC, Shulman JD. Acute ethanol toxicity from ingesting mouthwash in children younger than age 6, 1989-2003. *Pediatr Dent.* 2006;28(5): 405-409.
[Full text links] [PubMed] Google Scholar (12) Scopus (0)
35. Sharma R, Hebbal M, Ankola AV, et al. Effect of two herbal mouthwashes on gingival health of school children. *J Tradit Complement Med.* 2014;4(4): 272-278.
[Full text links] [Free PMC Article] [PubMed] Google Scholar (12) Scopus (6)

**Mochamad Fahlevi RIZAL**

DDS, PhD, Assistant Professor
Department of Oral Health Science Division of Preventive Dentistry
Graduate School of Medical and Dental Sciences
Niigata University, Niigata, Japan



## CV

Mochamad Fahlevi Rizal is a Pediatric Dentist in Indonesia. He has been a lecturer in the Department of Pediatric Dentistry, Faculty of Dentistry, Universitas Indonesia since 1998. In 2018 he became visiting lecturer in the Niigata University and made collaborative research with the Division of Preventive Dentistry, Department of Oral Health Science, Graduate School of Medical and Dental Sciences, Niigata University.

## Questions

### 1. Which was the matcha used in this study?

❑a. 5 g in 100 mL water;
❑b. 0.5 g in 100 mL water;
❑c. 0.05 g in 100 mL water;
❑d. 50 g in 100 mL water.

### 2. What species of mutans streptococci were used in this study?

❑a. *Streptococcus ferus* and *Streptococcus pneumonia*;
❑b. *Streptococcus mutans* and *Streptococcus sobrinus*;
❑c. *Streptococcus macacae* and *Streptococcus ratti*;
❑d. *Streptococcus criceti* and *Streptococcus downei*.

### 3. What was the antibacterial used to compare the effectiveness of matcha in this study?

❑a. Ethil alcohol 70%;
❑b. Povidone iodine;
❑c. Chlorhexidine;
❑d. Gentian violet.

### 4. What was the result of this study?

❑a. All strain of mutans streptococci were suppressed significantly by matcha;
❑b. Only serotype c was suppressed significantly by matcha;
❑c. Only serotype c, e, and d were suppressed significantly by matcha;
❑d. Only serotype c, e, f, and d were suppressed.

# Revolutionary Mouth Rejuvenation

# Y10


## Mouth refreshing

The combination of Peppermint in Y10 toothpaste and RF current lead to mouth refreshing sensation.

## Teeth whitening

provides for remarkable improvement of several shade degrees in accordance with the common shading grading.

## Gums Rejuvination

The unique combination between RF current and unique Y10 toothpaste ingredients are magnifying and accelerating these processes.

www.btonix.com

BrightTonix


## We care. We protect you.

... and there is a bit of truth in every cliché.

Over the course of a day, a total of eight billion bacteria form in your treatment center. They might not turn into monsters at night, but should not be underestimated. That means taking infection prevention seriously. And that's why an automatic cleaning system prevents infections and can save you up to 2.5 hours of your time per month.

Learn the truth at www.dentsplysirona.com/new-perspective

Office & Showroom
98A Vulturilor Street, 3rd District
RO-030857 Bucharest, Romania
Tel: +40 774 074 094
e-mail: office.romania@dentsplysirona.com

Dentsply Sirona

Office & Showroom
98A Vulturilor Street, 3rd District
RO-030857 Bucharest, Romania
Tel +40 774 074 094
e-mail: office.romania@dentsplysirona.com

Dentsply Sirona

# Intego

## Performance you can rely on

# CURRENT PERSPECTIVES ON DIGITAL SMILE DESIGN

**Luca Levrini[1a*], Silvia Croceb, Sanda Mihaela Popescu[2c], Marian-Vladimir Constantinescu[3d], Riccardo Botta[b], Francesca Cattoni[4e]**

[1]Department of Medicine and Surgery, University of Insubria, Varese Como, Italy
[2]Dental Reabilitation and Medical Surgery Emergencies Department, Faculty of Dental Medicine, University of Medicine and Pharmacy of Craiova, Dolj, Romania
[3]Holistic Dental & Medical Institute – ROPOSTURO, Bucharest, Romania
[4]Department of Dentistry, Vita-Salute San Raffaele University, Milano, Italy

[a]MD, PhD, Associate Professor; University of Insubria, Varese, Italy; Assistant Medical Director, Dental Clinic, Fondazione Macchi Hospital, Varese, Italy
[b]DDS, private practice
[c]DDS, PhD, Professor, Head
[d]DDS, MSc, PhD, Professor, President
[e]MD, PhD, Adjunct Professor

These authors contributed equally to this work

DOI: 10.25241/stomaeduj.2018.5(4).art.3

## ABSTRACT

**Background:** Digital Smile Design (DSD) is a method that helps predict digitally the outcome of a smile based on the use of both static or dynamic images, in order to plan simple or complex rehabilitation cases, to "draw a smile". It is a valuable resource used to show the outcome of the treatment, to evaluate the aesthetic rehabilitation, to complete the diagnosis and improve communication with patients, laboratories and interdisciplinary clinicians. JPEG photos and STL files are forwarded to the laboratory and imported in CAD-CAM to make a mock-up and a provisional restoration. Thus, it is possible to check each step of the planning and make any corrections necessary.
**Objective:** The present article is a comprehensive review on DSD, including every field in which it extends.
**Data sources:** The research includes articles featuring the keywords: digital smile design, prosthodontic, surgery, digital flow, orthodontics and was conducted in two different databases, PubMed and Google Scholar.
**Study Selection:** After screening and removing the duplicates, 22 articles from Pubmed and 11 from Google Scholar were selected.
**Data extraction:** The analysis included 13 articles regarding prosthetic rehabilitations, 7 articles about surgery (periodontal or rehabilitation), 11 articles describing DSD and 2 articles about orthodontics. The research included articles in English from 2000 to 2018.
**Data synthesis:** DSD is an excellent way to design dental treatments thanks to its versatility in managing the treatment plan; however further improvements are required to refine the software and permit an appropriate clinical application.
**Keywords:** digital smile design, diagnosis, communication.



**Peer-Reviewed Article**

**Citation:** Levrini L, Croce S, Popescu SM, Constantinescu M-V, Botta R, Cattoni F. Current perspectives on digital smile design. Stoma Edu J. 2018;5(4):229-235.

**Academic Editor:**
Constantinus Politis, MD, DDS, MM, MHA, PhD, Professor & Chairperson, University of Leuven, Leuven, Belgium.

Received: November 14, 2018
Revised: November 30, 2018
Accepted: December 10, 2018
Published: December 11, 2018

***Corresponding author:**
Associate Professor Luca Levrini, DDS, PhD, President, Dental Hygiene School, Director, Research Centre Cranio Facial Disease and Medicine, University of Insubria
Via Giuseppe Piatti, 10, I-21100 Varese VA, Italy, Tel/Fax: 0332.825.663,
e-mail: luca.levrini@uninsubria.it



## 1. Introduction

In the digital era new technologies are revolutionizing the world of dentistry in order to facilitate and expedite normal procedures. Clinicians are seeking for new ways to implement more comfortable and rapid treatments yet keep high quality results. Due to the high aesthetic demand from patients, displaying a preview of the outcome is the new trend. As Coachman said, for every work of art such as painting, sculpture or dentistry, it is necessary to make a plan or a prototype [1]. Currently, there are some programs available like smile designer pro, digital smile design, aesthetic check, digital smile system to serve this purpose [2]. Digital Smile Design is among the most used, it is a software designed to make diagnostics and simulate the outcome of the future treatment: it can be seen as "outcome based workflow". Actually, for this reason the term digital smile design is considered as the main method to describe all the digital clinical works that simulate a dental treatment. The purpose of DSD is to simplify a complex task and to make sure that the patient can have a better impression of what the treatment is going to be. The virtual 2D smile design could make a diagnostic wax to facilitate clinical steps, as a computer-aided design and computer-aided manufacturing programs (CAD-CAM). Unfortunately, 3D virtual patient including intraoral soft tissue, craniofacial hard tissue and extra-oral soft tissue has some limitation, it is still complex to recreate as real [3]. Digital Smile Design (DSD) is based on the use of static and dynamic digital images, transferred to the digital software which uses different tools to "draw the smile". 2D smile design is gaining popularity as

an important tool for the communication between clinicians, between clinician and patient and also between clinician and laboratory [4]. Before DSD, dental technicians used to make restoration treatments either through standard rents, photos or instructions provided by the clinician. A lot of information was missing in regards to the context in which the restoration was done, including lip position, middle facial line, incisal plane, and some characterizations of the nearby teeth, such as colour, shape, spots or cracks. DSD can help the dental technician to make higher quality restorations and more exactly, avoid extra phases that delay the treatment. Furthermore, it is possible to re-evaluate every step of the rehabilitation, comparing it with the diagnostic plan. The use of DSD can help plan simple and complex cases with more control by the laboratory and the clinician[1]. First, digital intraoral photos against black backgrounds are needed: full smile from the front, left and right side, upper and lower occlusal view (The American Academy of Cosmetic Dentistry Photographic Accreditation Review in 1995)[5]. Second, the extra-oral photos: full smile, mid facial right and left; the patient's 3D facial soft tissues are captured with a 3D scanner (Sense, 3D system Inc). Files are then transferred as a JPEG format to the software. A diagnostic impression with an intraoral scanner in a stereolithography file format (STL) is also transferred into the software. Intraoral photos and the 2D virtual smile design are superimposed to create a virtual patient with facial tissue and a full smile.

The above mentioned are used to show the final result. The JPEG photos and STL files are then forwarded to the laboratory and subsequently imported to the CAD-CAM software to make a mock-up and a provisional restoration, even if the conversion from the 2D design to the 3D waxing could still cause distortions of the images. The definitive restoration will be created based on the test with provisional restoration and in accordance with the diagnostic plan [3].

In view of the advantages that this system has, a learning curve is required to use it to its full potential. Starting from these considerations, we decided to develop this review to analyze the most relevant literature about on the theme.

## 2. Methodology

A computerized database search was performed to identify relevant articles. The purpose of this work was not to aim at being a systematic review of literature, but to state the topic from the point of view of the literature analysis. The keywords introduced for the research were: Digital Smile Design, DSD, digital work flow, Digital Smile Design and Orthodontics. The databases used are PubMed and Google Scholar and the research includes works in English from 2000 to 2018. The articles were analyzed and a unique file was created for each of them with the most important information about the topic and what marks it.

## 3. Results

At the end of the research 33 relevant articles were found: 22 articles from Pubmed and 11 from Google Scholar. We can divide the articles selected in four groups, each one belonging to a different argument:

1. Prosthetic rehabilitations: 13 articles were about the use of digital smile design as a means to plan a prosthetic rehabilitation, like aesthetic veneers, singular crown, metal-ceramic bridges or porcelain.
2. Digital Smile Design (DSD): 11 articles were about the main theme, described the method to acquire the digital information and to develop it
3. Surgery: 7 articles were about surgery, periodontal plastic surgery, bone sculpturing, gummy smile, or implant rehabilitation
4. Orthodontics: 2 articles were found about the use of digital smile design associated to the Clin Check software of Invisalign aligners.

There are several application fields; traditionally the digital design was associated to conservative dentistry; although its use will be improved in prosthodontic, surgery and in particular in orthodontic in the future.

## 4. Discussion

### 4.1. Digital Smile Design (DSD)

Digital Smile Design (DSD) can be performed with Key Note (for Macintosh) and Power Point (for windows). Through DSD, pre-existing dental anomalies such as shape, size, position, color or texture can be identified and modified with the ultimate goal of designing the optimal smile [6]. It starts with data gathering and digital planning. On the full face extra-oral photo horizontal and sagittal plane are tracked in accordance with anatomical references: inter-pupillary line and middle facial line (glabella-nose-chin).

These lines are transferred to the full smile intraoral photo for a comparison with the occlusal plane and the dental midline.

The second step is the dental analysis (horizontal lines): the outline of each tooth is drawn and enclosed in a rectangular, combined with the future treatment, the tip of each canine, the incisal edge of both central incisor and dental midline. The ideal proportions of length and width are placed to be compared with the project, including measurements in millimeters to calibrate the size of each element. Finally, the smile design is superimposed on the initial situation to show the relation with the gingival contour, and then the virtual waxing is performed [7,17]. A digital ruler is used to show the measurement of the teeth.

After having investigated the patient's expectations, the treatment proposals are exposed; the patient approves the design and chooses which treatment

plan to proceed with and subsequently the clinicians decide the operative time table. In the traditional DSD protocol the digital wax-up is transferred to the master cast, maintaining the tooth's design, and it is used to fabricate the silicone guide for the provisional denture[8]. It is important to have a check list to follow in each step; there is a constant double-check between the DSD and every phase of the treatment to identify and correct any errors and give a higher quality to the treatment [9].
If patients are not satisfied with the result of an aesthetic rehabilitation the clinician can change something about the design and can adapt the functionality. Thanks to the DSD clinicians can reach the patient's compliance and patients have no surprise at the end of the treatment thanks to the pre-visualization of the outcome [10].

**4.2. DSD in Prosthodontics**

In recent years the expectations of dental patients have greatly increased regarding their aesthetic appearance, which has already reached the same importance as the function [11,12]. To pursue the least invasiveness is a priority in every prosthetic restoration which aims to improve the smile aesthetics, preserving as much dental tissue as possible and respecting the surrounding soft tissue [13]. As demonstrated by Magne et al, a veneer preparation approach driven by the final volume of the restoration (the mock-up) allows for more enamel preservation, avoiding unnecessary overpreparations by removing just the dental tissue needed to create proper prosthetic thicknesses, and more predictable bonding, biomechanics and final aesthetics [14]. According to Coachman's protocol, the realization of the diagnostic wax-up is anticipated and, above all, guided by the Digital Smile Design, which has proved to be a fundamental and useful tool for improving communication and the patient's acceptance, but all the remaining steps are the same as the traditional ones [15]. The DSD used for planning a prosthetic rehabilitation is probably the most common application of the software, as it also emerged from our literature review. It allows to design treatments without needing the patient to sit on a chair and analyze the treatment plan in this way, by considering all the aesthetic parameters [16].
The key to the success of the treatment is the harmony between the various components of the smile's aesthetics, such as colour, shape, volume, texture, dental alignment, gingival contour, the relationship between the teeth of the upper arch and those of the lower arch as well as the contextualization in the face [17].
The starting point is always drawing the references lines extra and intraorally: the reference planes are drawn (bipupillary line, middle facial line, Frankfurt plane), dental middle line, occlusal plane, tooth contour. When parameters are provided we proceed with designing the diagnostic wax-up, referring to the anatomical features, the lip dynamics, the incisal edge position and midlines [18]. With the DSD software it is possible to design different types of prosthetic rehabilitation such as porcelain laminates veneers, ceramic crown or bridges [19]. The most common are aesthetic veneers, both of feldspathic ceramic, lithium disilicate and zirconium. In order to perform an aesthetic rehabilitation with veneers/ dental crown a silicone index is obtained from the dental cast to evaluate the need for reduction and another silicone guide is for the provisional restorations [20]. The creation of an interim prosthesis allows us to visualize possible errors in the design and thus be able to make changes to the final prostheses; additionally, it is also serves as a further pre-visualization of the patient, even though he can already see the result thanks to the DSD software [21].
Often the aesthetics of the smile can be improved without resorting to a prosthetic treatment but preferring a more conservative treatment such as dental bleaching or the application of infiltrative resins or aesthetic reconstructions in composite [22]. In cases of morphology changes (microdontics, conical teeth) or colour (dyschromia, tinctures, dark non-vital teeth) and structure (enamel deficiency as hypoplasia, white spot) this is not possible and the prosthetic option remains the best choice [17,23].
While in the traditional DSD protocol the digital wax-up is transferred to the master cast, maintaining the tooth design, and it is used to fabricate the silicone guide for provisional denture [8], in recent months an evolution of smile design protocols has been achieved and a project using only digital methods has been executed called Digital Smile Planning [24]. In this case the design of the patient's restoration was then performed using the DSS-2D software (3D Lynx, 3D Lynx srl, Italy).
The software allows designing digital aesthetic and functional smile rehabilitation through a guided path, and which, thanks to the automatic calibration tools, can perform mathematically controlled measurements. This program allows the patient to preview the prosthetic result directly on a photograph of himself and provide the dental technician with all the information needed to perform the work through a detailed report [24]. The digital restoration project was realized using the patient's photos, and choosing dental shapes from the software libraries. The use of a specific landmark while taking the patient's photographs, with reference points, allows the software to calibrate the system on the picture so that it can give precise measurements in millimeters, useful to guide the work of the clinician and, above all, the technician. It is also necessary to take an intra oral optical impression to feed the original shape of the natural elements into the CAD software. The STL files of the patient's arches have been uploaded to the software for the realization of the digital wax-ups by the DSS-3D system (CAD Lynx-, 3D Lynx srl, Italy), direct implementation of the DSS-2D system, and a

milled mock up has been produced and tested in the mouth of the patient, to guide the tooth preparation and, if necessary, also the surgical evaluation of the soft tissue design.
Nowadays it is also possible to apply the digital planning protocol not only on natural teeth, in simple or complex cases, but also in the initial phase of the full-arch implant supported rehabilitation protocol [25]. The Virtual Implant-Prosthetic Procedure: VIPP Technique [25], can be used to integrate the prosthetic and the implant project helps the correct guided implant positioning [26], optimized either for bone volumes available and to absorb the masticatory loads and the fabrication of an adequate prosthesis, in compliance with the intermaxillary relationship, the function and the occlusal balance, the soft tissue support [27].

**4.3. DSD in Surgery**

Digital smile design has also found its usefulness in the surgical field. The digital workflow in the surgical area begins with the collection of radiographic data and then the photos. It is possible to superimpose on the CBCT the DICOMs files (Digital Imaging and Communications in Medicine) for planning the surgery. Unfortunately, the combination of several files can create image distortion and diagnostic dental models are needed to overcome this problem [2]. An analysis of the distance between the margin of the future prosthetic rehabilitation and the existing bone is necessary to determine if a grafting procedure will be required, if implants can be placed at the level of the bone, or if bone reduction is needed and if the future restoration needs to incorporate a pink prosthetic area. Some guidelines using the margin of the planned crown as a reference can be applied. Implants must be placed 3 mm apically from the margin of the planned crowns to create space for average biological width thickness [28]. Regarding the orthognathic surgery, a sagittal analysis with cephalometric guide is essential to place the maxillary central incisor in the best position and in harmony with the lips and face [28].
A combination between periodontal surgery and prosthetic rehabilitation is possible to carry out in case of a gummy smile. A preliminary study is essential to make the diagnosis: once the treatment has been established, if a bone or gingival reduction is necessary, digital planning of the mock up and the surgery is performed. The surgery is guided by a splint made according to the digital design so that the gum is in the correct position for the future prosthesis. The provisional made on the basis of the planning is used as a surgical stent [23,27]. In many cases it is not possible to correct a gummy smile only with a gingival reduction; often an orthognathic surgery or orthodontic treatment is required. Thanks to the digital smile design the patient can see the outcome and decide whether to accept the aesthetic compromise in case he does not want to undertake a more invasive treatment [29].

**4.4. DSD in Orthodontics**

Nowadays, modern orthodontic techniques (clear aligner) allow early visualizations of the orthodontic treatment that is necessary to proceed further with the production of aligners. In the perspective of considering DSD as a digital visualization of the result that could be obtained, this early visualization already guarantees an excellent projection of the result.
However, these simulations do not permit to predict how the results of an orthodontic treatment can be compared to the patient's mini-aesthetics (smile with the lips) and macro-aesthetic (face): the available digital models of orthodontic treatment, in fact, are substantially 3D-image digital devices that simulate only the patient's dentition.
For this reason, digital methods have been developed in a way which permitted to combine the views of orthodontic treatment with images of the patient's face: the result was an image that represented the patient's smiling face with the simulation of the teeth as it would appear after the changes at the micro- and macro-aesthetic level obtained thanks to the orthodontic treatment. These digital methods are generally performed with professional photo processing software (photo editing), such as Adobe Photoshop®.
For this aim it may be sufficient: -to make a digital transparent model that simulates the result of orthodontic treatment of the patient's dentition; - to position, overlap and manually align the transparent digital model onto an image of the smile or face of the patient with his original teeth and gingiva. This photo must be taken with the patient's occlusal plane in a perpendicular position to the lens, with the teeth in front view compared to the camera; - erase the original teeth and gingiva from the image of the smile or face, in order to obtain an image of the face without teeth but with a residual of the original gum on the transparent digital model; - bring the transparent digital model below the smile image or face without teeth and with a residual gum; - eliminate the transparency from the digital model, obtaining an image of the smile or face, which integrates the orthodontic simulation of the digital outcome; - change the color of the gums and the teeth to simulate a natural effect of the patient's gums and teeth.
Actually, this method can be called "orthodontic digital face design"; practically, an image of the patient's face or smile is produced and is integrated with the occlusal result of the orthodontic treatment. In this way, the patient is able to appreciate the simulation of the orthodontic outcome which he is undergoing or must undergo before starting and appreciate the aesthetic of his smile or face. It is possible to add restorative rehabilitation, either prosthetic or conservative. The method could also

include a patient's three-dimensional (3D) image of the smile or the face [22].

Schabel et al. published a study that compares the accuracy between photographs and video clips regarding the possible distortion of the image in a sample of patients treated orthodontically. The results showed that there was no significant difference between obtaining images using traditional photographic method or extrapolating them from video. Yet, a slight difference of 1mm was seen when analyzing the upper incisor in relation to the lower lip. Therefore, photography is still considered the best tool and the most immediate tool [5].

## 5. Conclusion

The appearance of a beautiful smile is impregnable, because the mouth is the most important manifestation of a human being. The DSD protocol, consisting in drawing reference lines on extra and intra-oral photos and superimposing the dental design, is an excellent tool for a diagnostic vision and help the team members to predict and facilitate the treatment [31]. It reduces the risk of asymmetries, disharmonies, guided by the diagnostic wax based on aesthetic principles. It works both with macro aesthetic (face and neck), mini aesthetic (the smile and the lips) and micro aesthetic (details about the shape, the color and defects of the teeth). The purpose of DSD is to guide every step of the treatment by focusing on anatomical features, parameters provided, and planes of references, each of them conducted by the wax-up design [33]. Among the advantages of this software one can list: reduction in the number of appointments, low clinical costs and a global access to the service as it allows the clinical staff to visualize the relevant data and transfer other information via Internet. Lot of diagnostic data are stored in a single software which allows sending all of them to the laboratory without the need of explaining the procedures [33]. DSD facilitate the interdisciplinary communication between dental technicians and the operator. The DSD is also useful to pre-visualize the outcome of the treatment to the patient and improve the communication with them by illustrating clearly the situation before and after [35]. It is a simple technique, it does not require specific equipment; however, a handling training is firmly needed. Nothing indicates how the information should be ideally gathered and implemented. Therefore, many of these diagnostic data may be lost if they are not transferred in an adequate way to the rehabilitation design. The DSD protocol consists in transferring data to a cast model that reproduces the wax-up diagnostic in such a way as not to lose the information (of the photos) [17]. In conclusion to this review it can be said that the digital smile design is an excellent tool for treatment planning, especially for aesthetic treatments, as it is more used and to design prosthetic rehabilitations in the anterior sector [36]. However, there are still uncertainties regarding the occlusion adjustment: in fact, errors can be found during the transfer of data from the scan to the realization of the study models. This could be the biggest disadvantage of the program. The chances of not reaching a correct occlusion emphasize the importance of the temporary restoration to recheck and correct any errors. For this reason, the technique requires a learning time to be able to take full advantage of its usefulness.

The topic is mainly addressed for the clinical application, for this reason there is not significant literature evidence; the idea could be to create a panel of experts in the fields to edit the clinical guidelines on the DSD.

## Author contributions

LL: Idea, study concept and preparation of manuscript. SC: literature search and analysis orthodontic topic. SMP: Contributed to re-writing manuscript. MVC: Revision of manuscript and literature search. RB: literature search and analysis surgery topic.
FC: literature search and analysis prosthodontics topic

## Acknowledgments

The authors have no conflicts of interest. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. The authors declare that the research was conducted in the absence of any commercial or financial relationship that could be construed as a potential conflict of interest.

## References

1. Coachman C, Van Dooren E, Gürel G, et al. Smile Design: from digital treatment planning to clinical reality. In: Michael Cohen, editor. *Interdisciplinary treatment planning*. Volume II: *Comprehensive case studies*. Batavia, IL, USA: Quintessence Publishing Co, Inc; 2011: 119-174.
Google Scholar(39)
2. Rojas Vizcaya F. Prosthetically guided bone sculpturing for a maxillary complete-arch implant-supported monolithic zirconia fixed prosthesis based on a digital smile design: A clinical report. *J Prosthet Dent*. 2017;118(5):575-580.
[Full text links] [PubMed] Google Scholar Scopus
3. Lin WS, Harris BT, Phasuk K, et al. Integrating a facial scan, virtual smile design, and 3D virtual patient for treatment with CAD-CAM ceramic veneers: A clinical report. *J Prosthet Dent*. 2018;119(2):200-205.
[Full text links] [PubMed] Google Scholar(7) Scopus(3)
4. McLaren EA, Culp L. Smile analysis. The photoshop smile design technique: part I. *Journal of Cosmetic Dentistry* 2013;29(1):94-108.
[PubMed] Google Scholar(3)
5. Schabel BJ, Baccetti T, Franchi L, McNamara JA. Clinical photography vs digital video clips for assessment of smile esthetics. *Angle Orthodontist*. 2010;80(4):678-684.
[Full text links] [PubMed] Google Scholar(42) Scopus(7)
6. Kravitz ND. Smile Analysis and Design in the Digital Era. *J Clin Orthod*. 2017;51(9):602-605.
[PubMed] Google Scholar
7. Coachman C, Calamita MA, Sesma N. Dynamic documentation of the Smile and the 2D/3D Digital Smile Design Process. *Int J Periodontics Restorative Dent*. 2017;37(2):183-193.
[PubMed] Google Scholar(13) Scopus(4)

8. Sodagar A, Rafatjoo R, Gholami Borujeni D, et al. Software design for smile analysis. *J Dent* (Tehran). 2010;7(4):170-178. [Full text links] [Free PMC Article] [PubMed] Google Scholar(14)
9. Coachman C, Paravina RD. Digitally enhanced esthetic dentistry – From treatment planning to quality control. *J Esthet Restor Dent*. 2016;28 Suppl 1: S3-S4. [Full text links] [PubMed] Google Scholar(14) Scopus(5)
10. Tak On T, Kois JC. Digital Smile Design meets the dento-facial analyzer: optimizing esthetics while preserving tooth structure. *Compend Contin Educ Dent*. 2016;37(1):46-50. [PubMed] Google Scholar(4) Scopus(2)
11. Peumans M, Van Meerbeek B, Lambrechts P, Vanherle G. Porcelain veneered: a review of literature. *J Dent*. 2000;28(3):163-177. Google Scholar(664)
12. Little D. The impact of aesthetics in restorative treatment planning. *Dent Today*. 2015;34(5):104,106-107. [PubMed] Google Scholar(1) Scopus(1)
13. Gürel G. Porcelain laminate veneers: minimal tooth preparation by design. *Dent Clin North Am*. 2007;51(2):419-431. [Full text links] [PubMed] Google Scholar(119) Scopus(33)
14. Magne P, Belser UC. Novel porcelain laminate preparation approach driven by a diagnostic wax up. *J Aesth Restor Dent*. 2004;16(1):7-16. [Full text links] [PubMed] Google Scholar(205) Scopus(55)
15. Coachman C, Calamita M. Digital Smile Design: a tool for Treatment Planning and communication in esthetic dentistry. *QDT*. 2012:1-9. Google Scholar(99)
16. Zandinejad A, Lin WS, Atarodi M, et al. Digital workflow for virtually designing and milling ceramic lithium disilicate veneers: a clinical report. *Oper Dent*. 2015;40(3):241-246. [Full text links] [PubMed] Google Scholar(17) Scopus(2)
17. Meereis CTW, de Souza GBF, Albino LGB, et al. Digital Smile Design for Computer-assisted esthetic rehabilitation: two-year follow up. *Oper Dent*. 2016;41(1):E13-E22. [Full text links] [PubMed] Google Scholar(17)
18. Zanardi RP, Zanardi RLR, Stegun RC, et al. The use of Digital Smile Design concept as an auxiliary tool in aesthetic rehabilitation: a case report. *Open Dent J*. 2016;29(10):28-34. [Full text links] [Free PMC Article] [PubMed] Google Scholar(6) Scopus(3)
19. Perez-Davidi M. Digital smile design and anterior monolithic restorations chair side fabrication with Cerec Cad/Cam system. *Refu'at Ha-peh Veha-shinayim* (1993). 2015;32(4):15-19, 25. [PubMed] Google Scholar(1) Scopus
20. Cattoni F, Mastrangelo F, Gherlone EF, Gastaldi G. A new total Digital Smile Planning Technique (3D-DSP) to fabricate CAD-CAM mockups for esthetic crowns and veneers. *Int J Dent*. 2016;2016:6282587. [Full text links] [Free PMC Article] [PubMed] Google Scholar(11) Scopus(5)
21. Pimentel W, Teixeira ML, Costa PP, et al. Predictable outcomes with porcelain laminate veneers: a clinical report. *J Prosthodont*. 2016;25(4):335-340. [Full text links] [PubMed] Google Scholar(16) Scopus(3)
22. Ercus S, Chung E, McLaren E. Esthetic with minimal tooth preparation achieved through a digital approach. *Compend Contin Educ Dent*. 2013;34(6):428-431. [PubMed] Google Scholar(1) Scopus(0)
23. Trushkowsky R, Arias DM, David S. Digital Smile Design concept delineates the final potential result of crown lengthening and porcelain veneers to correct a gummy smile. *Int J Esthet Dent* 2016;11(3):338-354. [PubMed] Google Scholar(8) Scopus(3)
24. Gastaldi G, Gherlone EF, Manacorda M, et al. A 3-D CAD/CAM technique in full-arch implant supported rehabilitations: the virtual implant-prothetic procedures (VIPP Technique). A prospective longitudinal study. *J Osseointegr*. 2018;10(1):2-10. Google Scholar(0) Scopus(0)
25. Arunyanak SP, Harris BT, Grant GT, et al. Digital approach to planning computer-guided surgery and immediate provisionalization in a partially edentulous patient. *J Prosthet Dent*. 2016;116(1):8-14. [Full text links] [PubMed] Google Scholar(14) Scopus(4)
26. Monaco C, Evangelisti E, Scotti R, et al. A fully digital approach to replicate peri-implant soft tissue contours and emergence profile in the esthetic zone. *Clin Oral Implants Res*. 2016;27(12):1511-1514. [Full text links] [PubMed] Google Scholar(22) Scopus(10)
27. Santos FR, Kamarowski SF, Lopez CAV, et al. The use of the digital smile design concept as an auxiliary tool in periodontal plastic surgery. *Dent Res J* (Isfahan). 2017;14(2):158-161. [Full text links] [Free PMC Article] [PubMed] Google Scholar(0)
28. Coachman C, Calamita MA, Coachman FG, et al. Facially generated and cephalometric guided 3D digital design for complete mouth implant rehabilitation: a clinical report. *J Prosthet Dent*. 2017;117(5):577-586. [Full text links] [Free PMC Article] [PubMed] Google Scholar(6) Scopus(5)
29. Arias DM, Trushkowsky RD, Brea LM, David SB. Treatment of the patient with gummy smile in conjunction with Digital Smile Approach. *Dent Clin North Am*. 2015;59(3):703-716. [Full text links] [PubMed] Google Scholar(9) Scopus(5)
30. Levrini L, Tieghi G, Bini V. Invisalign ClinCheck and the Aesthetic Digital Smile Design protocol. *J Clin Orthod*. 2015;49(8):518-524. [PubMed] Google Scholar(6) Scopus(1)
31. McLaren EA, Garber DA, Figueira J. The photoshop smile design technique: digital dental photography. *Compend Contin Educ Dent*. 2013;34(10):772,774,776. [PubMed] Google Scholar(34) Scopus(12)
32. Zimmermann M, Mehl A. Virtual smile design systems: a current review. *Int J Comput Dent* 2015;18(4):303-317. [PubMed] Google Scholar(29) Scopus(8)
33. Coachman C, Calamita MA. Virtual esthetic smile design. *Journal of Cosmetic Dentistry*. 2014;29(4):102-116. Google Scholar(10)
34. Ackerman MB, Ackerman JL. Smile analysis and design in the digital era. *J Clin Orthod*. 2002;36(4):221-236. [PubMed] Google Scholar(278) Scopus(105)
35. Kurbad A, Kurbad S. Cerec Smile Design-a software tool for the enhancement of restorations in the esthetic zone. *Int J Comput Dent*. 2013;34(6):428-431. [PubMed] Google Scholar(9) Scopus(6)

**Luca LEVRINI**
DDS, PhD, Associate Professor
Deputy President, Dental Hygiene School
University of Insubria, Varese, Italy
Assistant Medical Director
Dental Clinic Fondazione Macchi Hospital, Varese, Italy
President Fondazione Alessandro Volta, Como, Italy

## CV

Professor Luca Levrini, born in 1967. Associate Professor in Clinical Somatology and deputy president Dental Hygiene School, University of Insubria, Italy. Assistant Medical Director, Dental Department, Fondazione Macchi Hospital, Varese. Member of the Medical Council, Como, Italy. Medical Journalist. President Fondazione Alessandro Volta, Como, Italy. Author of more than 200 scientific papers dealing with oral prevention and orthodontics. He is an active member of Società Italiana di Ortodonzia and a Certificate speaker for Align Technology.

## Questions

**1. Which information is transmitted to lab through classical recordings?**

❑a. Lip position;
❑b. Middle facial line;
❑c. Incisal plane;
❑d. Tooth position.

**2. Which is the limitation of DSD?**

❑a. Simplifying a complex task and making sure that the patient can have a better impression of what is going to be the treatment;
❑b. Making a diagnostic wax;
❑c. Facilitating clinical steps, as a computer-aided design and computer-aided manufacturing programs (CAD-CAM);
❑d. Too complex to recreate as real.

**3. Digital Smile Design (DSD) can be performed with computer programs like:**

❑a. Key Note (for Macintosh);
❑b. Excel (for windows);
❑c. Word (for windows);
❑d. Paint (for windows).

**4. With the DSD software it is possible to design different types of prosthetic rehabilitation. Which are the most common?**

❑a. Aesthetic veneers;
❑b. Crown;
❑c. Bridge;
❑d. Denture.

Review Article

# LIGHT CURING MATTERS: FACTS OFTEN OVERSEEN BY DENTISTS

**Dayane Carvalho Ramos Salles de Oliveira**[1,2a*], **Mateus Garcia Rocha**[1,2b], **Jean-François Roulet**[1c]

[1]Department of Restorative Dental Sciences, College of Dentistry, University of Florida, 1395 Center Dr, 32610, Gainesville, FL, USA
[2]Department of Restorative Dentistry, Piracicaba Dental School, State University of Campinas, Avenida Limeira, 901, 13414-903, Piracicaba, SP, Brazil

[a]DDS, MSc, PhD, Post-Doctoral Researcher
[b]DDS, MSc, PhD, Researcher
[c]Dr med dent, Dr hc, Professor, Director of Center for Dental Biomaterials

DOI: 10.25241/stomaeduj.2018.5(4).art.4

## ABSTRACT

**Aim:** To make dentists aware on the importance of correctly used light cure resin composites.
**Method:** Highlighting important facts about light curing: Use of high quality light curing unit, use of the resin composite specific appropriate radiant exposure to adequately cure a resin composite, and highlighting important facts that may alter the radiant exposure received clinically by a resin composite restoration.
**Results:** Application of this knowledge should change the behavior of dentists when it comes to light curing.
**Conclusions:** The facts described should help educational institutes and professors to reinforce proper light curing techniques and associate training sessions within educational courses in order to improve teaching and learning.
**Keywords:** light curing, composites, teaching.


**Peer-Reviewed Article**

**Citation:** de Oliveira DCRS, Rocha MG, Roulet J-F. Light curing matters: Facts often overseen by dentists. Stoma Edu J. 2018;5(4):236-242.

**Academic Editor:** Nicoleta Ilie, Dipl-Eng, PhD, Professor, Ludwig-Maximilians-Universität München, München, Germany

Received: November 27, 2018
Revised: December 03, 2018
Accepted: December 17, 2018
Published: December 18, 2018

***Corresponding author:**
Dr. Dayane C. R. S. de Oliveira, DDS, MSc, PhD, Researcher
Department of Restorative Dental Sciences, College of Dentistry, University of Florida
1395 Center Dr, 32610, Gainesville, FL, USA
Tel: +1 352 273 5850;
Fax: +1 352 846 1643,
e-mail: dayoli87@gmail.com



## 1. Introduction

When placing a restoration, dentists are mainly performing a manufacturing process. This presumes good equipment, materials and process techniques. This short article will focus on the latter. A prerequisite for a proper functionality of a resin composite restoration in the oral cavity [1] is to receive sufficient radiant exposure (= irradiance of the light curing unit x exposure time).

In advertisements, light curing units (LCU) are usually characterized by their irradiance, which is expressed in mW/cm$^2$. This parameter alone is, however, by far insufficient to assess the quality of light curing. It should be mentioned that currently, the range of prices for dental LCUs varies among $18.59 (best-selling offer on e-bay on December 3$^{rd}$ 2018) and even more than $1000. While the irradiance of low-cost and expensive LCUs may be comparable, the price difference is reflected in the homogeneity of the light beam, the diameter of the light exiting window, the collimation of the light beam, the battery management to deliver a constant radiant exposure over time (Fig. 1). Saving on the cost of a light curing unit is saving on the wrong side. It should be emphasized here that, related to the total costs of a resin composite restoration, the use of an expensive LCU does not exceed 1%. This investment is worth, considering that the use of a deficient LCU may result in a poorly polymerized resin composite restoration, while the materials used will not perform as intended by the manufacturer.

Generally, manufacturers clearly indicate the radiant exposure necessary to adequately polymerize their materials (e.g. 20 seconds at 800 mW/cm$^2$). However, a fact that is often forgotten by dentists is to take into account the incremental thickness of the applied resin composites. Resin composites absorb, reflect and scatter the light they receive during polymerization. This means that if the maximum recommended incremental thickness is exceeded, the polymerization of the material may be insufficient, with the consequences described above. The incremental thickness recommended for most regular resin composites is 2 mm, while for bulk fil resin composites it may be extended to 4-5 mm. It should be emphasized that darker shades and less translucent resin composites will absorb more light and show a reduced depth of cure (= incremental thickness that is adequately cured) [2].

Besides the above-mentioned reasons, the success of resin composite restorations depends on further factors [3], while the less known and most neglected factor is the light curing process [4-6]. Resin composite restorations increasingly fail due to marginal failures

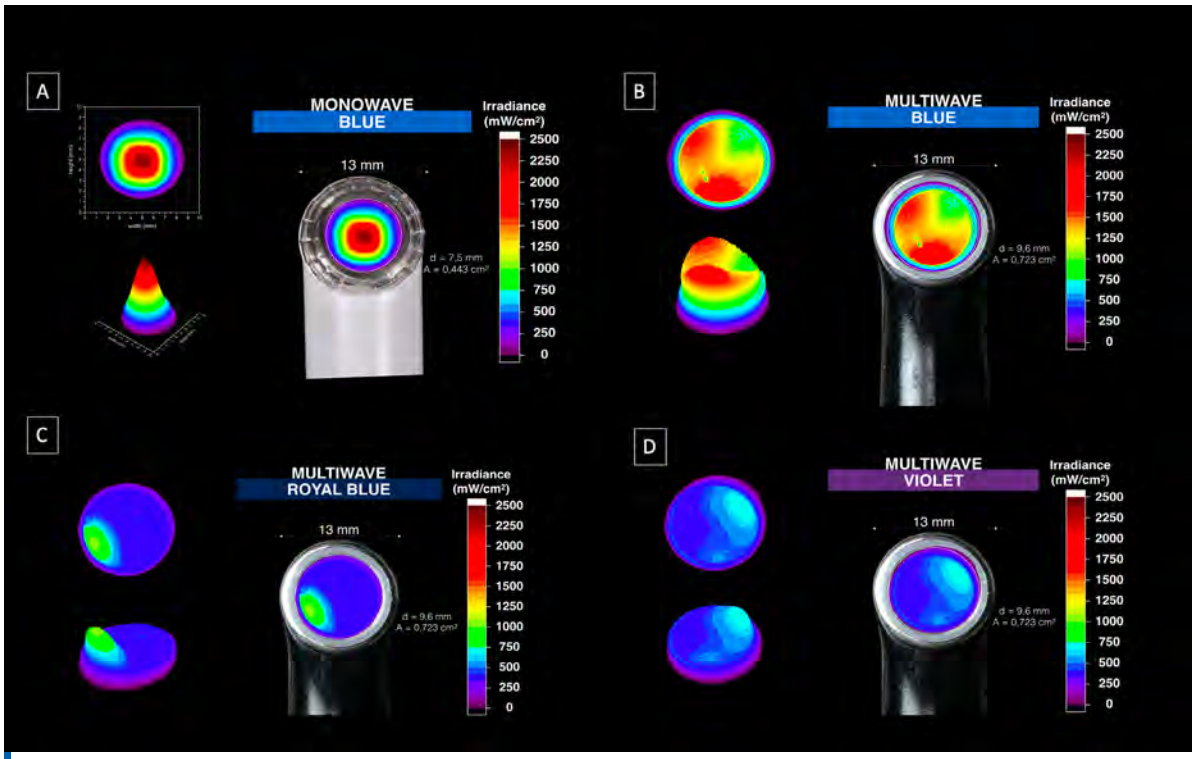



**Figure 1.** Homogeneity differences in light beam profile of mono- (Radii, SDI) and multi-wave (VALO Cordless, Ultradent) LED curing lights.

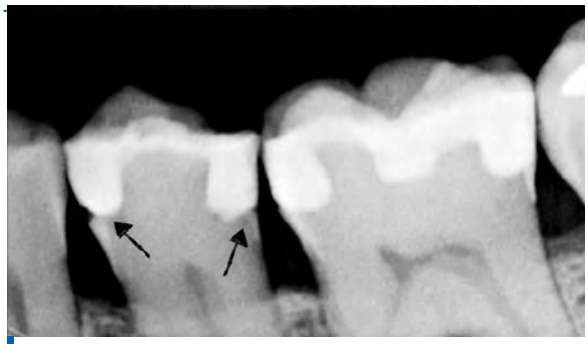


**Figure 2.** Marginal breakdowns due to inadequate light curing.
(Source: H. Strassler on youtube: https://www.youtube.com/watch?v=48XZgR37djY)

[7,8], as evidenced especially in Cass II restorations, which might be found in periodical x-rays (Fig. 2). What the majority of dentists do not know is that the most common reason for this kind of marginal breakdown is inadequate light curing [9].

It is nowadays well-documented that there is a large variation between operators in delivering the radiant exposure during the light curing process of a resin composite restoration. The use of an efficient LCU is therefore not a guarantor for an adequate polymerization [5,9-11]. Fortunately, education associated with proper training was proved to be efficient to improve light curing skills (Fig. 3) [9-11].

## 2. Clinical aspects

The first important factor that can lead to improper light curing is not paying attention [9-11]. Modern curing lights emit irradiances above 1000 mW/cm$^2$ [12], thus looking into the light during polymerization is not recommended due to potential risk for ocular hazards [13-15]. In response to that, most dentists avoid looking to the patient's mouth during the light curing process.

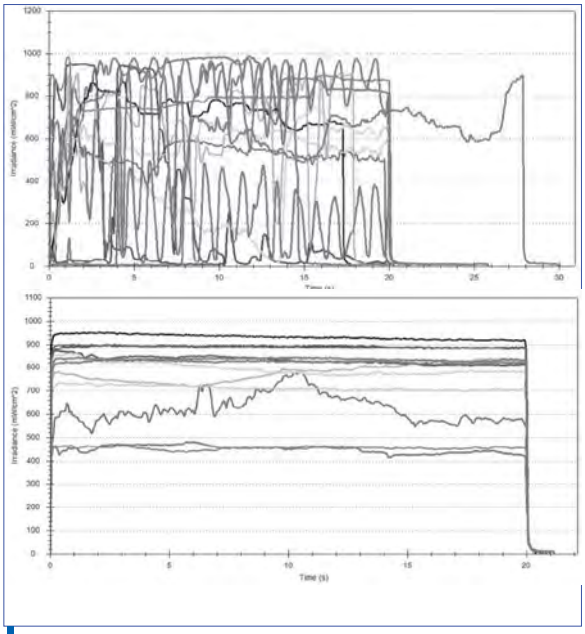


**Figure 3.** Light curing skills tested before and after training.

### 2.1. Blue-blocking filters

The right way to properly cure a restoration is positioning the light tip as close as possible and parallel to the restoration and stabilize and maintain it throughout the exposure [15]. In order to do so, some kind of blue-blocking shield is extremally needful. Different kinds of orange filters are available in the market to provide protection to the eyes during the light curing process (Fig. 4). These filters are able to block at least 97% of the light emitted from dental curing lights [16]. As can be observed in Fig. 5, the radiant emittance from the curing light is 1000 mW/cm$^2$, however, after interposing a blue-block filter in between the curing light emission and the sensor, the irradiance emittance from the curing


**Figure 4.** Blue-blocking filters:
a) hand-held light filter,
b) blue-blocking protective glasses,
c) flip-up shield,
d) clip-on shield,
e) ease-in removable shield.

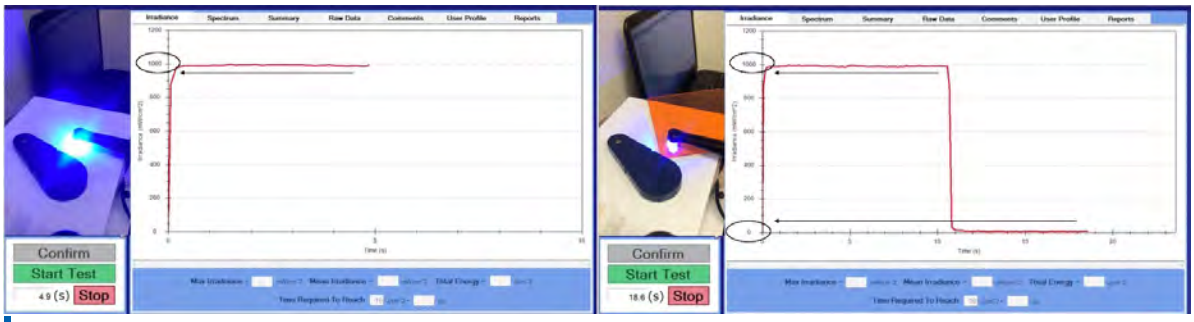



**Figure 5.** Effect of blocking blue-light irradiance from a multi-wave light curing unit during light exposure.


**Figure 6.** Irradiance increase as a result of using magnification loupes.

light is totally blocked. It is worthwhile mentioning that while using magnification loupes, the irradiance received at the pupil can be increased by up to 8 times greater than when no loupes are used (Fig. 6) [13]. Despite almost no publicity even from the own brands, blue-blocking filters specially made for loupes are available in the market, as previously illustrated in Fig. 3.

### 2.2. Positioning

The ideal case scenario is to light cure positioning the light tip as close as possible and parallel to the restoration during light curing [15]. However, different clinical situations can make this difficult or almost impossible, such as the restauration location and the light tip angulation versus patient mouth aperture (Fig. 7) [17,18].

Another aspect that cannot be neglected is that different curing lights have different light tip sizes. The light tip diameter of the curing lights in the market are between 7 and 12 mm [19,20]. Usually fiber optic guides vary from 7 to 9 mm in diameter [19], while quartz lenses such as used in the VALO Cordless and VALO Grand (Ultradent, South Jordan, UT, USA) are 10 and 12 mm in diameter, respectively [19,20]. Usually pre-molar are about 7 mm wide, but average molars are about 10 mm wide (Fig. 8) [21]. Thus, special attention in positioning the curing light is encouraged when light curing proximal boxes in Class II restorations, as well as two light curing procedures in each end (mesial and distal) while using bulk fill composites in Class II restorations (Fig. 9) [4,6,15].

When the light tip is not positioned properly,

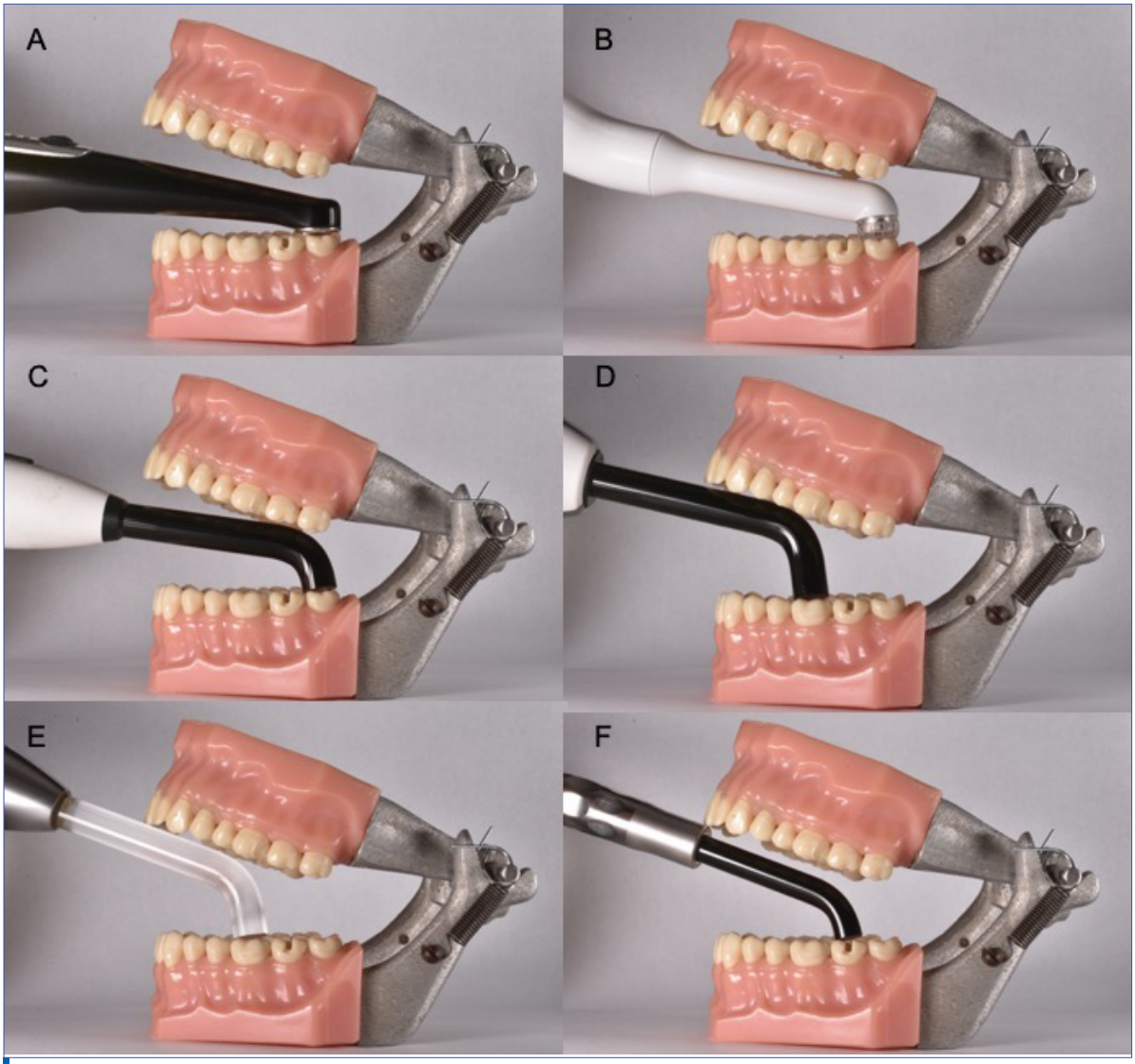



**Figure 7.** LCU tip angulation and ideal positioning, at same mouth aperture situation: A) VALO Cordless (Ultradent), B) Radii Plus (SDI), C) Bluephase Style (Ivoclar Vivadent), D) Bluephase G2 (Ivoclar Vivadent), E) Elipar S10 (3M ESPE), F) G-light (GC).

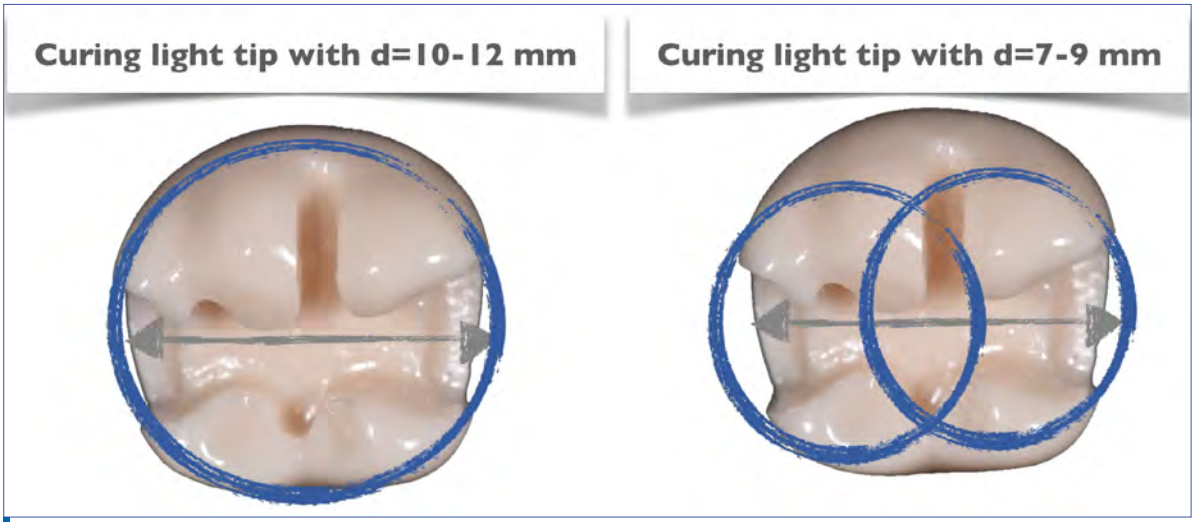



**Figure 8.** Overlapping ofa 10 mm wide molar with different light guides sizes

either because of limitations due to its size (Fig. 8) or because of angulations caused by mouth aperture (Fig. 10), not enough light will reach the resin material and polymerization can be affected [15], especially in depth, possible causing marginal breakdowns such as exemplified in Fig. 1.

### 2.3. Cleaning and maintaining

Finally, leaning and maintaining should not be forgotten. It is already known that broken and dirty light curing tips can affect the polymerization of the material [15]. Usually, when the light tip gets in direct contact with the resin composite or adhesive

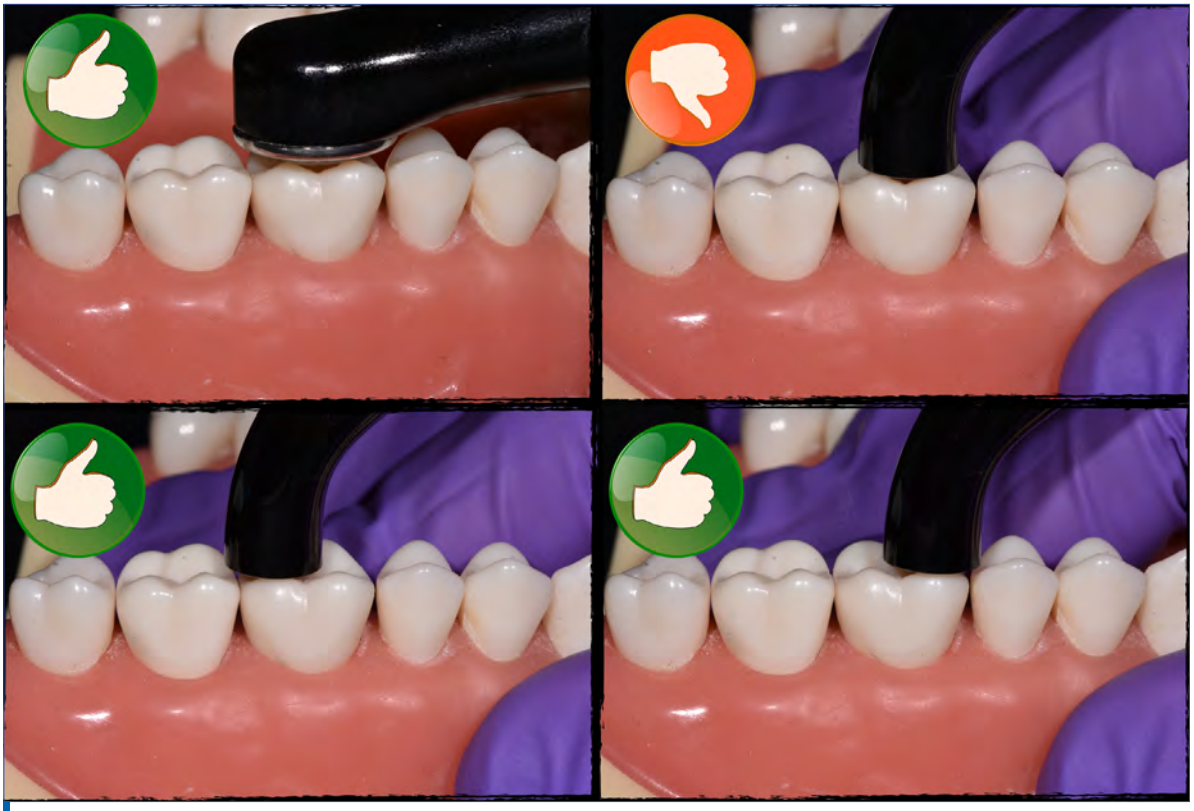


**Figure 9.** Instructions on light curing a 10 mm wide molar using different light tip sizes.

**Figure 10.** Instructions on positioning the curing light properly.

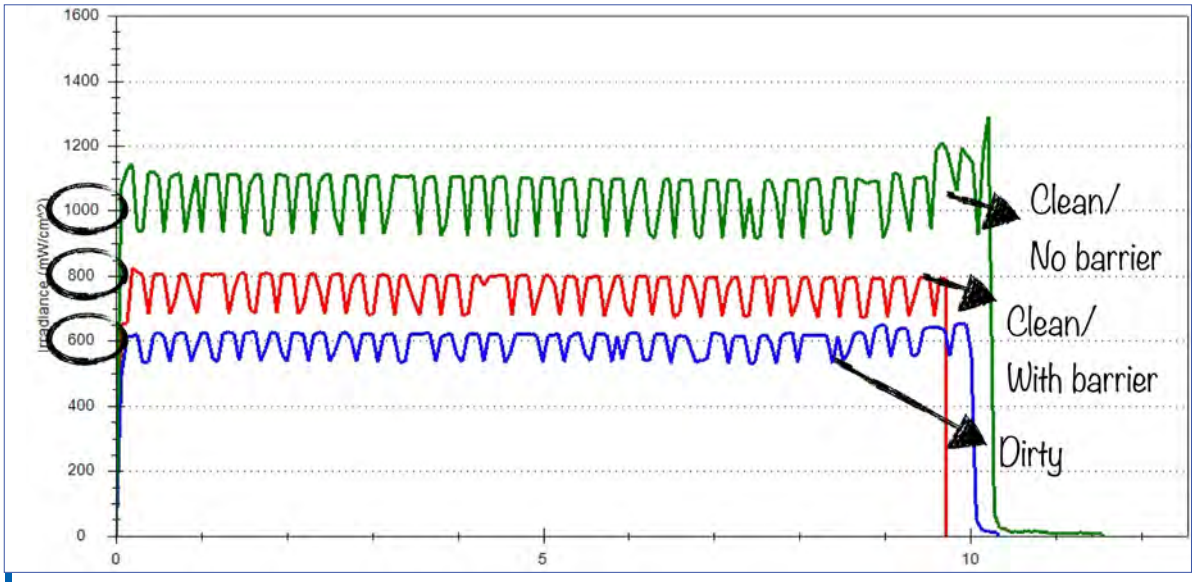



**Figure 11.** Irradiance emittance drop from a curing light with dirty tip and use of barrier sleeve.

during polymerization, part of this material adheres to the light tip. The problem is that not only does the restoration lose shape because part of the resin material is transferred to the light tip, but the next increment of resin will not receive the same radiant exposure than the first one. Light curing sleeves are

not only able to protect from cross-contamination, but the light tip from resin material adhesion when accidental contact is made with the restoration during the light curing process. It is known that using light curing sleeves can cause a small reduction in the irradiance emittance from the curing light, but it is already proven not to influence on polymerization [22]. Fig. 11 illustrates an exemplification of the drop in the irradiance emittance from a curing light when no barrier sleeve is used and the light tip is clean, when the light tip is dirty and when a barrier sleeve is used. Of course, using a barrier sleeve is extremally important to protect the light tip, and guarantee proper polymerization.

## 3. Conclusions

To conclude this topic, it is worthwhile mentioning that several studies have demonstrated that the education provided to dentists and dental students seems to be insufficient to teach them how to deliver the proper amount of radiant exposure from a curing light to the restoration [9-11]. On the other hand, education associated with proper training was proved to be efficient to improve light curing skills, even in short training sessions [9-11]. Educational institutes and professors shall reinforce proper light curing techniques and associate training sessions within educational courses in order to improve teaching and learning.

## Author Contributions

DO: written and proofread the manuscript.
MR: written and proofread the manuscript.
JFR: written and proofread the manuscript.

## Acknowledgments

DO is a Post-Doctoral Researcher at São Paulo Research Foundation - FAPESP (grant #2016/05823-3 and #2017/22161-7). MR is a PhD candidate at São Paulo Research Foundation - FAPESP (grant #2016/06019-3 and #2017/22195-9).

## References

1. Strassler H, Oxman J, Rueggeberg F. Light Curing - Tips on choosing your next curing light. *CDA Essentials* 2016;3:30-33. [Full text links]
2. Ilie N, Plenk E-M. Light transmission through resin composites. *Stoma Edu J.* 2018;5(3):148-154. [Full text links]
3. Moraschini V, Fai CK, Alto RM, Dos Santos GO. Amalgam and resin composite longevity of posterior restorations: a systematic review and meta-analysis. *J Dent.* 2015;43(9):1043-1050. [Full text links] [PubMed] Google Scholar(64) Scopus(33)
4. Rueggeberg FA, Giannini M, Arrais CAG, Price RBT. Light curing in dentistry and clinical implications: a literature review. *Braz Oral Res*. 2017;31(1):e61. [Full text links] [PubMed] Google Scholar(10) Scopus(4)
5. Samaha S, Bhatt S, Finkelman M, et al. Effect of instruction, light curing unit, and location in the mouth on the energy delivered to simulated restorations. *Am J Dent*. 2017;30(6):343-349. [Full text links] [PubMed] Google Scholar(0) Scopus(0)
6. Lima RBW, Troconis CCM, Moreno MBP, et al. Depth of cure of bulkfill resin composites: a systematic review. *J Esthet Restor Dent*. 2018;29 [epub ahead of print]. [Full text links] [PubMed] Google Scholar(0)
7. Demarco FF, Correa MB, Cenci MS, et al. Longevity of posterior restorations: not only a matter of materials. *Dent Mater*. 2012;28(1):87-101. [Full text links] [PubMed] Google Scholar(530) Scopus(307)
8. Demarco FF, Collares K, Correa MB, et al. Should my composite restorations last forever? Why are they failing? *Braz Oral Res*. 2017;31(1):e56. [Full text links][PubMed] Google Scholar(10) Scopus(5)
9. Price RB, Felix CM, Whalen JM. Factors affecting the energy delivered to simulated Class I and Class V preparations. *J Can Dent Assoc*. 2010;76:a94. [Full text links][PubMed] Google Scholar(52) Scopus(32)
10. Price RB, Strassler HR, Price HL, et al. The effectiveness of using a patient simulator to teach light-curing skills. *J Am Dent Assoc*. 2014;145(1):32-43. [Full text links] [PubMed] Google Scholar(18) Scopus(16)
11. Mutluay MM, Rueggeberg FA, Price RB. Effect of using proper light-cuing techniques on energy delivered to a Class 1 restoration. *Quintessence Int*. 2014;45(7):549-556. [Full text links] [PubMed] Google Scholar(17) Scopus(14)
12. Soares CJ, Rodrigues MP, Oliveira LRS, et al. An evaluation of the light output from 22 contemporary light curing units. *Braz Dent J*. 2017;28(3):362-371. [Full text links] [PubMed] Google Scholar(2) Scopus(2)
13. Price RB, Labrie D, Bruzell EM, et al. The dental curing light: a potential health risk. *J Occup Environ Hyg*. 2016;13(8):639-646. [Full text links] [PubMed] Google Scholar(12) Scopus(8)
14. Labrie D, Moe J, Price RB, et al. Evaluation of ocular hazards from 4 types of curing lights. *J Can Dent Assoc*. 2011;77:b116. [Full text links] [PubMed] Google Scholar(21) Scopus(13)
15. Price RB. Light curing guidelines for practitioners: a consensus statement from the 2014 symposium on light curing in dentistry, Dalhousie University, Halifax, Canada. *J Can Dent Assoc*. 2014;80:e61. [Full text links] [PubMed] Google Scholar(6) Scopus(6)
16. Soares CJ, Rodrigues MP, Vilela ABF, et al. Evaluation of eye protection filters used with broad-spectrum and conventional LED curing lights. *Braz Dent J*. 2017;28(1):9-15. [Full text links] [PubMed] Google Scholar(5) Scopus(4)
17. Andre CB, Nima G, Sebold M, et al. Stability of the light output, oral cavity tip accessibility in posterior region and emission spectrum of light-curing units. *Oper Dent*. 2018;43(4):398-407. [Full text links] [PubMed] Google Scholar(0) Scopus(0)
18. Bhatt S, Ayer CD, Price RB, Perry R. Effect of light and restoration location on energy delivered. *Compend Contin Educ Dent*. 2015;36(3):208-210. [Full text links] [PubMed] Google Scholar(7) Scopus(4)
19. Shortall AC, Felix CJ, Watts D. Robust spectrometer-based methods for characterizing radiant exitance of dental LED light curing units. *Dent Mater*. 2015;31(4):339-350. [Full text links] [PubMed] Google Scholar(13) Scopus(10)
20. Shimokawa CAK, Turbino ML, Giannini M, et al. Effect of light curing units on the polymerization of bulk fill resin-based composites. *Dent Mater*. 2018;34(8):1211-1221. [Full text links][PubMed] Google Scholar(0) Scopus(0)
21. Babu SS, Nair SS, Gopakumar D, et al. Linear odontometric analysis of permanent dentition as a forensic aid: a retrospective study. *J Clin Diagn Res*. 2016;10(5):C24-C28. [Full text links] [Free PMC Article] [PubMed] Google Scholar(3) Scopus(1)
22. Scott BA, Felix CA, Price RBT. Effect of disposable infection control barriers on light output from dental curing lights. *J Can Dent Assoc*. 2004;70(2):105-110. [Full text links] [PubMed] Google Scholar(42) Scopus(18)

Review Article

**Dayane C. R. S. DE OLIVEIRA**

DDS, MSc, PhD, Researcher
Department of Restorative Dental Sciences College of Dentistry,
University of Florida
Gainesville, FL, USA

## CV

Dayane Oliveira, DDS, MS, PhD, is a post-doc fellow of the Department of Restorative Dentistry at Piracicaba Dental School, State University of Campinas (UNICAMP), in Brazil, and visiting researcher of the Department of Restorative Dental Sciences at the University of Florida. Dr. Oliveira is a young researcher that contributed to 6 textbook chapters, authored 7 patents and own many awards in her area of expertise. Her areas of interest include aesthetic dentistry, color science and biomaterials development and characterization.

## Questions

### 1. Is the characterization of a light curing unit by its irradiance a sufficient parameter?

❑a. Absolutely yes;
❑b. It tells the dentist most of the performances of the light curing unit;
❑c. It only tells the user about the stability of the batteries;
❑d. No, further parameters like e.g the homogeneity of the light beam should also be considered.

### 2. The quality of a class II resin composite restoration depends mainly on

❑a. The brand of the used resin composite;
❑b. Dentists' application technique of the light curing unit;
❑c. The brand of the light curing unit;
❑d. The patients' behavior.

### 3. The use of orange filters are needed

❑a. To protect the dentist from eye damage during curing;
❑b. Only to allow dentists to better see what they are doing;
❑c. To prolong the working time of a light cured composite;
❑d. To prevent the tooth from overheating.

### 4. When light curing a resin composite restoration, dentists are recommended to:

❑a. Look to what they are doing, since this will improve the quality of polymerization, since the blue light of modern LCUs represents no risk for ocular hazards;
❑b. Position the light tip as close as possible and parallel to the restoration, while using blue-blocking filters;
❑c. Polymerize in one-shot, irrespective of the size of the restoration and LCUs tip, to reduce shrinkage stress;
❑d. Not to use light curing sleeves, since they induce a massive reduction in irradiance.

# ADVANCES IN 3D BIOPRINTING FOR BONY DEFECTS OF THE MANDIBLE

**Simon Cleemput[1a*], David Las[2b], Reinhilde Jacobs[1c], Constantinus Politis[1d]**

[1]OMFS-IMPATH research group, Department of Imaging & Pathology, KU Leuven & Oral and Maxillofacial Surgery, Faculty of Medicine, University Hospitals Leuven, BE-3000 Leuven, Belgium
[2]University Hospital Brussels, Free University Brussels, BE-1090 Brussels, Belgium

[a]MD
[b]MD, DDS
[c]DDS, MSc, PhD, Professor
[d]MD, DDS, MHA, MM, PhD, Professor

Review Article

## ABSTRACT

DOI: 10.25241/stomaeduj.2018.5(4).art.5

**Background:** A series of conditions can leave the human mandible with a bony defect that is still difficult to compensate for with current clinical techniques. 3D bioprinting (computer-controlled, highly organized deposition of bio-materials and stem cells into a 3D structure) is a new tissue engineering strategy showing potential to contribute to the treatment of these defects.
**Objective:** The aim of this review is to give clinicians an idea of how 3D bioprinting works, where this technology is currently at and how it is developing towards clinical application in the field of maxillo-facial surgery.
Data sources: Bone tissue engineering literature was searched for articles that describe the use of additive manufacturing (collective term for layer-wise stacking of materials, including 3D printing) with use of biomaterials and stem cells.
**Study selection:** 3D bioprinting reviews and research articles presenting bone tissue constructs were selected.
**Data Extraction:** Information on 3D bioprinting background, design, applied techniques and used biomaterials for bone tissue were bundled. Research projects aiming at creating viable bone constructs were selected.
**Data Synthesis:** This review presents a comprehensive summary of 3D bioprinting basics and shows how this technique is evolving towards bone tissue constructs with the potential of clinical application in the management of bony mandibular defects.
**Keywords:** tissue engineering, 3D printing, bioprinting, biomaterials, bone, mandible.



**Peer-Reviewed Article**

**Citation:** Cleemput S, Las D, Jacobs R, Politis C. Advances in 3D bioprinting for bony defects of the mandible. Stoma Edu J. 2018;5(4):243-253

**Academic Editor:** Gabi Chaushu DMD, MSc, Professor, Head, The Maurice and Gabriela Goldschleger School of Dental Medicine, Tel Aviv-University, Tel Aviv, Israel

Received: November 06, 2018
Revised: November 14, 2018
Accepted: November 27, 2018
Published: November 29, 2018

***Corresponding author:**
Simon Cleemput, MD
OMFS-IMPATH research group, Department of Imaging & Pathology, Faculty of Medicine, University Hospitals Leuven, BE-3000 Leuven, Belgium
Tel: 0032485310696, Fax: 003216332410, e-mail: simon.cleemput@student.kuleuven.be



## 1. Introduction

Previous methods of dealing with substantial bony defects in the maxillo-facial area (most often arising from trauma, osteonecrosis, tumour removal or congenital disorders) have sought to replace the missing tissue with either artificial materials or with tissue from elsewhere in the body. To this idea, metals and polymers have been used, as well as autogenic parts of the fibula, radius bone, iliac bone and scapula. Though these modalities have proven themselves worthy of performing over not treating the defect at all, they both present some major downsides and limitations. Artificial materials remain foreign objects to the body, lack regenerative capacities and suffer from wear whilst autogenic transplants are never fully compatible with the defect, require difficult moulding and provide donor site morbidity.
Recent advancements in the fields of stem cell research, biomaterial development and computerized 3D printing have given birth to a new tissue engineering strategy named 3D bio-printing, aiming to artificially recreate human tissue by cultivating stem cells applied onto (or even printed directly into) a 3D printed scaffold.

Most of the cutting-edge research that applies this tissue engineering strategy currently operates in the in vitro-domain, with just a few experiments transferring towards animal studies. Recent years however have brought incredible expansion of the spectrum of applicable materials and techniques. Researchers are creating extensive designs and customized processes to unite the properties of all of these techniques into constructs with a viability that was previously unknown outside of the body.
Following is an overview of the general workflow, the printing techniques, materials, properties and designs of 3D bioprinting and some illustrative examples of what is currently state of the art concerning bone tissue constructs.

## 2. Background

Paraphrasing the introduction, "3D bioprinting" is to simply put "3D printing with biocompatible materials and with living cells". It is thus a variant of 3D printing, a manufacturing technique which has been around since 1984, when Charles Hull invented an "Apparatus for making three-dimensional objects

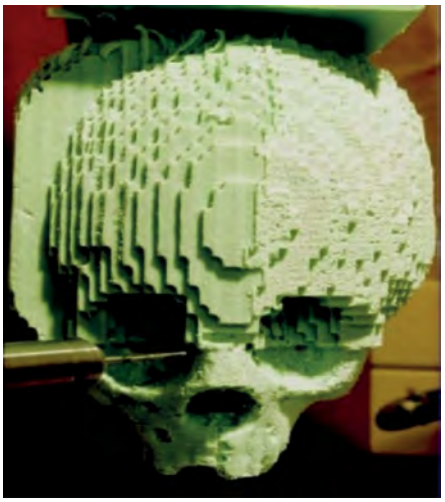


**Figure 1.** One of the earliest CT-based, plaster-milled study-models of a human skull (1987). Reprinted with permission by Dr. T. Lambrecht.)

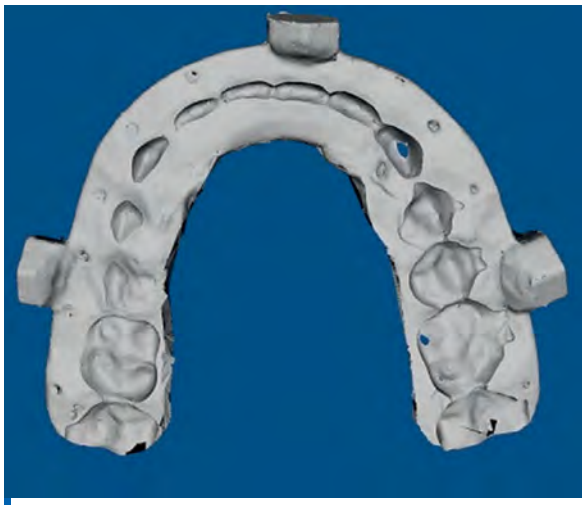


**Figure 2.** An STL formatted model of a modern surgical wafer, printed by stereolithography[1]. Reprinted with permission by Elsevier.

**Figure 3**

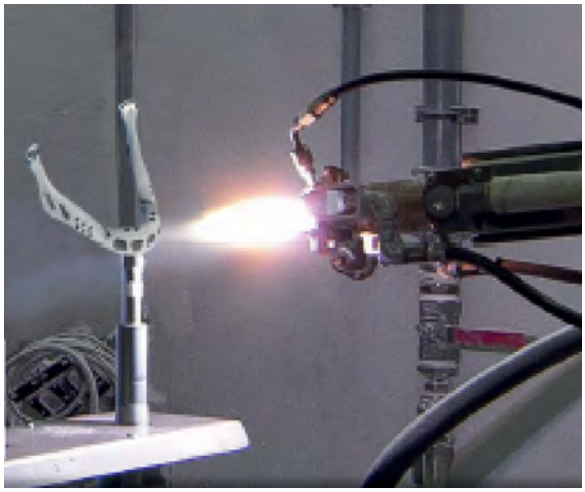


**Figure 4**

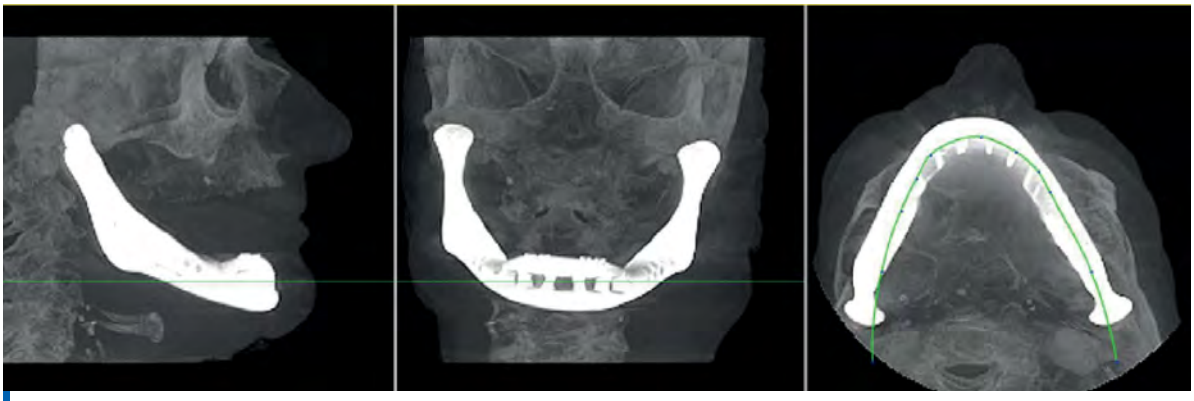


**Figure 5**

**Figure 3, 4, 5.** The hydroxy-apatite-coated, laser-melted, titanium full mandible, produced by Xilloc® and implanted by Dr Poukens in 2012. Reprinted with permission by Xilloc®.

by stereolithography". Steady development and improvement have made 3D printing applicable to several production processes in modern life and already useful in the maxillofacial clinic. For example, 3D printed study models (Fig. 1) have been around since 1987, proving themselves useful in evaluating pathology or planning of surgery. Several maxillofacial departments already use 3D printing to produce acrylic wafers [1] or cutting guides (Fig. 2), which are then sterilized and applied during surgery.

And (often in collaboration with specialized 3D printing design and production firms), patients are even treated with 3D printed, patient-specific implants, such as custom titanium meshes to cover up craniectomy sites and as of 2012 a fully functional, titanium mandible (Fig. 3), successfully implanted in an 83-year-old suffering from severe osteomyelitis.

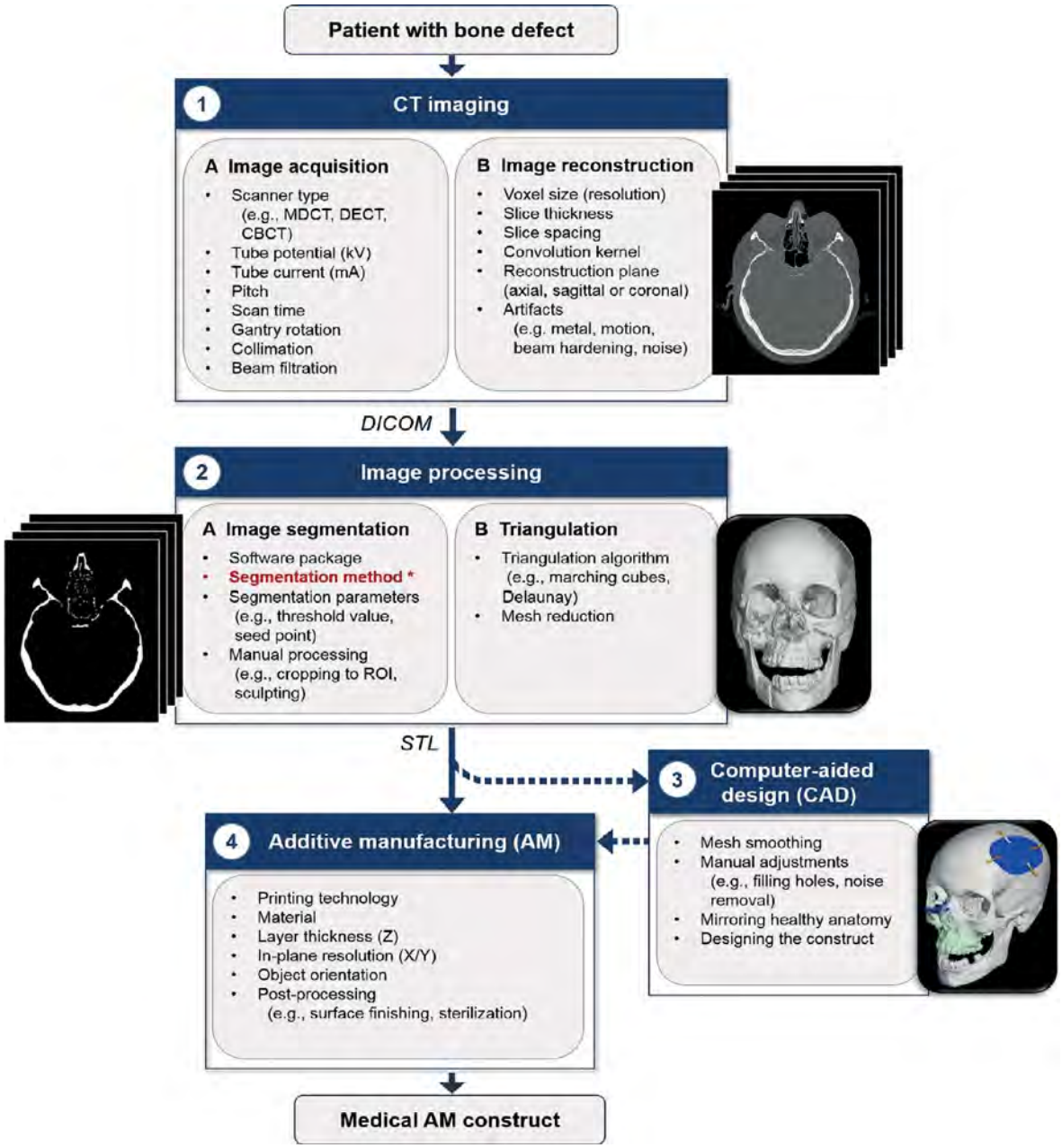



**Figure 6.** Overview of the parameters affecting accuracy of medical AM constructs [5].
Overview of the process of creating personalized medical constructs by "additive manufacturing" (= collective term for production techniques based on layer-wise stacking of materials, including 3D printing methods) with parameters that can influence the accuracy of the constructs [5]. This research group found the differences between the imaged reality and 3D printed construct to range between 0.04 mm and 0.62 mm, when applying the most commonly used segmentation technique of "global thresholding". Reprinted with permission by Elsevier.

## 3. From medical image to 3d (bio) printing design

It is remarkable how early on medicine jumped on the wagon of 3D printing, with maxillofacial surgery apparently at its forefront. In part this reflects the great demand of maxillofacial surgery for highly customized constructs. On the other hand, the application of 3D printing in medicine has benefited greatly from the readily available high quality medical imaging, which can serve as a reference for the 3D printing construct (at least for the gross contouring) when processed by appropriate computer programs.

Converting medical images into a structural reference for the 3D printer usually begins with feeding the medical images (JPEG, TIFF, BMP, but mostly raw DICOM data) through 3D converting software to create a 3D surface model [2]. This digital process performing this transition is named "segmentation" and the most popular type "global thresholding". The model thus obtained can be a helpful tool by itself in evaluating existing pathology or planning surgery and can at this stage also easily be digitally adjusted, in which case it becomes a 3D CAD model.

A second process named "slicing" converts the obtained 3D surface model (or adjusted CAD model) into structural guidance for the 3D printer. So called "slicer-software" will firstly reconstruct the unstructured surface of the 3D surface model into a

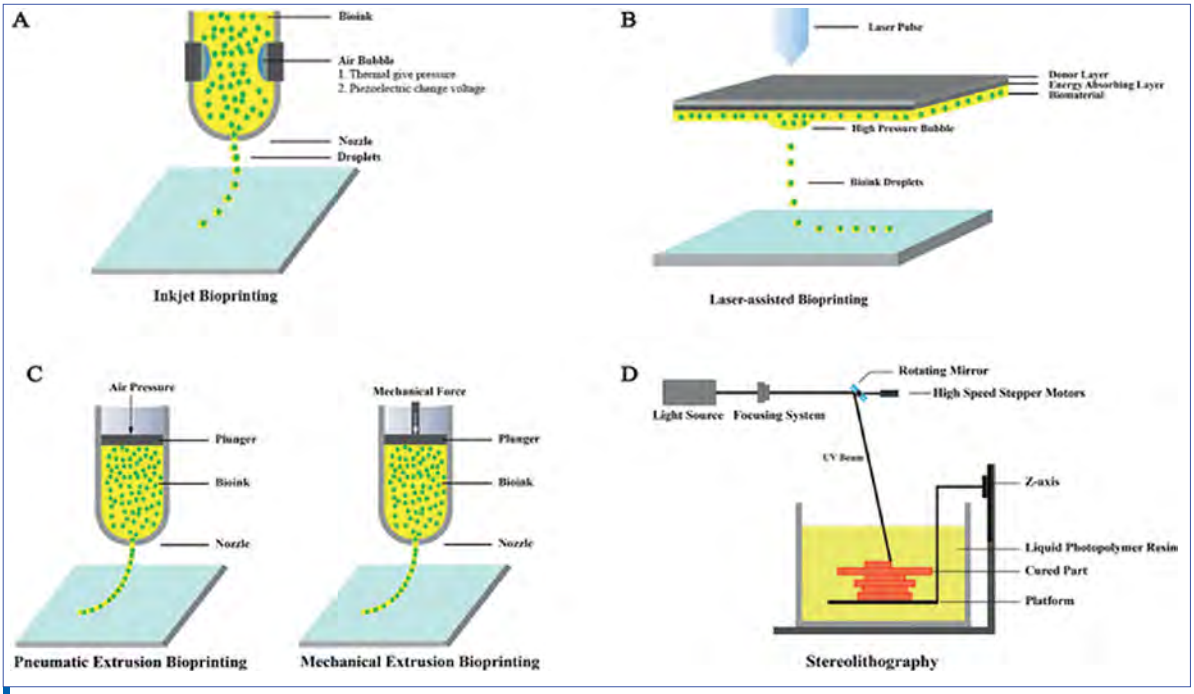



**Figure 7.** Schematic drawing representing the major bioprinting techniques [12]. (A) Inkjet bioprinting (B) Laser-assisted bioprinting (C) Extrusion bioprinting (D) Stereolithography. Reprinted with permission by Wiley.

standard tessellation language (.stl formatted) model with a surface consisting of triangles (a process called "triangulation", most often performed by applying the technique of "marching cubes") [3]. Secondly the software will help design an appropriate structural framework to support the geometrically-approached surface and fill up the volume underneath.
After this, the software will effectively slice the obtained 3D model horizontally into layers and it will write "G-code" which will serve as computer commandos for the 3D printer on the course it has to run the nozzle through while printing the digital model, layer on top of layer in a CNC-like way [4].

## 4. The different types of 3D bioprinters

The previous paragraph described a design process that is very similar for 3D printers as it is for 3D bioprinters. The outside look of a 'regular' 3D printer and a 3D bioprinter can also be very similar, as companies such as 'Cellink' are now selling desktop models starting at approx. 5000 USD. However, most of the cutting-edge 3D bioprinting research preformed nowadays makes use of very specific biomaterials and even more specific strategies of processing these materials. As a result, a lot of researchers modify existing 3D printers to these specific requirements, creating dozens of unique 3D bioprinters.
The exact method of delivering materials into a 3D structure however can always be narrowed down to one of 4 mechanisms, described below and illustrated in Fig.7 [6].

### 4.1. Inkjet bioprinting

This type of bioprinting relies on the formation of small air bubbles to push droplets of bio-ink (the chosen mixture of biomaterials and cells) out of the nozzle of the printer. The bubbles can be generated by local heat (thermal), current over a crystal (piezoelectric), sound waves (acoustic) or static electricity [7-11].The first two of these methods are the most widely applied and even though heat generation would seem a risk for cell viability, more difficulty is experienced with the piezoelectric mechanism.

### 4.2. Extrusion-based

Similar to inkjet bioprinting, extrusion- based bioprinting uses pressure to force the bioink out of the nozzle of the printer but does this by applying direct mechanical force or air pressure onto a plunger in a syringe-type of depositor [7-10]. With this robust depositing system, extrusion-based printers can handle more viscous types of bioink with higher cell densities (groups of cells, organoids), resulting in a continuous cylindrical stream rather than droplets.

### 4.3. Laser-assisted

A third type of 3D bioprinting is based on the mechanism of laser-induced forward transfer of energy (LIFT). It uses the energy of a pulsed laser beam, focused and directed onto a specially designed 2-layer plate (called "a ribbon"), consisting of an absorbing layer generating local heath and ultimately small high-pressure bubbles which force droplets of bioink to form from an underlaying plate of biomaterial [9,11]. Since there is no (mechanical stress-inducing) nozzle for the cells to pass through, cell viability is relatively high and precise focussing of the laser beam can provide good resolution of the printed construct. The process of printing however is rather slow and the 2-layered "ribbon" is an expensive component.

### 4.4. Stereolithography

This last category of 3D bioprinting also applies focused UV light, but uses this to cure or selectively solidify a photosensitive biomaterial [9,13]. It is the oldest type of bioprinting and has yielded good resolutions with polymers with high molecular weights. The direct

| | | | | |
|---|---|---|---|---|
| Biomaterials used in 3D bioprinting | polymers | natural | - collagen<br>- gelatine<br>- fibrin<br>- hyaluronic acid<br>- heparine | Present in humans |
| | | | - alginate<br>- chitosan<br>- (carboxy-methyl) cellulose<br>- pectine<br>- silk fibre<br>- chondrotine sulfaat<br>- carrageenans<br>- xanthan<br>- dextran | Found in bacteria, fungi,… |
| | | synthetic | - PGA (poly-glycolic acid)<br>- PLA (poly-lactic acid)<br>- PCL (poly ε- caprolactone)<br>- PPF (poly propylene fumarate)<br>- PEG (poly ethylene glycol)<br>- PU (polyether urethane)<br>- PEEK (polyether ether ketone) | |
| | ceramics | | - Hydroxyapatite<br>- B- tricalcium phosphate<br>- coralline<br>- Bioglass<br>- calcium-silicate | |
| | composites | | Hybrid hydrogels<br>+ ceramics,<br>+ synthetic polymer fibres<br>+ peptides<br>+ … | |

**Table 1.** Overview of popular biomaterials used in bioinks.

UV lighting of the biomaterial however is known to induce stress, lowering cell viability.

## 5. Combining biomaterials and cells into the bioink

Up to this point we have described the part of 3D bioprinting that consists of computer programming and printing apparatuses. The part that is "bio", consists of the cells that will be printed and the bio-compatible materials which will accommodate these cells. Together they form the bio-ink. To give an understanding of the spectrum of biomaterials, table 1 provides a summarization categorizing them as polymers, ceramics and composite materials [6,8,14,15].

The group of natural polymers consists of organic polysaccharides that are spontaneously formed by organisms in nature. Some of these appear in humans, such as collagen and gelatine. Others are of fungal or bacterial origin, such as chitosan [16] or alginate [17]. Since they attract lots of water, these polymers can be easily made into hydrogels, closely resembling the natural cell environment and thus providing good bio-compatibility, osteo-conductivity and low immunogenicity [8]. These hydrogels can be printed at relatively low temperatures, which also favours cell survival. The lack of intrinsic strength however almost always demands crosslinking of the polymer; for example, with $Ca^{2+}$ or $Mg^{2+}$ in the case of alginate and NaOH in the case of chitosan. Crosslinking can be done by heat, chemicals or UV light, most often right after printing, but all of these are known to induce stress on the printed cells. When implanted in the body, the polymer construct would be degraded by enzymes such as collagenase and the degradation product would not be toxic. Variation in locale enzyme concentration however would make the degradation rate hard to control.

Using polymers that are instead synthetic linear aliphatic polyesters, would eliminate some of the problems of unpredictable characteristics associated with naturally occurring saccharides. Their molecular weight and size distribution are known and can stably be controlled and reproduced [14]. Their intrinsic strength is much higher than that of the natural

**Figure 8.** 3D printed gelatine mandibular condyle mold [24]. Reprinted with permission by Elsevier.

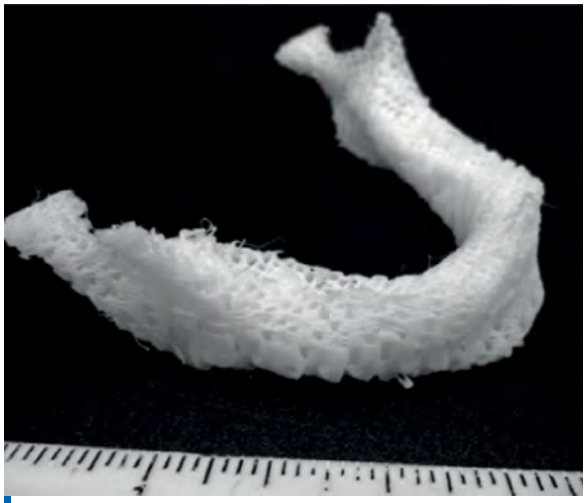


**Figure 9.** 3D-printed, porous PCL scaffolds of a mandible at 40% infill density[4]. Reprinted with permission by Wiley.

polymers; thus they allow constructs with a more complex architecture. Unfortunately, liquefying these synthetic polymers for printing requires temperatures between 60° and 200°C [18]. Degradation of these constructs, though spontaneous and predictable by simple hydrolysis, results in local accumulation of acids. Both of these characteristics negatively impact cell survival.

Bio-ceramics are also a category of biomaterials used in 3D bioprinting and they can rely on a longer tradition of clinical application, as some of them already exist as injectables and are approved by the FDA. They surpass synthetic polymers in compressive strength, and the often-high calcium content and porous microstructure provide good osteo-conductivity. However, as they are processed as a sludge, directly printing them together with cells is difficult and has not yet yielded high cell survival.

It is almost impossible to present an exhaustive list, as the category of composite materials is by far the largest as it is made up of combinations of materials. Not only combinations of components from the first two categories, but also combinations of biomaterials and bioactive compounds are currently in use. As mentioned above, most 3D bioprinting research is not performed by standard printers, but by custom-tailored variants. This is because researchers constantly try to unite biomaterial properties, printing techniques and tissue engineering designs into projects with viability. Some examples are described below. We have mentioned the good cell viability of natural polymer-based hydrogels such as alginate and gelatine, and their lack of intrinsic strength. Researchers went by this and have made mixtures of:

- Gelatine and acryl, resulting in methacrylated gelatin hydrogels [14].
- Alginate, gelatine and calcium phosphate, showing improved adhesion and cell proliferation when printed with bone-related Saos-2 cells [19].
- Alginate crosslinked with gelatine, combined with Bioglass [20] or Hydroxyapathite [21], showing improved mechanical strength, as well as improved proliferation and mineralisation when printed with Saos-2 cells.

Synthetic polymers are generally stronger than natural polymers, but less bio-compatible. They too can be made suitable for 3D bioprinting when mixed into composite materials, such as:

- Polycaprolactone crosslinked to alginate, resulting in improved strength[22].
- Polycaprolactone, added as a microfiber to hybrid hydrogels of alginate and gelatine, or to collagen, resulting in accelerated new bone formation, even in in vivo experiments [23].

These are just a few examples of biomaterial-configurations that show potential for 3D bioprinting, as they are able to unite viable conditions for living cells with processability and favourable characteristics towards scaffold design. Strictly, 3D bioprinting can be done by printing these combinations of biomaterials (without any cells) and allowing the printed construct to be colonised by cells, either in vitro or upon implantation. Some examples of this "indirect" 3D bioprinting are listed below.

In 2013 Lee et al. bioprinted a mandibular condyle out of gelatine (Fig. 8), with an outer surface and anatomical shape based on patient specific imaging and an inner structure of a regular (cuboid) lattice with tubes of 1.3 mm diameter and pores of 1.7 mm. By infiltrating the structure thus obtained with a PCL or chitosan solution and washing away the gelatine afterwards, the same construct was obtained in PCL and chitosan. These constructs were also successfully seeded with mouse bone marrow stromal cells (mBMSC's), which showed good spread and proliferation, especially when coating the construct with hydroxyapatite [24].

In 2014, Temple et al. managed to bioprint a complete human mandible (Fig. 9) and maxilla directly out of PCL, using a self-designed 3D bio-printer (a converted CNC, able to melt and extrude PCL through a nozzle of 470 µm at a speed of 2.7 mm/s). They based the design on patient specific imaging and used a slicer programme which filled up the inner structure with a cuboid lattice and automatically created extra supporting structures, which were trimmed away after printing. The 3D bio-printed mandible however was not seeded with stem cells [4]. These examples demonstrate that reconstruction of a human mandible (or at least fragments) with an accurate shape and with some sort of viability has been lying within the interest field of 3D bioprinting research for some time already. Implanting these structures however would seem

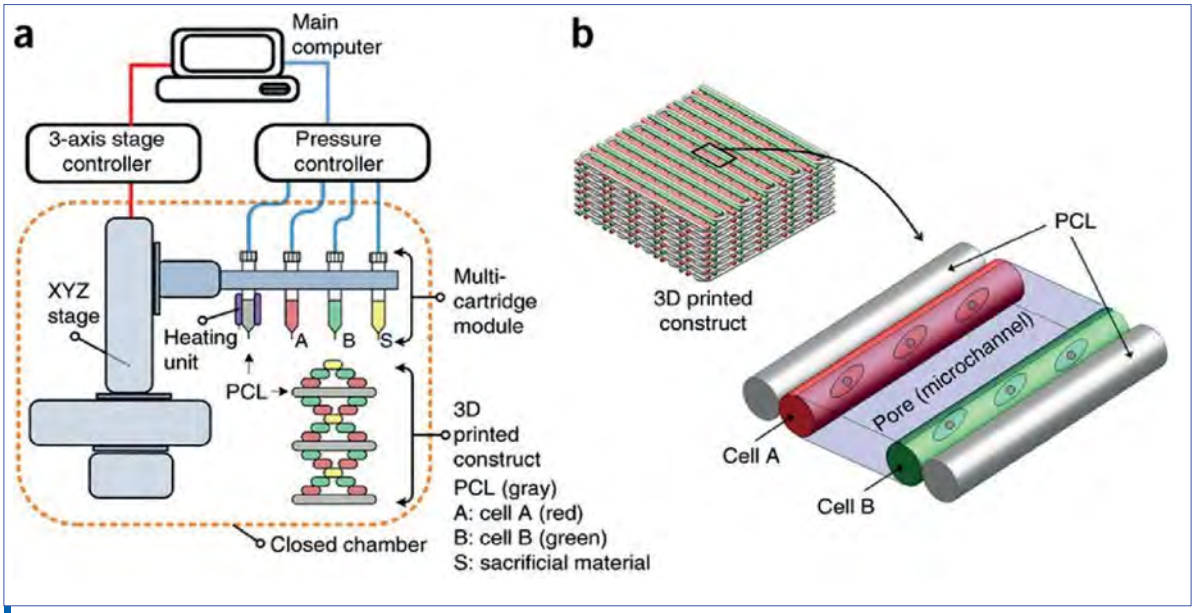



**Figure 10.** The ITOP system [36]. (a) The ITOP system consists of three major units: (i) 3-axis stage/controller, (ii) dispensing module including multi-cartridge and pneumatic pressure controller and (iii) a closed acrylic chamber with temperature controller and humidifier. (b) Illustration of basic patterning of 3D architecture including multiple cell-laden hydrogels and supporting PCL polymer.
Reprinted with permission by Nature America.

insensible, as we would all sense they would have to mimic the human mandible much closer if they should replace it, survive in its environment, be subject to the forces it withstands.

## 6. 3D bioprinting design

It is clear that more elaborate designs for 3D bioprinting are still to precede possible attempts at implantation. Executing these proceedings, many researchers are now focussing on creating smaller patches of tissue, with more realistic viability. Incredible ingenuity has already led to several successful constructs and in doing so, several 3D bioprinting parameters have been studied. The obtained insights are also broadening the view on how tissue engineering a load-bearing structure, such as required for bone tissue should be approached. A few key features contributing to a successful 3D bioprinting design for bone tissue are described below.

### 6.1. Configuration of the construct (design of the scaffold)

Current approaches towards load-bearing bone range from loose configurations of hydrogels already containing stem cells, to rigid, volumetric and morphologically adequate printed scaffolds, later to be seeded with stem cells. Generally, constructs are more bio-compatible and supporting of self-organising capacities of the cells as they are more natural polymer based, and more structured and mechanically strong as they contain more synthetic polymers or bio-ceramics. It must be noted that the majority of all 3D bioprinting research currently makes use of the more organised approach.
The scaffolds created are most often regular shaped, supported by space-filling lattices (regular cubes or honeycomb pattern (e.g. Fig 8). This is despite the fact that algorithms and even libraries and tools have been developed to create more complex scaffolds with functional grading and with known characteristics, more closely mimicking the complexity of tissue [25]. Supposedly it is due to the small scale of the research and focus on cell-viability that these more complex algorithms have not yet been applied to in vitro 3D bio-printing studies, because most likely they would not cause executional problems.

### 6.2. Choice of cells

Many researchers favour the direct printing of cell-laden bioinks, as it allows for niche formation and a level of interaction with the scaffold that cannot be matched when colonizing the scaffold from the outside. The cells that would then be embedded in the bioink can either be functional primary cells with supporting cells (osteoblasts, osteoclasts and perhaps osteocytes) for bone tissue, or stem cells (adipose derived or bone marrow derived mesenchymal). Stem cells require stimulation towards differentiation but contain much more regenerative capacities and are clearly the preference in 3D bioprinting. Survival of the construct when implanted however, would unlikely succeed if there were no additional colonisation of cells from the outside of the construct.

### 6.3. Pore size

To allow such cells to enter and continuously recolonize the 3D bioprinted construct and to allow them to proliferate and function, the construct needs to offer appropriate passages-spaces. This is also necessary to allow nutrients to reach the cells within the construct by diffusion. Keeping in mind the µm size of pre-osteoblasts, it was established that the appropriate pore size for a vascularized bone matrix would be 200-300 µm in diameter [26]. A larger pore size seems to be met with more vascular differentiation of stem cells whilst a smaller one seems to favour osteogenic differentiation [27]. The established porosity percentage of 90% for bone tissue is left redundant as many researchers have achieved favourable results with

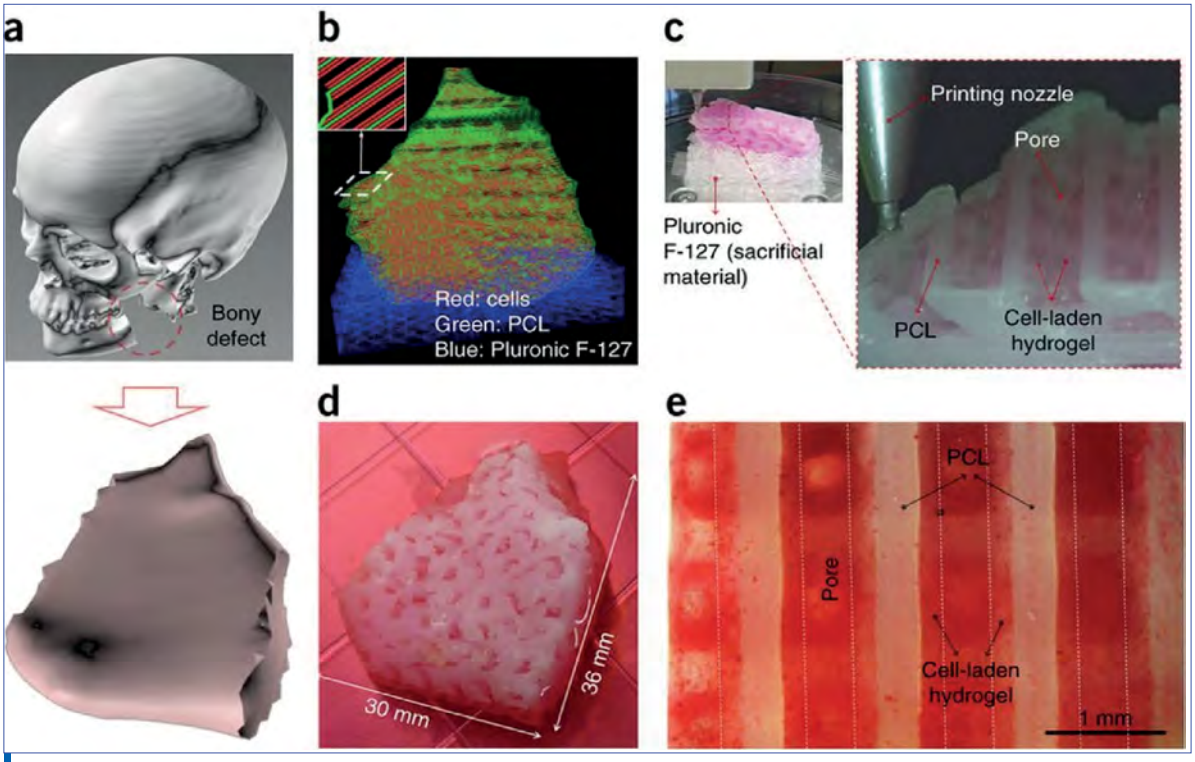



**Figure 11.** Mandible bone reconstruction [36].
(a) 3D CAD model recognized a mandible bony defect from human CT image data. (b) Visualized motion program was generated to construct a 3D architecture of the mandible bone defect using CAM software developed by our laboratory. Lines of green, blue and red colors indicate the dispensing paths of PCL, Pluronic F-127 and cell-laden hydrogel, respectively. (c) 3D printing process using the integrated organ printing system. The image shows patterning of a layer of the construct. (d) Photograph of the 3D printed mandible bone defect construct, which was cultured in osteogenic medium for 28 d. (e) Osteogenic differentiation of hAFSCs in the printed construct was confirmed by Alizarin Red S staining, indicating calcium deposition.
Reprinted with permission by Nature America.

smaller percentages [4,26]. Also, there is an increased interest in creating a pore size gradient throughout constructs, as this could allow to control growth and mineralisation rates and would fit in the strategy of making scaffold give time-dependant instructions to the stem cells (Time, often referred to as the "4th dimension in 3D printing").

### 6.4. Cell adhesion

Porosity of the construct also contributes to cell adhesion, albeit more on a micro-level (pores in the scaffold surface = micro-roughness of the scaffold). To this idea, scaffolds have been conjugated with porogens like F-127 [28], NanoHA and $NH_4HCO_3$ + Mg [29], often slightly compromising the strength, but improving cell adhesion. Polarity and surface tension of the construct also play a pivotal role in cell adhesion as they determine the hydrophility of the construct, which accounts for cell adhesion throughout protein binding to the scaffold. Strategies of reducing the often very negative surface tension (expressed as "surface zeta" value; ex. PLA = -40 mV) include coating the surface with dopamine [28], PEG or Bioglass [30], effectively reducing contact-angles of PLA from 131.2° to 51.9°, making cell-adhesion much easier.

### 6.5. Ability of the scaffold to send biological cues/ interact with stem cells

Various researchers have experimented with methods of mimicking the interaction between cells and their micro-environment.

Examples include slowing down degradation of bio-ceramics (like Wollastonite; $CaMgSiO_3$) to provide a steady release of ions, which serves as a bio-cue for bone forming cells [31], adding protein residues such as a cyclic arg-gly-asp chain to bio-gels to stimulate osteogenic differentiation [32], as mentioned above, or even adding plasmid DNA complexes to PLLA/ collagen scaffolds to stimulate BMP-2 expression [33].

### 6.6. Ability to develop vasculature

As mentioned above, tissue-engineered bone tissue could not succeed in viability without proper supply of nutrients and oxygen throughout the construct, hence the need for pores. When dealing with a larger bone construct, it would be hard to imagine adequate supply without development of vasculature in the construct.
Actually, this need for vasculature within the engineered bone tissue is presumed indispensable and this is reflected by the considerable amount of researchers simultaneously evaluating bone- and vasculature-formation in their 3D printed scaffolds [4]. Most research truly focussing on (micro)vessel development within 3D bio-printed bone have either (architecturally) created spaces for endothelial cells to arrange into tubes or have aimed to attract (micro)vessel-infiltration from the supporting outside environment.
Examples include silicate bio-ceramics printed into hollow tubes releasing angiogenesis-inducing ions like Mg, Ca, and Si [34], porous CaP scaffolds releasing

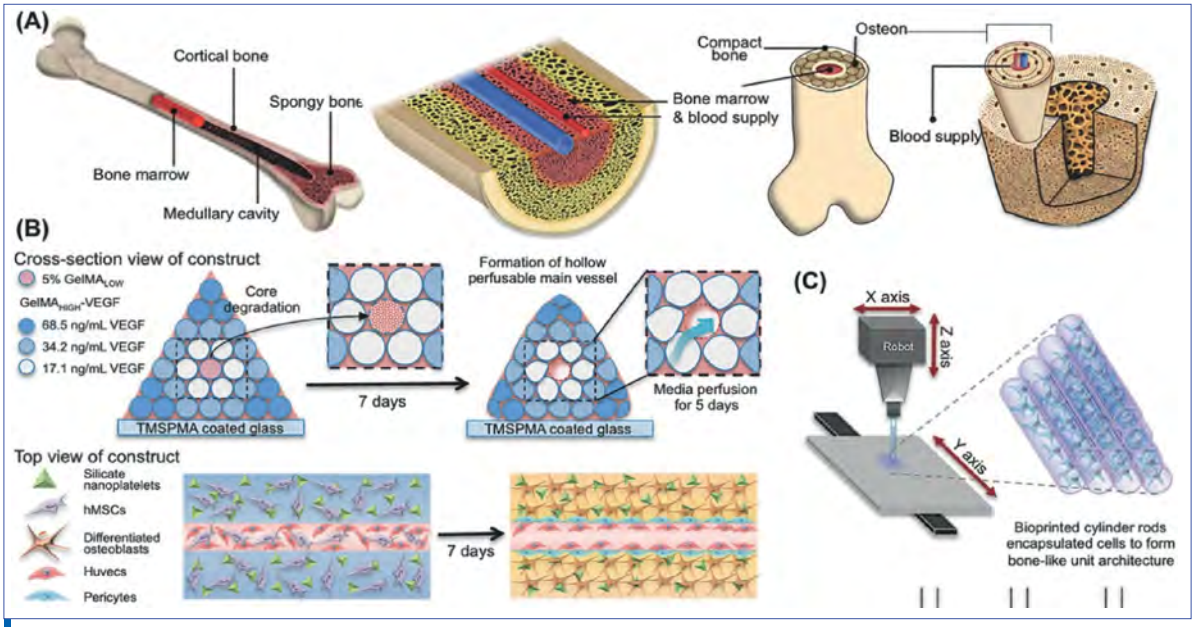



**Figure 12.** Fabrication of bone mimetic 3D architecture containing osteogenic and vasculogenic niches [37].
(a) Schematic illustration of complex bone tissue structure. (b) Illustration of the bioprinting strategy for fabricating complex bone tissue architecture. A perfusable vascular lumen lined with HUVECs can be fabricated within a pyramidal bioprinted construct by arranging individual rods of VEGF-functionalized GelMA bioinks with different mechanical strengths. The hMSCs-laden three outer layers of cylinders were loaded with silicate nanoparticles to induce osteogenic differentiation of hMSCs into bone tissue. The VEGF was covalently conjugated into the three outer layers of the cylindrical hydrogels. The concentrations of conjugated VEGF were determined with ELISA as 17.1, 34.2, and 68.5 ng $mL^{-1}$.
(c) Scheme of the 3D printing procedure of independent cell-laden cylinders using an automatized and computer-controlled bioprinter.
Reprinted with permission by Wiley.

angiogenic growth factors, up to scaffolds with a tube alignment that creates interconnected channels with vascular-like flow patterns [35].

We would like to conclude this design-section with 2 examples of the latest wave of 3D bioprinting research, making use of various, combined techniques to unite the characteristics described above and bundling it all into a direct 3D bioprinted result. The ITOP (integrated tissue-organ printer) by Kang et al. (Figs. 10 and 11), made use of several different cartridges, simultaneously printing combinations of PCL, cell-laden hydrogels of various compositions and a pluronic F-127 component (to stabilize the printing process) into "vascularized cellular constructs of clinically relevant size, shape and structural integrity". Amongst their productions was a mandible tissue construct (Fig. 11) consisting of PCL/TCP, F-127 and a human amnionic fluid derived stem cell (hAFSC)-laden hydrogel consisting of 35 mg/mL of gelatine (to allow liquification above 37°C), 20 mg/mL fibrinogen (for stability, cell conductivity and cell proliferation) and 10% glycerol (to prevent nozzle clogging). After printing, the fibrinogen was directly crosslinked with thrombin for stabilization after which the rest of the hydrogel components (except for the stem cells of course) were washed away. The outline of the mandible construct was CT image- and CAD model-based and the inner architecture consisted of tubes of PCL/TCP (of 130 µm in diameter) and tubes of hAFSC-laden hydrogel, creating micro-channels of 500 x 300 $\mu m^2$. Cell viability throughout printing (1 day after printing) was shown to be 91 ± 2%, proving this complex printing process did not adversely influence cell viability and after 28 days in culture. Osteogenic differentiation was proven by Alizarin Red S staining for calcium deposition [36].

The need for substantial vasculature within a large 3D bio-printed bone construct was creatively met by Batzaya et al. in their 2017 publication (Fig. 12) in which they presented their pyramidal construct of 28 bio-printed tubes with varying compositions of stem cells, gelatine-methacryloyl, VEGF and Si-nanoparticles. A commercially available 3D bio-printer was used to lay down a central tube of HUVEC- and hMSC -laden gelatine with low methacryolyl substitution (gelMaLOW), which would later gradually degrade to a central open channel, surrounded by 3 layers of 3D bio-printed tubes of hMSC-laden gelatine with high methacryolyl substitution (gelMaHIGH) and a gradient of covalently bound VEGF and Si-nanoparticles. After 7 days in culture, the central tube had become a perfusable lumen with an inner surface of HUVEC's and an outer surface of supporting hMSC's, differentiated into supporting smooth muscle cells.

The construct was then perfused with an osteogenic medium for 5 days, which supported proliferation and osteogenic differentiation of hMSC's in the outer tubes, which, 21 days after printing, showed formation of mature bone niches, supported by micro-vasculature [37].

## 7. Conclusion

The sample of recent studies listed above gives us some idea of what is currently being investigated in 3D bioprinting research focussed on bone tissue engineering. It seems clear that obtaining viable 3D printed bone constructs will require a combination of techniques and bio-materials with different characteristics.

Clinical application in the field of maxillofacial surgery might not seem up for discussion yet, but research seems to be going the right way at a rapid pace. It is

also remarkable how many of these cutting-edge bone tissue engineering projects are already projecting their experiments towards the maxillofacial area.

Amongst bioengineers it seems understood that maxillofacial surgery is a field with great interest in new tissue engineering applications. Several authors describe further elaboration of constructs with closer reproduction of the bone forming niche, more bio-interaction and a higher overall strength of the construct as the major obstacles to overcome in the further development of 3D bioprinting based bone tissue engineering. The further transit toward implantation would also be preceded by more in vitro maturation studies, animal studies and perhaps ethical and regulatory discussions.

Aiming at overcoming the patient-inflicted burdens associated with autogenic transplantation, the clinician would be remis not to follow these developments carefully and critically, offering feedback on available materials and constructs and perhaps suggestions in the design process.

## Author Contribution

SC: provided data gathering, analysis and interpretation. DL: provided data gathering. RJ: provided the core concept, protocol, and revision. CP: provided critical revision and guidance.

## Acknowledgements

The authors wish to thank Mostafa EzEldeen from OMFS-IMPATH for sending in quality research.

## Funding

The authors declare no grants or funding.

## References

1. Shqaidef A, Ayoub AF, Khambay BS. How accurate are rapid prototyped (RP) final orthognathic surgical wafers? A pilot study. *Br J Oral Maxillofac Surg*. 2014;52(7):609-614. [Full text links] [PubMed] Google Scholar(27) Scopus(13)
2. Wilde F, Hanken H, Probst F, et al. Multicenter study on the use of patient-specific CAD/CAM reconstruction plates for mandibular reconstruction. *Int J Comput Assist Radiol Surg*. 2015;10(12):2035-2051. [Full text links] [PubMed] Google Scholar(53) Scopus(37)
3. Krujatz F, Lode A, Seidel J, Bley T, et al. Additive biotech-chances, challenges, and recent applications of additive manufacturing technologies in biotechnology. *N Biotechnol*. 2017;39(Pt B):222-231. [Full text links] [PubMed] Google Scholar(14) Scopus(2)
4. Temple JP, Hutton DL, Hung BP, et al. Engineering anatomically shaped vascularized bone grafts with hASCs and 3D-printed PCL scaffolds. *J Biomed Mater Res - Part A*. 2014;102(12):4317-4325. [Full text links] [PubMed] Google Scholar(122) Scopus(90)
5. van Eijnatten M, Van Dijk R, Dobbe J, et al. CT image segmentation methods for bone used in medical additive manufacturing. *Med Eng Phys*. 2018;51:6-16. [Full text links] [PubMed] Google Scholar(8) Scopus(4)
6. Huang Y, Zhang XF, Gao G, et al. 3D bioprinting and the current applications in tissue engineering. *Biotechnol J*. 2017;12(8):1-16. [Full text links] [PubMed] Google Scholar(21) Scopus(11)
7. Zhang X, Zhang Y. Tissue engineering applications of three-dimensional bioprinting. *Cell Biochem Biophys*. 2015;72(3):777-782. [Full text links] [PubMed] Google Scholar(60) Scopus(33)
8. Obregon F, Vaquette C, Ivanovski S, et al. Three-dimensional bioprinting for regenerative dentistry and craniofacial tissue engineering. *J Dent Res*. 2015;94(9 Suppl):143S-152S. [Full text links] [PubMed] Google Scholar(80) Scopus(51)
9. Mandrycky C, Wang Z, Kim K, Kim DH. Research review paper 3D bioprinting for engineering complex tissues. *Biotechnol Adv*. 2016;34(4):422-434. [Full text links] [Free PMC Article] [PubMed] Google Scholar(280) Scopus(197)
10. Li J, Chen M, Fan X, Zhou H. Recent advances in bioprinting techniques: approaches, applications and future prospects. *J Transl Med*. 2016 Sep 20;14:271. [Full text links] [Free PMC Article] [PubMed] Google Scholar(99) Scopus(65)
11. Sears NA, Seshadri DR, Dhavalikar PS, Cosgriff-Hernandez E. A review of three-dimensional printing in tissue engineering. *Tissue Eng Part B Rev*. 2016;22(4):298-310. [Full text links] [PubMed] Google Scholar(102) Scopus(79)
12. Bertassoni LE, Coelho PG, Editors. Engineering Mineralized and Load Bearing Tissues. In: *Advances in Experimental Medicine and Biology*. Series Volume 881. Cham, CH: Springer International Publishing; 2015. [Full text links]
13. Roseti L, Parisi V, Petretta M, et al. Scaffolds for bone tissue engineering: state of the art and new perspectives. *Mater Sci Eng C Mater Biol Appl*. 2017;78:1246–1262. [Full text links] [PubMed] Google Scholar(68) Scopus(53)
14. Radhakrishnan J, Subramanian A, Krishnan UM, Sethuraman S. Injectable and 3D bioprinted polysaccharide hydrogels: from cartilage to osteochondral tissue engineering. *Biomacromolecules*. 2017;18(1):1-26. [Full text links] [PubMed] Google Scholar(39) Scopus(34)
15. Axpe E, Oyen ML. Molecular sciences applications of alginate-based bioinks in 3D bioprinting. *Int J Mol Sci*. 2016;17(12). pii: E1976. [Full text links] [Free PMC Article] [PubMed] Google Scholar(48) Scopus(34)
16. Visscher DO, Farré-Guasch E, Helder MN, et al. Advances in bioprinting technologies for craniofacial reconstruction. *Trends Biotechnol*. 2016;34(9):700-710. [Full text links] [PubMed] Google Scholar(27) Scopus(19)
17. Neufurth M, Wang X, Wang S, et al. 3D printing of hybrid biomaterials for bone tissue engineering: calcium- polyphosphate microparticles encapsulated by polycaprolactone. *Acta Biomater*. 2017 Dec;64:377-388. [Full text links] [PubMed] Google Scholar(15) Scopus(13)
18. Wang X, Tolba E, Schröder HC, et al. Effect of bioglass on growth and biomineralization of SaOS-2 cells in hydrogel after 3D cell bioprinting. *PLoS One*. 2014;9(11):e112497. [Full text links] [Free PMC Article] [PubMed] Google Scholar(32) Scopus(26)
19. Wüst S, Godla ME, Müller R, Hofmann S. Tunable hydrogel composite with two-step processing in combination with innovative hardware upgrade for cell-based three-dimensional bioprinting. *Acta Biomater*. 2014;10(2):630-640. [Full text links] [PubMed] Google Scholar(115) Scopus(92)
20. Ahn G, Min KH, Kim C, et al. Precise stacking of decellularized extracellular matrix based 3D cell-laden constructs by a 3D cell printing system equipped with heating modules. *Sci Rep*. 2017;7(1):8624. [Full text links] [Free PMC Article] [PubMed] Google Scholar(13) Scopus(10)
21. Jang CH, Ahn SH, Yang GH, Kim GH. A MSCs-laden polycaprolactone/collagen scaffold for bone tissue regeneration. *RSC Adv*. 2016;6(8):6259-6265. [Full text links] Google Scholar(9) Scopus(4)
22. Lee JY, Choi B, Wu B, Lee M. Customized biomimetic scaffolds created by indirect three- dimensional printing for tissue engineering. *Biofabrication*. 2013;5(4):045003. [Full text links] [Free PMC Article] [PubMed] Google Scholar(97) Scopus(69)
23. Giannitelli SM, Accoto D, Trombetta M, Rainer A. Current trends in the design of scaffolds for computer-aided tissue engineering. *Acta Biomater*. 2014;10(2):580-594. [Full text links] [PubMed] Google Scholar(199) Scopus(155)
24. Choi SW, Zhang Y, Xia Y. Three-dimensional scaffolds for tissue engineering: the importance of uniformity in pore size and structure. *Langmuir*. 2010;26(24):19001-19006. [Full text links] [Free PMC Article] [PubMed] Google Scholar(91) Scopus(63)
25. Gregor A, Filová E, Novák M, et al. Designing of PLA scaffolds for bone tissue replacement fabricated by ordinary commercial 3D printer. *J Biol Eng*. 2017;11:31. [Full text links] [Free PMC Article] Google Scholar(14) Scopus(13)
26. Lee SJ, Lee D, Yoon TR, et al. Surface modification of 3D-printed porous scaffolds via mussel-inspired polydopamine and effective immobilization of rhBMP-2 to promote osteogenic differentiation for bone tissue engineering. *Acta Biomater*. 2016;40:182-191. [Full text links] [PubMed] Google Scholar(57) Scopus(48)
27. Tan Q, Li S, Ren J, Chen C. Fabrication of porous scaffolds with a controllable microstructure and mechanical properties by porogen fusion technique. *Int J Mol Sci*. 2011;12(2):890-904. [Full text links] [Free PMC Article] [PubMed] Google Scholar(41)

Scopus(31)
28. Chen C, Bang S, Cho Y, et al. Research trends in biomimetic medical materials for tissue engineering: 3D bioprinting, surface modification, nano/micro-technology and clinical aspects in tissue engineering of cartilage and bone. *Biomater Res*. 2016 May 4;20:10.
[Full text links] [Free PMC Article] [PubMed] Google Scholar(27) Scopus(22)
29. Shao H, Sun M, Zhang F, et al. Custom repair of mandibular bone defects with 3D printed bioceramic scaffolds. *J Dent Res*. 2018;97(1):68-76.
[Full text links] [PubMed] Google Scholar(4) Scopus(4)
30. Heo DN, Castro NJ, Lee SJ, et al. Enhanced bone tissue regeneration using a 3D printed microstructure incorporated with a hybrid nano hydrogel. *Nanoscale*. 2017;9(16):5055-5062.
[Full text links] [Free PMC Article] [PubMed] Google Scholar(21) Scopus(19)
31. Zhao X, Komatsu DE, Hadjiargyrou M. Delivery of rhBMP-2 plasmid DNA complexes via a PLLA/collagen electrospun scaffold induces ectopic bone formation. *J Biomed Nanotechnol*. 2016;12(6):1285-1296.
[Full text links] [PubMed] Google Scholar(19) Scopus(16)
32. Zhang W, Feng C, Yang G, et al. 3D-printed scaffolds with synergistic effect of hollow-pipe structure and bioactive ions for vascularized bone regeneration. *Biomaterials*. 2017;135:85-95.
[Full text links] [PubMed] Google Scholar(26) Scopus(14)
33. Holmes B, Bulusu K, Plesniak M, Zhang LG. A synergistic approach to the design, fabrication and evaluation of 3D printed micro and nano featured scaffolds for vascularized bone tissue repair. *Nanotechnology*. 2016;27(6):064001.
[Full text links] [Free PMC Article] [PubMed] Google Scholar(35) Scopus(33)
34. Kang HW, Lee SJ, Ko IK, et al. A 3D bioprinting system to produce human-scale tissue constructs with structural integrity. *Nat Biotechnol*. 2016;34(3):312-319.
[Full text links] [PubMed] Google Scholar(652) Scopus(461)
35. Byambaa B, Annabi N, Yue K, et al. Bioprinted osteogenic and vasculogenic patterns for engineering 3D bone tissue. *Adv Healthc Mater*. 2017;6(16):1700015.
[Full text links] [PubMed] Google Scholar(32) Scopus(25)

**Simon CLEEMPUT**
MD
OMFS IMPATH Research Group
Department of Imaging & Pathology
Faculty of Medicine
KU Leuven, Leuven, Belgium

## CV

Dr. Cleemput graduated Medicine in 2018 (MD). He is currently studying Dentistry and is enlisted in a Postgraduate Programme in Biomedical Engineering at KU Leuven, Belgium .

## Questions

### 1. "Inkjet bioprinting" is:

❑a. The first developed type of bioprinting;
❑b. The most precise type of bioprinting (highest resolution);
❑c. A bioprinting technique that generates droplets of bio-ink;
❑d. A jet-laser-based bioprinting technique.

### 2. Inducing bio-ceramics printed into hollow tubes releasing ions like Mg, Ca, and Si was found to:

❑a. Increase the strength of the porous CaP scaffolds;
❑b. Increasing the E-Modulus of porous CaP scaffolds;
❑c. Stimulate osteogenic differentiation of hMSC's;
❑d. Create interconnected channels with vascular-like flow patterns in porous CaP scaffolds.

### 3. The first 3D printer was invented by:

❑a. Charles Hull;
❑b. Jules Pouckens;
❑c. Huan Wook Kang;
❑d. Thomas Lambrecht.

### 4. An appropriate pore size for vascularized bone matrix was established at:

❑a. 20-30 µm, which is within reach of modern 3D bioprinters;
❑b. 20-30 µm, which is NOT within reach of modern 3D bioprinters;
❑c. 200-300 µm, which is within reach of modern 3D bioprinters;
❑d. 200-300 µm, which is NOT within reach of modern 3D bioprinters.

# Caries ruins smiles. Back pain kills careers.

## We care. We protect you.

... and there's a bit of truth in every cliché.

Back pain plagues the majority of dental practitioners. Musculoskeletal disorders in the neck, shoulder and lower back are considered to be the most common reason for early retirement and even loss of work for dentists worldwide. But there is a solution to avoid neck and shoulder discomfort: investing in ergonomically designed treatment center today is a long-term investment in your health that could also save you up to 32 hours per year.*

Learn the truth at www.dentsplysirona.com/new-perspective

* Assumptions: 8 working hours per day/1 minute per hour to relax/ 240 working days per year

Office & Showroom
98A Vulturilor Street, 3rd District
RO-030857 Bucharest, Romania
Tel: +40 774 074 094
e-mail: office.romania@dentsplysirona.com

Dentsply Sirona

CEREC

# Do it your way

CEREC is just what you need it to be. From the nitial scan to a full CAD/CAM system providng single-visit solutions - CEREC is your partner every slep of the way. Be free to start your digital workflow just the way you want. With CEREC.

Conquer your future now at dentsplysirona.com/CEREC

Office & Showroom
98A Vulturilor Street, 3rd District
RO-030857 Bucharest, Romania
Tel: +40 774 074 094
e-mail: office.romania@dentsplysirona.com

Dentsply Sirona

Case Report

# MASKING POSTERIOR TOOTH DISCOLORATIONS WITH COLOR MODIFIERS

**Andreas Spaveras**[1a], **Frantzeska Karkazi**[2b*], **Maria Antoniadou**[1c]

[1]Department of Operative Dentistry, Dental School, National and Kapodistrian University of Athens, GR-11527 Athens, Greece
[2]Department of Stomatology and Maxillofacial Surgery, Faculty of Medicine, Comenius University in Bratislava, SK- 81250 Bratislava, Slovakia

[a]DMD, Postgraduate Student
[b]MDDr
[c]DDS, PhD, Assistant Professor

DOI: 10.25241/stomaeduj.2018.5(4).art.6

## ABSTRACT

**Aim:** The present article provides the clinician with a fundamental principle for achieving success with direct application of resinous materials in cases of discolored posterior teeth, mainly due to amalgam corrosion of a previous restoration. The procedure, advantages, and limitations of the technique are discussed.
**Summary:** A first upper right molar previously filled with amalgam was prepared for a direct composite resin restoration, due to secondary caries. The discolored dentin on the pulpal floor was treated with a white opaquer and a resinous corn color tint also applied with a round painter's brush. Dentin and enamel shade stratification was performed according to the layering technique following the anatomical morphology of the tooth. Finishing was performed with extra-fine diamond burs and aluminum oxide disks. Then a silicon-rubber polishing cups system was used with a 5 μm diamond polishing paste in order to achieve high surface gloss.
**Key learning points:** The preparation of dentin should be kept in minimum in order to follow the principle of minimally invasive dentistry. The application of an opaquer over the discolored dentin should be made in a very thin layer of 0.1 mm. The resinous color modifiers should be applied and layered homogeneously.
**Keywords:** esthetic conservative direct restoration, posterior tooth, discolored dentin, color modifiers, tints.


Peer-Reviewed Article

**Citation:** Spaveras A, Karkazi F, Antoniadou M. Masking posterior tooth discolorations with color modifiers. Stoma Edu J. 2018;5(4):256-262.

**Academic Editor:** Dana Cristina Bodnar, DDS, PhD, Professor, "Carol Davila" University of Medicine and Pharmacy Bucharest, Bucharest, Romania

Received: October 15, 2018
Revised: October 24, 2018
Acccepted: November 07, 2018
Published: November 08, 2018

***Corresponding author:**
Dr. Frantzeska Karkazi, MDDr, Department of Stomatology and Maxillofacial Surgery, Faculty of Medicine, Comenius University in Bratislava, Heydukova 10, SK- 81250 Bratislava, Slovakia
Tel: +30 6976698009, Fax: +421 2/3224 9724, e-mail: fkarkazi@aol.com



## 1. Introduction

The aesthetic appearance of dentition is of concern to a great percentage of the population. Natural teeth demonstrate translucency, opalescence, and fluorescence, all of which must be replicated by restorative materials in order to achieve clinical success. Therefore, pursuing dental treatment and respecting the natural color of the teeth is of particular cosmetic importance. Frequently, after the removal of a previous amalgam restoration, the exposed dentin commonly appears as a black discoloration, which is attributed to the penetration of corrosion products of amalgam into the dentin.

Composites are translucent by nature; even the most opaque shades transmit nearly 60% of the visible light [1]. As a result, composites require a certain thickness to maintain their intended shade, especially if the underlying substrate is particularly dark. Nevertheless, sometimes even relatively thick composite restorations might not be capable of covering discolored dentin. The dark pulpal wall absorbs a significant part of light that would otherwise reflect towards the occlusal surface, and the restoration, due to that phenomenon, appears a non-vital monochromatic grayish color [2].

Treatment options of direct posterior restorations to minimize the effect of background color include single shade or layering shade technique (dentin /chromatic/achromatic enamel shades), as well as the use of opaquers and tints (color modifiers) willingly. Single-shade restorations are simpler; less technique-sensitive and can reduce chair side time for both the patient and the clinician. However, it is not always easy to achieve a natural tooth structure by using a monochromatic technique, since teeth are multichromatic with color variations. Layering shade technique is required in restorations of high aesthetical demand. The final restoration is usually more natural that single-shade technique, but it is technique sensitive and more time consuming. The proper knowledge of differences in translucency and the required thickness to mask dark background of the applied resin seems to be essential, though little information is available.

Miotti et al. [3] evaluated the ability of three resin composite systems (IPS Empress Direct- Ivoclar Vivadent, Charisma Diamond-Heraeus Kulzer and Filtek Z350 XT-3M, ESPE) to mask a severely discolored background by the application of a layering technique. Three groups presented clinically acceptable color difference values; however, the Filtek Z350 XT system was the only restoration system capable of masking the C4 background. Moreover, Ikeda et al. [4] evaluated the translucency parameter

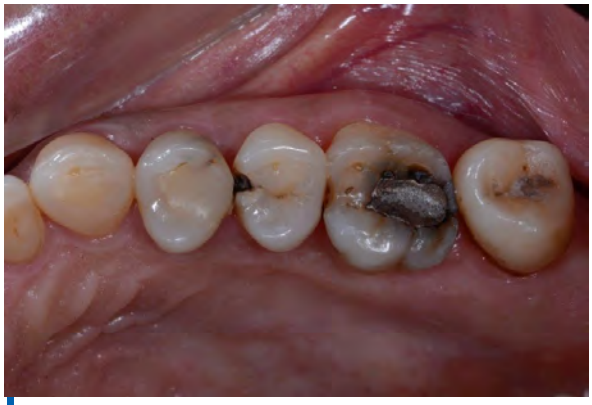


**Figure 1.** Preoperative occlusal view: insufficient amalgam restoration.

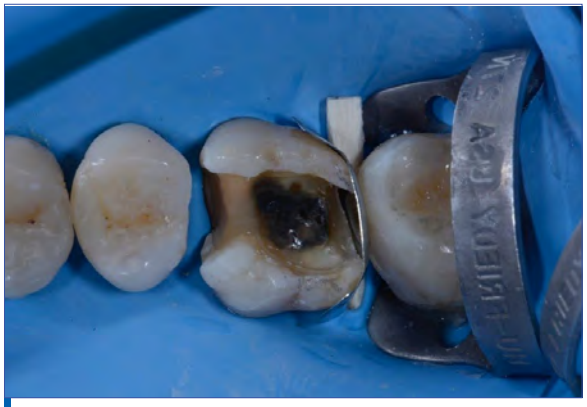


**Figure 2.** Postoperative situation: examination of the dark discoloration.

and masking ability of three resin composites with two shades (A3 and opaque A3) and in 1 and 2 mm thicknesses. They concluded only 2 mm thickness of the opaque-shade materials could mask the dark background. However, Darabi et al. [5], compared the translucency parameter of five different opaque or dentin A2 shade resin composites Gradia (GC; Tokyo, Japan), Herculite XRV (Kerr, Scafati, Salerno, Italy), Vit-l-escence (Ultradent, South Jordan, UT, USA), Crystalline (Confi-dental, Louisville, KY, USA) and Opallis (FGM, Joinville, Brazil) in different thicknesses and evaluated their masking ability in black backgrounds. They concluded that in relatively thin thicknesses, these opaque/dentin shade composite resins could not mask the black background color.

Color modifiers are used as base liners to counterbalance discolorations or to imitate the natural fissures of the occlusal wall. During the restorative procedure, opaquers block out dark colors, while tints bring the desired color back to the tooth. Opaquers are liquid dimethrycrylate resins (BIS-GMA), which are usually photopolymerised and they contain potent pigments and high opacity percentages in different dentinal shades plus white and pink. They consist of 15% opaque metal oxides (titanium, zirconium, barium etc.), which increase the opacity and thus the ability to mask dark discolorations [6]. Opaquers are available in a flowable viscocity, in base-catalyst paste form and powder/liquid one. The main benefit of using color modifiers is that there is no need of extended removal of sound dentin, in order to perform a natural looking restoration [7]. When opaquers are used, the protocol presupposes that the discoloration should be covered approximately at 70%. A lower percentage (<70%) will result in a grayish restoration, while a higher one (>70%) will form an unnatural opaque final appearance. Their application should be in meticulous layers [8]. In highly demanding cases, opaquers and tints could be mixed with composite resins of low viscosity to enhance the opacity of the composites.Tints are resinous materials containing strong pigments, which increase hue and chroma. They transmit light, therefore they add translucency back to restorations after the placement of the opaquer. They are also used in order to reproduce anatomical characteristics and improve the aesthetics of restorations. Their application should be minimal and under the final composite layer. Shades such as honey, yellow, light/dark brown, ocher and pink are frequently used in the restorations of posterior teeth [9]. It is suggested that clinicians should get familiarized with different color modifiers in laboratory conditions before performing their clinical application. This would enhance their knowledge concerning color modifiers' masking ability and optical characteristics. Moreover, it enables the attainment of individualized and customized composite restorations. The aim of this article is the presentation of a step-to-step direct masking of the discolored dentin of a posterior tooth (#16) with the aid of color modifiers. Specific clinical tips and potential mistakes made by using such materials are also described thoroughly.

## 2. Case Presentation

A 35-year-old female patient requested the replacement of an insufficient old amalgam restoration of the upper right first molar (#16), due to secondary caries (Fig. 1).

During the clinical inspection, the tooth did not react sensitively in the cold test and showed no negative reaction to the percussion test. The buccal and palatal walls were measured and were greater than 1.5 mm in width; therefore a direct restoration could be performed. Tooth shade selection was performed before field isolation to avoid color mismatching, due to the dehydration of dental hard tissues during the procedure. Since, successful composite resin restorations are based on the bond formed between the dental hard tissues and the composite, isolation is an important part in direct restorations. It prevents moisture contamination and ensures increased gingival retraction compared to other techniques. In this clinical case, the upper posterior teeth were isolated with a medium weight rubber dam (Nictone, MDC Dental, Mexico). Two wedges (wooden, orange, Polydentia, Switzerland) were inserted in the mesial and distal interproximal spaces (pre-wedging technique) to overcome the close proximity with the adjacent teeth to prevent removal of sound enamel. The preparation of the cavity was performed mesially,

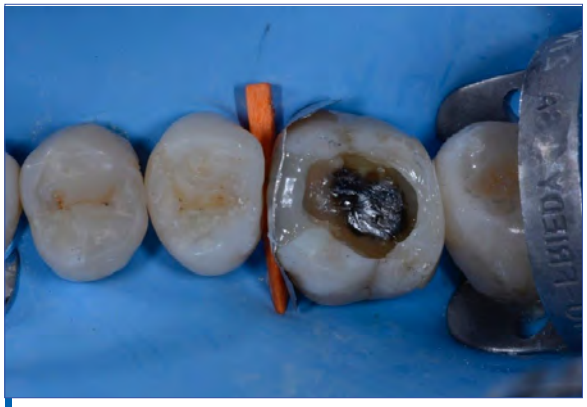


**Figure 3.** Formation of the distal and mesial walls with enamel shade resin.

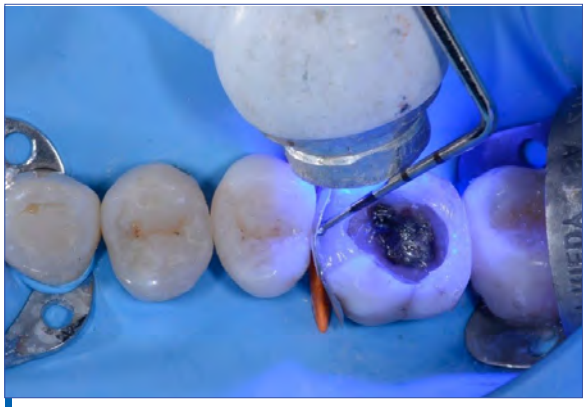


**Figure 4.** Pressing the sectional matrix towards the neighboring tooth to perform the appropriate contact point..

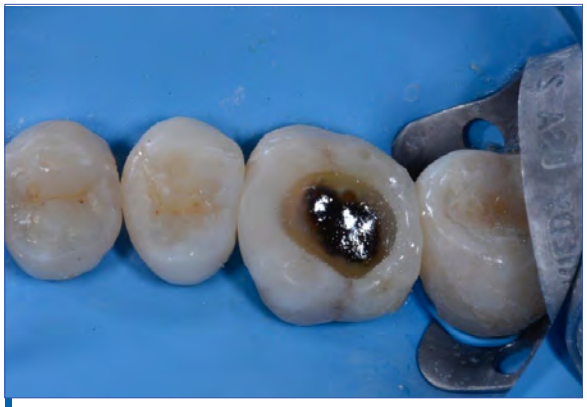


**Figure 5.** Occlusal view after polymerization of the proximal walls.

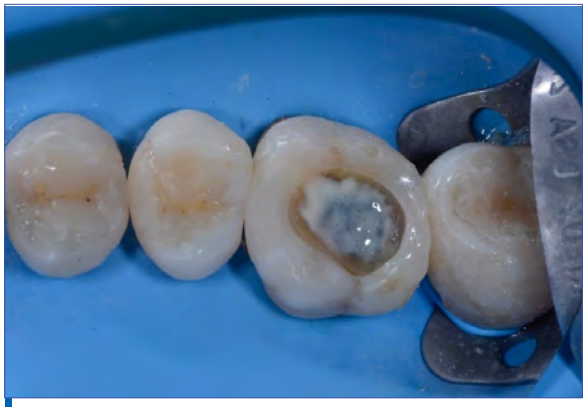


**Figure 6.** Opaquer placement to the discolored pulpal wall.

occlusally and distally with a medium pear diamond (856, 0.16 mm, 10 mm, Comet Gebr., Brasseler) under water-cooling.

After removing the amalgam and while conserving the remaining dental hard tissues, a strong dark discoloration was observed on the pulpal wall (Fig. 2). A 37.5 % phosphoric acid (Gel-Etchant, Kerr Corporation, Orange, CA, USA) was applied to the prepared enamel and dentin for 30 and 15 seconds, respectively. Dental tissues were rinsed and nearly dried with a light air pressure spray (2 or 3 seconds). As soon as the etching was performed, sectional matrices (Palodent, Dentsply Sirona) with wedges (wooden, white and orange, Polydentia, Switzerland) were placed on the distal and mesial walls respectively. An adhesive procedure was performed with a three-step etch-and-rinse system (Optibond FL, Kerr Corporation, Orange, CA, USA) according to the manufacturer's instructions of use. Following the adhesion, the proximal walls were formed in order to transform the Class II cavity into a Class I cavity. An enamel shade (Enamel A2, Filtek Supreme Ultimate, 3M ESPE) was used (Fig. 3) for the buildup of the proximal walls. During the polymerization, the sectional matrix was pressed towards the adjacent tooth with a periodontal probe, in order to achieve the appropriate contact point (Fig. 4). Following the interproximal walls construction, the dark discolored pulpal wall was examined carefully, in order to estimate the proper amount of opaquer, which should be used (Fig. 5). A small amount of the opaquer (Venus Color White, Heraeus Kulzer GmbH, Hanau, Germany) was applied uniformly in a very thin layer (0.1 mm) on the discolored pulpal wall with a round painter's brush (Da Vinci, Series 373, Flat No. 2) (Fig. 6). Then, the yellow tint (Corn Inspiro, Edelweiss DR AG, Mercandor, Switzerland) was applied again uniformly in a very thin layer (0.1 mm) over the previous opaque layer, in order to imitate the yellowish shade of dentin and add some translucency to the restoration (Fig. 7). Each layer was photopolymerized separately with a LED-curing device (TechnoGaz, Parma, Italy) for 20 seconds according to manufacturers' directions of use (Fig. 8). After that, the layering of the dentin composite (Dentin A2, Filtek Supreme Ultimate, 3M ESPE) was performed, in order to achieve better esthetic appearance of the restoration. The incremental technique was used, to ensure the complete polymerization of all the underlying layers (Fig. 9). A thin layer of the appropriate enamel shade of the same composite system (Enamel A2, Filtek Supreme Ultimate, 3M ESPE), was applied in relation to the morphology of the first upper molar and photopolymerized for 40 s, according to the manufacturers' directions of use (Fig. 10). Finally, the occlusal check was performed with an articulating paper to confirm that the restoration conformed precisely to the patients pre-existing occlusal scheme, in both the intercuspal position and all excursions (Fig. 11). Finishing for accomplishing contouring, shaping and smoothing of the restoration

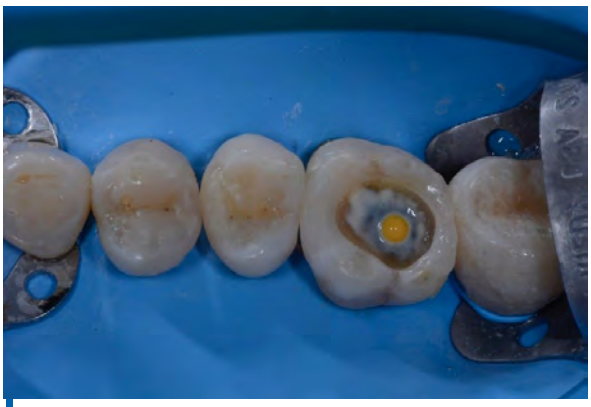


**Figure 7.** Corn color placement with a small round painter's brush.

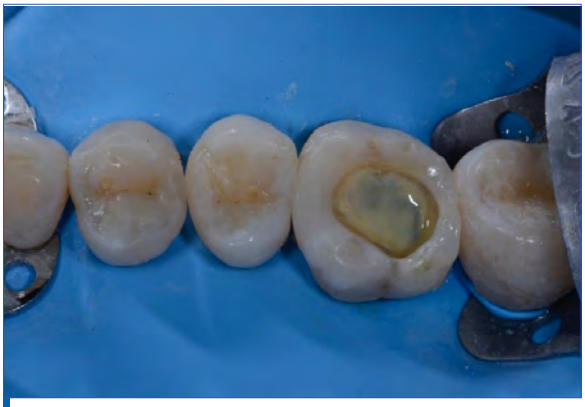


**Figure 8.** After the polymerization of the tint.

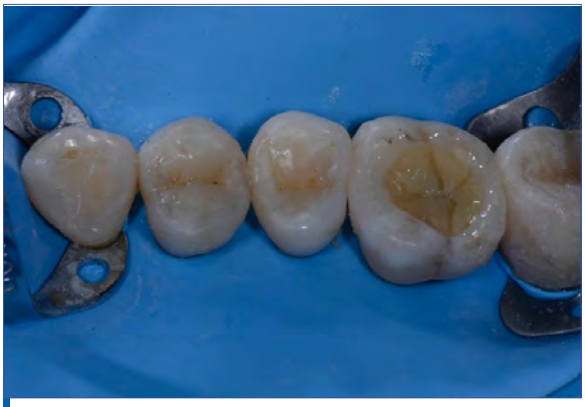


**Figure 9.** Stratification of the composite resin of dentin shade.

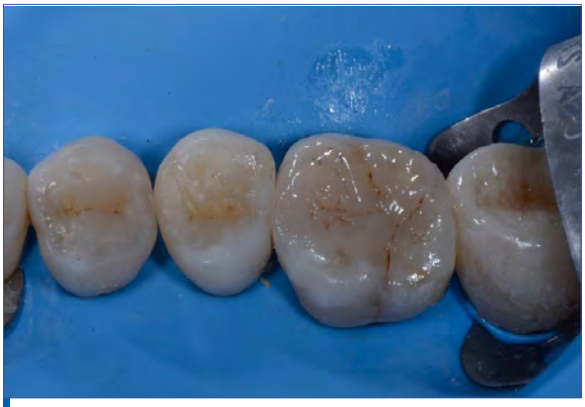


**Figure 10.** Enamel shade composite placement of the same system.

were performed with an extra-fine diamond bur and aluminum oxide disks (Sof-Lex, 3M ESPE AG, Seefeld, Germany), in order to give the proper anatomical morphology and simultaneously to remove all excess at the tooth restoration interfaces. For the polishing, a two-step silicon-rubber polishing cups system (Flexi Cups, Cosmedent, Chicago, IL, USA) and a 5 μm diamond-polishing paste (Diamond Polish Mint, Ultradent Products Inc, South Jordan) were used for 30 seconds, to achieve a higher surface gloss. The final restoration and the neighboring teeth were photo-documented at the end of the restoration (Fig. 12).

## 3. Discussion

Many amalgam restorations have to be replaced due to micro-leakage, recurrent caries, bulk amalgam fracture and sometimes the aesthetic demands of the patient [10]. Amalgam corrosion products penetrate deeply into the dentinal walls and cause dark discolorations [11]. The penetration of black pigments in dentin underneath both high-Cu and low-Cu amalgams in demineralized specimens are unevenly distributed and observed predominantly in dentin near to pulp horns. Discoloration in the majority of cases is not limited to the outer demineralized dentin but extended beyond this zone. An evenly distributed bluish-green discoloration is frequently observed underneath all high-Cu amalgam specimens independent of demineralization [12]. Therefore, the extension of the cavity preparation to ameliorate the discoloration might be not beneficial.

Furthermore, a scanning electron microscope (SEM) study of Harnirattisai et al. [13] shows that the majority of the dentinal tubules in cases of discolored dentin were open, but plasma proteins inside the dentinal fluid may reduce the permeability of dentin and interfere with the ability of the resin monomer to infiltrate. As a result, discolored dentin could be considered as a different substrate during clinical procedures, which is able to decrease the bond strength. However, on the basis of an in vitro study, there are no benefits in extending the cavity walls of the preparation, when replacing amalgam restorations [14]. The application of dental liners, bases and cavity varnishes results in reducing micro-leakage that may cause sensitivity, discolorations and bacterial invasion, due to the fact that these materials are able to seal the dentinal tubules.

Discolorations of posterior teeth should be restored primarily with the least invasive techniques. In more detail, dental bleaching can be used as an alternative or the first treatment step before a direct restoration or to treat a stained arrested caries lesions [15]. Apart from bleaching and the well-established restorative options, a restoration that covers both buccal and cuspal areas can be used, the so called "vonlay". Generally, they are monolithic structure fabricated from lithium disilicate, a vonlay is a hybrid of an onlay with an extended buccal veneer surface for use in bicuspid regions where there is mostly enamel to bond to [16]. Even if extra tooth structure is removed, the problem

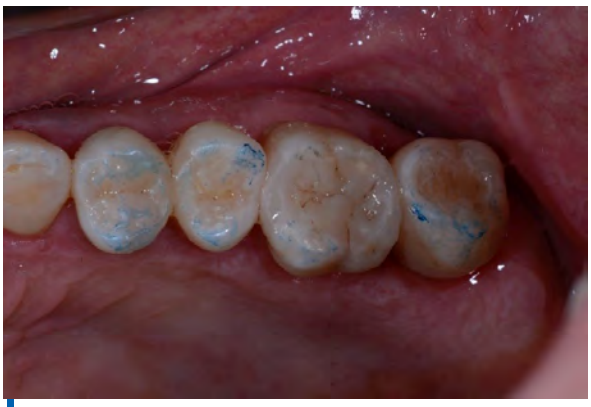


**Figure 11.** Checking occlusion.

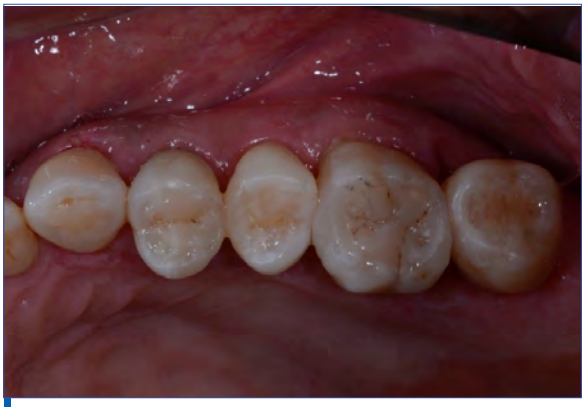


**Figure 12.** Final occlusal view.

of obtaining an optimal result can be more difficult due to the effect of the underlying resin cement. The tooth shade can also vary somewhat after placing the specific restorations because of a color shift in the polymerized resin cement. On the contrary, the shade of direct composite restorations can be easily modified in order to obtain the optimal result.

It is recommended that general dental practitioners consider adopting minimally invasive techniques in the first instance before moving on to more invasive treatment plans. Indirect restorations require more tooth preparation and more than one appointment to be completed [17–20]. Metal ceramic restorations though they have shown long-term success due to good mechanical properties [21], achieving a natural appearance is more challenging with a metal-ceramic restoration than an all-ceramic restoration due to the fact that metal copings prevent light transmission [22]. Additionally, since porcelain is the main material of choice in the aforementioned treatment plans, there is a high probability of excessive wear of the opposing restoration or the natural tooth, due to the friction between the two [23]. Direct resin composite materials exhibit a promising long-term clinical performance when rehabilitation of posterior teeth is needed [24]. Therefore, they may be used as an equivalent alternative to glass-rich-ceramic inlays regarding mechanical performance [25]. As a result, a direct composite restoration may be the preferable choice, especially if there is adequate tooth structure and the patient is a perfectionist.

In addition, the new generation of composites (nanohybrid composites) has been improved in respect of shade, wear and fracture resistance [26,27]. Nanohybrid resin composites are able to imitate ceramic materials in functional and optical aspects [28,29]. Even dischromatic posterior areas could be covered with great effectiveness. However, because of their low opacification ability, they sometimes fail to cover very dark discolored pulpal walls of previous amalgam restorations.

In these demanding cases opaquers and tints should be used to counterbalance even the darkest discolorations and simultaneously follow a minimally invasive approach. Therefore, the correct and moderate use of opaquers and tints should be suggested in presenting the "lege artis" of direct posterior restorations.

Clinical tips of how to apply correctly the color modifiers in the posterior restorations will be mentioned below. Color modifiers should be applied homogeneously in very thin layers (0.1–0.5 mm each) with a small round brush. Moreover, they should be selected carefully. Some of them are highly pigmented, therefore only a single thin layer is needed to obtain an adequate coverage of a discoloration; whereas others may require the application of two or more layers of color modifiers [30]. The clinician has to prepare and preserve an adequate space (minimum 1.5 mm); to be filled with resin composite [2,31]. Masking of the opaque layer is also an esthetic necessity. Monochromatic or layering techniques can be either used. However, aesthetics in these situations is usually of high importance, the layering shade technique (enamel-dentin shades) is preferred by many clinicians.

In addition, potential problems regarding the tone of the restorations will be discussed below. Grey restorations may result due to the inefficacy of the opaquer to mask the discoloration or insufficient amount of opaquer applied. A matte restoration may be the result of one of the following: (a) too strong opacification ability of the opaquer, (b) excessive amount of the opaquer and (c) close proximity of the opaquer to the occlusal surface (less than 1.5 mm). Spotted restorations are mainly the result of uneven layering of color modifiers [32].

The knowledge and the correct use of color modifiers, as well as, the skills and the aesthetic perception of the dentist are the key factors in establishing a natural result [33,34], particularly when the restoration relates to a single discolored tooth. Therefore, the ability to accurately perceive and differentiate the color characteristics of natural dentition is a major prerequisite for a successful restoration. The aesthetic success of the restoration depends mainly on the correct choice of the shade of the composite and the total opacification ability of the opaquer and the composite materials used. The importance of the specific technique is that even the most difficult and dark pulpal wall discolorations can be covered by simultaneously following the minimally invasive

approach of cavity preparation.

## 4. Conclusions

Restoring a single posterior discolored posterior tooth with composite resin is a demanding task.
Color modifiers should be applied to ameliorate the dark discolorations and simultaneously follow a minimally invasive technique. Their use demands knowledge, experience, training and a feeling of cause and effect. Success in a posterior direct restoration is achieved by applying resinous color modifiers in meticulous layering, use of nanohybrid composite resins of both dentin and enamel shades, finishing and polishing.

## Author Contributions

AS: performed the clinical case. FK: contributed to summarizing the literature and writing the manuscript. MA: contributed to reviewing the manuscript.

## Funding

This research received no external funding.

## Conflicts of Interest

The authors declare no conflict of interest.

## References

1. Naeimi Akbar H, Moharamzadeh K, Wood DJ, Van Noort R. Relationship between color and translucency of multishaded dental composite resins. *Int J Dent.* 2012;2012:708032. [Full text links] [Free PMC Article] [PubMed] Google Scholar(24) Scopus(7)
2. Dias WR, Pereira PN, Swift EJ Jr. Maximizing esthetic results in posterior restorations using composite opaquers. *J Esthet Restor Dent.* 2001;13(4):219-227. [Full text links] [PubMed] Google Scholar(14) Scopus(6)
3. Miotti LL, Santos IS, Nicoloso GF et al. The Use of Resin Composite Layering Technique to Mask Discolored Background: A CIELAB/CIEDE2000 Analysis. *Oper Dent.* 2017;42(2):165-174. [Full text links] [PubMed] Google Scholar(5) Scopus
4. Ikeda T, Murata Y, Sano H. Translucency of opaque-shade resin composites. *Am J Dent.* 2004;17(2):127-130. [PubMed] Google Scholar(73) Scopus(37)
5. Darabi F, Radafshar G, Tavangar M et al. Translucency and masking ability of various composite resins in different thicknesses. *J Dent (Shiraz).* 2014;15(3):117-122. [Free PMC Article] [PubMed] Google Scholar (5)
6. Lambert D. Simplified solutions to daily anterior aesthetic challenges using a nano-optimized direct restorative material. *Dent Today* 2005;24(5):94-97. [PubMed] Google Scholar (6)Scopus
7. Al-Khreisat AS. Evaluating the relative optical translucency of opaquers composite resins. *J R Med Serv.* 2006;13(2):62-66. Google Scholar(1)
8. Chalkley Y. Treatment of a single stained anterior tooth utilizing visible light-cured opaquer resin and microfill composite resin. *Iowa Dent J.* 1984;70(1):37-39. Google Scholar (2)
9. Le Sage BP. Aesthetic anterior composite restorations: a guide to direct placement. *Dent Clin North Am*. 2007;51(2):359-378. [Full text links] [PubMed] Google Scholar(56) Scopus(14)
10. Gawriołek M, Sikorska E, Ferreira LF et al. Color and luminescence stability of selected dental materials in vitro. *J Prosthodont.* 2012;21(2):112-122. [Full text links] [PubMed] Google Scholar(29) Scopus(13)
11. Mjör IA, Gordan VV. Failure, repair, refurbishing and longevity of restorations. *Oper Dent.* 2002;27(5):528-534. [PubMed] Google Scholar(250) Scopus(142)
12. Scholtanus JD, Van der Hoorn W, Ozcan M et al. Staining of dentin from amalgam corrosion is induced by demineralization. *Am J Dent.* 2013;26(4):185-190. [PubMed] Google Scholar(5) Scopus(3)
13. Harnirattisai C, Senawongse P, Tagami J. Microtensile bond strengths of two adhesive resins to discolored dentin after amalgam removal. *J Dent Res*. 2007;86(3):232–236. [Full text links] [PubMed] Google Scholar(19) Scopus(11)
14. Ghavamnasiri M, Eslami S, Ameri H et al. Effect of amalgam corrosion products in non-discolored dentin on the bond strength of replaced composite resin. *J Conserv Dent.* 2015;18(1):25-29. [Full text links] [Free PMC Article] [PubMed] Google Scholar(1) Scopus
15. Al-Angari SS, Hara AT. A conservative approach to esthetically treat stained arrested caries lesions. *Quintessence Int.* 2016;47(6):499-504. [Full text links] [PubMed] Google Scholar(2) Scopus(1)
16. McLaren EA, Figueira J, Goldstein RE. Vonlays: a conservative esthetic alternative to full-coverage crowns. *Compend Contin Educ Dent*. 2015;36(4):286-289. [PubMed] Google Scholar(7) Scopus(2)
17. Barber AJ, King PA. Management of the single discoloured tooth. Part 2: Restorative options. *Dent Update.* 2014;41(3):194-196. [Full text links] [Free PMC Article] [PubMed] Google Scholar(3) Scopus(1)
18. Fradeani M, D'Amelio M, Redemagni M, Corrado M. Five-year follow-up with Procera all-ceramic crowns. *Quintessence Int*. 2005;36(2):105-113. [PubMed] Google Scholar(153) Scopus(69)
19. Raigrodski AJ, Chiche GJ, Potiket N et al. The efficacy of posterior three-unit zirconium-oxide-based ceramic fixed partial dental prostheses: a prospective clinical pilot study. *J Prosthet Dent.* 2006;96(4):237-244. [Full text links] [PubMed] Google Scholar(612) Scopus(341)
20. Shi JY, Li X, Ni J, Zhu ZY. Clinical Evaluation and Patient Satisfaction of Single Zirconia-Based and High-Noble Alloy Porcelain-Fused-to-Metal Crowns in the Esthetic Area: A Retrospective Cohort Study. *J Prosthodont*. 2016;25(7):526-530. [Full text links] [PubMed] Google Scholar(11) Scopus(5)
21. Harada K, Raigrodski AJ, Chung KH et al. A comparative evaluation of the translucency of zirconias and lithium disilicate for monolithic restorations. *J Prosthet Dent.* 2016;116(2):257-263. [Full text links] [PubMed] Google Scholar(52) Scopus(24)
22. Tabatabaian F, Javadi Sharif M, Massoumi F, Namdari M. The color masking ability of a zirconia ceramic on the substrates with different values *J Dent Res Dent Clin Dent Prospects*. 2017;11(1):7-13. [Full text links] [Free PMC Article] [PubMed] Google Scholar(4) Scopus
23. Rashid H. The effect of surface roughness on ceramics used in dentistry: A review of literature. *Eur J Dent*. 2014;8(4):571-579. [Full text links] [Free PMC Article] [PubMed] Google Scholar(48) Scopus(24)
24. Angeletaki F, Gkogkos A, Papazoglou E, Kloukos D. Direct versus indirect inlay/onlay composite restorations in posterior teeth. A systematic review and meta-analysis. *J Dent.* 2016;53(October):12-21. [Full text links] [PubMed] Google Scholar(33) Scopus(10)
25. Belli R, Geinzer E, Muschweck A, Petschelt A, Lohbauer U. Mechanical fatigue degradation of ceramics versus resin composites for dental restorations. *Dent Mater.* 2014;30(4):424-432. [Full text links] [PubMed] Google Scholar(120) Scopus(60)
26. Suzuki S, Nagai E, Taira Y, Minesaki Y. In vitro wear of indirect composite restoratives. *J Prosthet Dent*. 2002;88(4):431-436. [Full text links] [PubMed] Google Scholar(103) Scopus(64)
27. Ku CW, Park SW, Yang HS. Comparison of the fracture strengths of metal–ceramic crowns and three ceromer crowns. *J Prosth Dent.* 2002;88:170-175. [Full text links] [PubMed] Google Scholar(108) Scopus(42)
28. Fahl N Jr. A polychromatic composite layering approach for solving a complex Class IV/direct veneer/diastema combination: Part II. *Pract Proced Aesthet Dent*. 2007;19(1):17-22. [PubMed] Google Scholar(74) Scopus(17)
29. Beddis HP, Nixon PJ. Layering composites for ultimate aesthetics in direct restorations. *Dent Update*. 2012;39(9):630-632, 634-636. [PubMed] Google Scholar(7) Scopus(1)
30. An JS, Son HH, Qadeer S, Ju SW, Ahn JS. The influence of a continuous increase in thickness of opaque-shade composite resin on masking ability and translucency. *Acta Odontol Scand*. 2013;71(1):120-129. [Full text links] [PubMed] Google Scholar(10) Scopus(4)

31. Milhauser SA, Molnick CP. Clinical application and evaluation of two light-activated color modifiers for composite resin restorations. *N Y State Dent J*. 1983;49(6):397-398. [PubMed] Google Scholar(3) Scopus(1)
32. Felippe LA, Monteiro S Jr, Baratieri LN et al. Using opaquers under direct composite resin veneers: an illustrated review of the technique. *J Esthet Restor Dent*. 2003;15(6):327-336; discussion 337. [Full text links] [PubMed] Google Scholar(24) Scopus(7)
33. Bichacho N. Direct composite resin restorations of the anterior single tooth: clinical implications and practical applications. *Compend Contin Educ Dent*. 1996;17(8):796-862. [PubMed] Google Scholar(25) Scopus(13)
34. Dietschi D. Layering concepts in anterior composite restorations. *J Adhes Dent*. 2001;3(1):71-80. [PubMed] Google Scholar(177) Scopus(56)

**Andreas SPAVERAS**
DMD, Postgraduate Student
Department of Operative Dentistry Dental School,
National and Kapodistrian University of Athens,
GR-11527 Athens, Greece

## cv

Dr. Andreas Spaveras received his degree in dentistry (DMD) in 2013 from the Semmelweis University of Budapest, Hungary. Currently, he is finishing his postgraduate studies (MSc) at the Restorative Dentistry Department, Dental School of the National and Kapodistrian University of Athens, Greece. He has published several scientific articles in the field of restorative dentistry.

## Questions

### 1. Color Modifiers promote:

❑a. Non-invasive procedures;
❑b. Minimally invasive indirect restorations;
❑c. Minimally invasive direct restorations;
❑d. Invasive restorations.

### 2. Color modifiers should be applied:

❑a. In very thin layers (0.1-0.5 mm each);
❑b. In thin layers (0.5-0.7 mm each);
❑c. In moderate layers (0.7-1.2 mm each);
❑d. In thick layers (1.2-1.5 mm each).

### 3. Opaquers and Tints should be applied homogeneously with:

❑a. A probe;
❑b. A micro-brush;
❑c. A small round painter's brush;
❑d. A flat painter's brush.

### 4. The clinician has to prepare and preserve:

❑a. A minimum 1.0 mm space to be filled with resin composite;
❑b. A minimum 1.5 mm space to be filled with resin composite;
❑c. A minimum 2.0 mm space to be filled with resin composite;
❑d. A minimum 3 mm space to be filled with resin composite.

# ROTATIONAL PATH PARTIAL DENTURES: AN UNDERUTILIZED TREATMENT MODALITY IN AESTHETIC DENTAL MEDICINE

**Adam Perry Tow**[1a*]

[1]Department of Restorative Dental Sciences, College of Dentistry, University of Florida, Gainesville, FL 32610, USA

[a]MBA, DMD Candidate

**ABSTRACT**

**DOI: https://doi.org/10.25241/stomaeduj.2018.5(4).art.7**

**Aim:** To design a highly aesthetic prosthesis at low cost, which replaces maxillary anterior teeth without showing removable denture clasps.

**Summary:** Today's clinical practice is highly dictated by the increasingly demanding aesthetic standards of the modern patient. While advances in biomaterials and titanium osseo-integrated implants have made replacing missing teeth possible in a natural-looking way, many patients are not candidates for these fixed restorations due to physiological or financial barriers. In this case report, a patient with a history of anterior maxillary incisor partial-edentulism for whom fixed restorations were not feasible was treated using a rotational path of insertion partial denture.

With this technique, the author was able to design a removable partial denture with no clasps showing, irrespective of the smile line height.

The final result completely obscures the retentive mechanisms upon smiling and is highly aesthetic, on par with implant-retained fixed restoration, at a fraction of the cost and without the associated risks and complications of surgically-driven prosthetic cases.

**Learning Points:** This article will review this case and the supporting literature, as well as provide guidance on laboratory prescription writing and optimal case selection.

**Keywords:** Denture, Partial, Removable (D003832) Esthetics, Dental (D004955) denture, partial, removable (D003832) esthetics, dental (D004955).



**Peer-Reviewed Article**

**Citation:** Tow AP. Rotational path partial dentures: An underutilized treatment modality in aesthetic dental medicine. Stoma Edu J. 2018;5(4):263-269

**Academic Editor:** Alexandru Eugen Petre, DDS, PhD, Professor, "Carol Davila" University of Medicine and Pharmacy, Bucharest, Romania

Received: December 05, 2018
Revised: December 07, 2018
Accepted: December 14, 2018
Published: December 15, 2018

***Corresponding author:**
Dr. Adam P. Tow, MBA
Department of Restorative Dental Sciences, College of Dentistry, University of Florida, 1395 Center Dr, Gainesville, FL 32610, USA
Tel/Fax: +1 970-823-2605,
e-mail: aptow@dental.ufl.edu



## 1. Introduction and Background

Today's clinical practice is highly dictated by the increasingly demanding aesthetic standards of the modern patient. While advances in biomaterials and titanium osseo-integrated implants have made replacing missing teeth possible in a natural-looking way, many patients are not candidates for these fixed restorations due to physiological or financial barriers. In this case report, a patient with a history of anterior maxillary incisor partial-edentulism for whom fixed restorations were not feasible was treated using a rotational path of insertion partial denture.

Removable partial dentures, abbreviated RPDs, are a popular, inexpensive treatment option for the partially dentate patient seeking full arch rehabilitation. Generally, well-designed RPDs are composed of the following basic components: (1) a cast metal major connector that forms the majority of the body of the prosthesis, (2) areas of metallic mesh upon which acrylic gingiva and denture teeth are affixed, (3) guide planes, metal areas which contact the, often purposely adjusted, proximal teeth in edentulous areas, (4) cast metal occlusal rests which fit into messio-occlusal rest seats prepped into the teeth, (5) and metal retentive and reciprocal clasp elements which engage undercuts on the buccal (or lingual) surface, which are connected to the prosthesis via connecting metal referred to as the minor connector.

The clasping systems which attach the prosthesis to the dentition are generally cast metal, though soldered wrought wire, and thermoplastic options do exist [1,2]. Indeed, various components of the RPD may also be made with thermoplastic elements, though in cases similar to the one reviewed here, the author will suggest that the rotational path RPD design is clinically superior.

The rotational path of insertion removable partial denture was first reported on by Humphereys in 1935 and credited to Hallen Back [3]. The concept is broadly divided into two categories, Category I and Category II prosthetics [4,5]. The former are useful when mesially tipped molars do not have adequate buccal undercuts for traditional clasp retention. The latter are the subject of this article and are useful in Kennedy Class IV and similar situations where missing anterior teeth need to be replaced esthetically. The advantage of the type of prosthetic discussed herein is that it has no anterior clasps, making the transition from prosthesis to natural tooth seamless.

Because the design of these prosthesis is considered "complicated" by many practitioners, this technique is seldom taught in the dental school curriculum. According to Jacobson, et. al., nearly 20% of surveyed prosthodontists report only a "superficial understanding" of rotational path RPDs [5]. The author believes this lack of familiarity is likely only increased as our profession has turned its focus

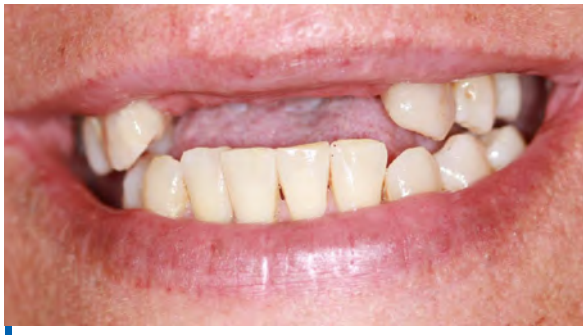


**Figure 1.** Shows patient without prosthetic after perio treatment

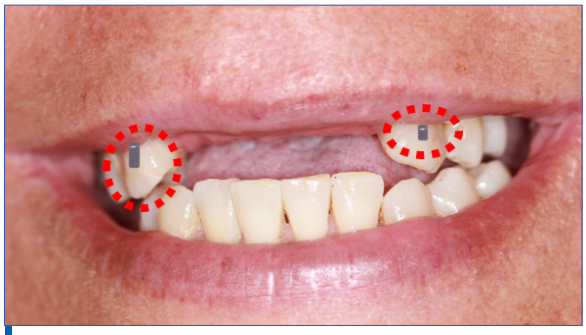


**Figure 2.** Shows a simulated digital smile analysis, revealing that i-bar clasps would likely create an unattractive metal display.

toward osseointegrated implants, new restorative materials, and fixed treatment modalities.

As will be shown here, this treatment modality is both accessible and attractive to patient and clinician alike. While the rotational path RPD may lack the 'glamor' of newer surgical fixed treatments, it more than compensates with highly aesthetic treatment results which outshine other removable options and even rival more complex treatments.

## 2. Case Presentation

### 2.1. Initial Presentation and Phase 0-II Therapy

A forty-year old female patient presented to the clinic with a history of maxillofacial trauma, having lost her maxillary incisors in an equestrian accident in her youth. She presented to the clinic with an ill-fitting flipper with which she was unhappy. Her chief complaint was her smile aesthetics and poor functioning prosthetic, as well as some acute pain on tooth #18. Her medical history was generally non-contributory to her dental evaluation, except that she was a 20 pack-year smoker who quit smoking over the course of her dental treatment described here. She also disclosed that her smile had negative effects on her self-esteem and discussed the significance of her "semi-colon" wrist tattoo with her dental provider. (Semi-colon tattoos are a symbol of the suicide struggle awareness and prevention movement.) As might be expected, data have shown that comorbid depression and anxiety are associated with partial edentulism [6].

In addition to the maxillary partial endentualism, she also presented with need for acute treatment of a mandibular molar which was extracted due to carious invasion of the pulp. The patient examination classified her as high caries risk, with several active lesions and missing teeth on both arches. The patient was diagnosed with mild-moderate chronic generalized periodontal disease with localized moderate-severe disease around the upper right first molar. Phase I treatment evaluation showed substantial improvement in periodontal health after scaling and root planning therapy, including stabilization and marked improvement of the periodontal health of the maxillary molar. Fig. 1 shows a photograph of the patient after completion of initial periodontal treatment. Caries risk was also

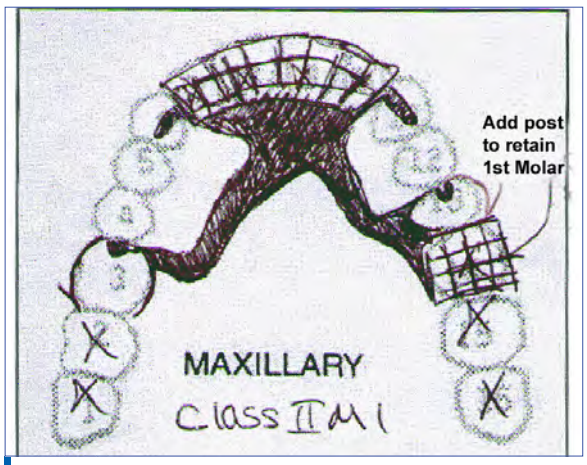



**Figure 3.** The figure shows the drawn lab script for rRPD.

decreased by extensive restorative dentistry and significant improvement in patient home-care via oral hygiene instructions delivered in the dental operatory.

### 2.2. Definitive Treatment Planning and Phase III Therapy

With active dental disease controlled, the patient was cleared for definitive prosthetic treatment. Because finances were a significant factor in treatment, implant or traditional fixed bridge therapy were not considered. This made removable partial dentures the only financially and medically viable treatment available. Initially, a classic metal-acrylic RPD design was proposed, with infrabulge or i-bar style clasps utilized on the maxillary canine teeth. A similar design was proposed for the lower arch. Smile analysis, however, as simulated in Fig. 2 showed that this would likely cause the maxillary anterior clasps to be visible upon smiling and functional movement. Though infrabulge clasps are a good first instinct for the RPD architect attempting to obscure clasps, they are often contra-indicated in the aesthetically conscious young patient whose labial tissues and gingival show cause the clasps to be visible, especially in the anterior maxillary arch [7]. An experienced dentist can quickly ascertain whether clasps will be visible by visual inspection; however, digital prosthetic smile design techniques such as the one show in Fig. 2 are simple and fast ways to communicate the

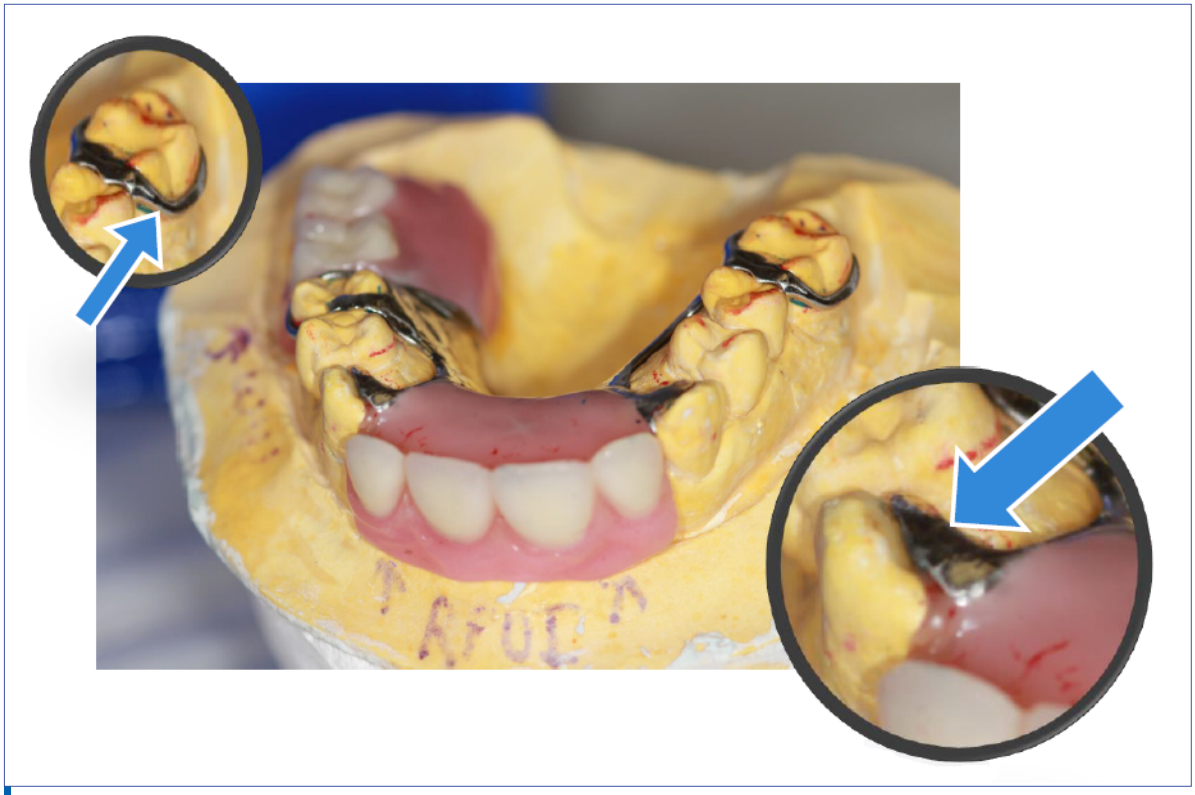


**Figure 4.** Shows the prosthetic on the master cast, with blue arrows indicating the conventional posterior clasp (left) and the long anterior rest seats (right).

issue to a patient, if needed. Several options exist to address this issue of exposed clasps and they will be discussed now in brief. One option is to use a Valplast or similar thermoplastic clasp which can be tooth colored. This option has several limitations. First, the clasp is still visible. It is merely less noticeable. Second, thermoplastic materials are more prone to fatigue and fracture [1,2]. Though most clinical studies support the use of thermoplastics for their aesthetic advantages, their reported "clinical acceptability" does not make them equals with respect to mechanics to their metal counterparts. A second option is the use of precision attachments. These come in two varieties, intra and extracoronal attachment systems [7]. The intracoronal variety have several limitations including that they require a certain level of laboratory sophistication, i.e. the precision aspect of the attachment requires the parts mate exactly, without the inherent leeway about a broad tooth contour traditional bulge-articulating clasps have. Additionally, these clasps require more significant preparation of the teeth, and cementation, both of which introduce obvious short and long-term clinical issues for both clinician and patient. The second subtype of precision attachment are extracornonal attachments, which function by cantilevering a hoop off of the abutment teeth into which a pin on the RPD fits. This requires a certain level of space within the prosthesis and presents with issues of retaining the attachment, as well as the introduction of a fixed, iatrogenic plaque trapping area beneath the attachment. Though not an issue in this case, these attachment systems may also be contraindicated in the elderly or other patients with limited dexterity. Given the large comorbidity associated with low dexterity and partial edentualism, this is a significant limitation of these systems. As a history of high caries risk and significant periodontal disease virtually ubiquitous among partially edentulous patients, there is ample reason for caution in prescribing these treatment options.

### 2.3. Rotational Path Partial Denture Treatment Option

The rotational path of insertion removable partial denture (rRPD) was selected as the treatment modality for this case in the maxillary arch, as shown in the lab prescription reproduced in Fig. 3. Due to the available mandibular premolar abutment teeth, a traditional i-bar design was possible for the lower arch. Therefore, the discussion that follows will concentrate on the maxilla were the rRPD was used.

The rRPD was first introduced in the 1930's by Hallen Back and has been investigated by several more contemporary authors, most notably Krol and Jacobson [4,5,8]. Unfortunately, the technique is virtually never taught in the predoctoral dental curriculum and it was reported by Jacobson in 1994 that nearly 20% of surveyed prosthodontist felt they had only a "superficial" understanding of the topic [4]. With the recent focus of our profession on osseointegrated fixed restorations, it is doubtful that this number has decreased in recent years. That said, especially with the risks associated with the increasingly popular bisphosphonate therapy and several other financial and medical issues which

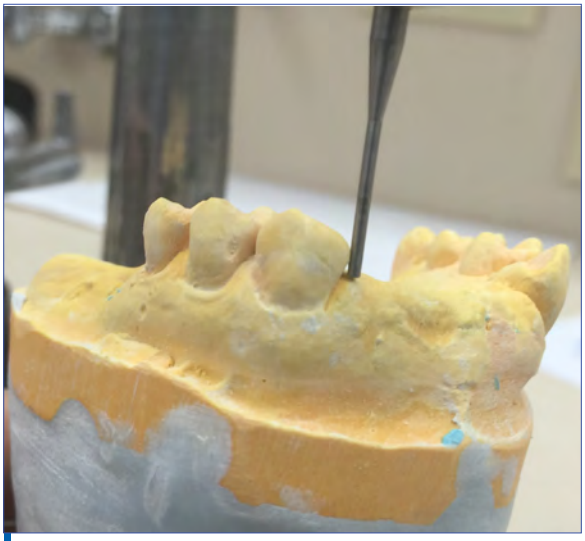


**Figure 5.** Study model on surveyor, showing triangular undercut needed for rigid retainer.

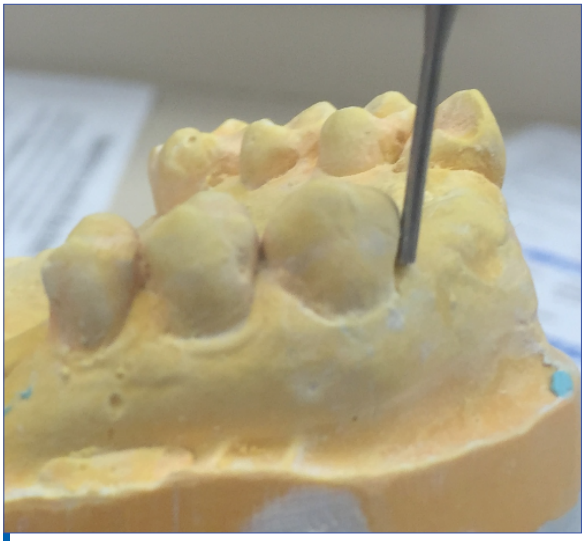


**Figure 6.** Shows the analyzing rod parallel to the mesial undercut with the terminus at the 'A-point' of rotational path.

complicate or contraindicate implants, the need for aesthetic removable options for patients is certainly real. The rRPD relevant to our discussion is the Category II Rotational Path of Insertion RPD. Because of its usefulness in aesthetic cases and its accessibility, it is hoped that adding a representative case study to the literature will contribute positively toward informing clinicians about this treatment option, and dispelling the notion that it is "too complicated" for the average dental practitioner or lab to be viable in modern practice.

*2.3.1. Review of rRPD Case Selection and Basic Components*

The rRPD is a fully cast framework RPD which employs a specialized guide plane called a rigid retainer to lock into mesial undercuts and a curvilinear path of insertion to retain a denture with no anterior clasps. The rRPD has the following basic components: (1) anterior mesial undercuts (2) rigid retainers (3) long rest seats on the claspless abutment teeth (4) conventional posterior clasps. Several of these features can be appreciated by examining Fig. 4, which shows the prosthetic on the master cast. Because of the non-linear path of insertion, Kennedy modification spaces complicate the treatment. To accommodate these, the clinician must carefully assess rotational path during guide plane enameloplasty planning. There are paralleling devices which can be used to accomplish this; however, it is suggested that, especially for the occasional prescriber, these cases which require complex guide planes on modification space teeth be avoided. Instead, the ideal case for this treatment is a Kennedy Class IV or Class I or II with a single anterior modification space. In these cases, the surveying can be done with relatively little additional knowledge or skill, and rRPD specific challenges with cast framework try-in are minimized. Of course, there are many other cases in which rRPDs are useful, such as so-called Category I rRPDs which can be used for tipped posterior molars [5]. However, the goal of this paper is to demonstrate what the author believes is the simplest and most powerful use of the technique, the anterior edentualism situation. This case is a prototypical example of a straightforward case for which rRPD is indicated: Infrabulge or thermoplastic clasps are aesthetically untenable, and there is a single anterior edentulous space continuous with distant posterior tooth abutments.

*2.3.2.Surveying Concepts*

To design the prosthetic, study models were analyzed with the occlusal plane roughly parallel to the base of the surveyor. The analyzing rod is placed on the edentulous anterior ridge on the mesial surfaces of both abutment teeth, ideally canines. A significant undercut should be identified or created by enameloplasty or addition of resin-based composite, the latter being the case here where the undercuts were augmented with composite. A triangular wedge of light should shine through the space between the rod, tooth, and gingival stone. The occlusal plane and tilted surveying are shown in Figs. 5 and 6, respectively. The cast is now tilted so that the analyzing rod contacts the full inciso-cervical mesial surface of the abutments. In other words, the "triangle" is now closed, with the analyzing rod placed on its hypotenuse, that is, flush to the mesial surface, as shown in Fig. 6. The terminus of the analyzing rod is now touching the gingiva at the "A-point," the pivot around which the rotational path of insertion will rotate in the final prosthetic [4]. The posterior teeth can now be surveyed for facial undercuts on the posterior abutment teeth which will utilize standard cast circumferential or CC-clasps. The author recommends a lingual arm for counter retention of the posterior clasp to reduce the complexity of the metal framework and better accommodate adjustment, if needed.

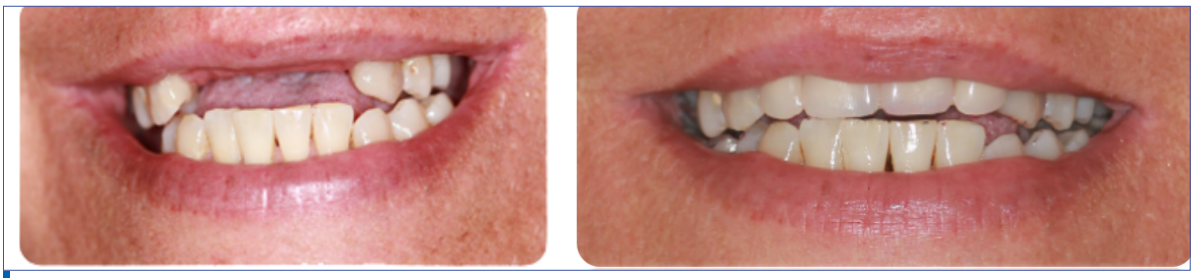


**Figure 7.** Are pre and post treatment photographs of the patient at rest showing the highly aesthetic results.

*2.3.3. Biomechanics*

The prosthetic works based on a simple principle common to all RPDs: that vertical displacing forces perpendicular to the surveyed occlusal plane must be resisted to keep the prosthetic engaged and prevent dislodgment during function. In the posterior, this is accomplished by a traditional CC-clasp, wherein the buccal contour of the clasped tooth entraps the clasp and secures it against a physiological vertical dislodging force. The anterior portion of the prosthetic relies on the 'rigid retainer' which is entrapped by the 'triangular' mesial undercut, thereby also resisting the vertical force, as the framework is 'wedged under' the tooth. For the rRPD, only a rotationally directed force about the radius defined by the A-point at the mesio-gingival terminus of the mesial abutment teeth can dislodge (or seat) the prosthetic. Visualizing how the prosthetic would 'get stuck' by the posterior buccal buldge and anterior mesial undercuts will help the clinician appreciate the simple principle by which these prosthetics operate.

**2.4. Teeth Preparations**

As discussed, the rigid retainer abutting teeth may require some adjustment to accommodate the prosthesis; however, the natural anatomy of canines often lends itself to this application unmodified. The rigid retainer teeth should be supported by long anterior rests which extend from the mesial surface approximately half the mesio-distal distance of the tooth. The remainder of the rest seats are prepared traditionally.

**2.5. Fabrication of Prosthesis**

After preparation and impression, the metal framework is fabricated and the patient is reappointed for try-in. At this appointment, the doctor should verify the fit of the prosthesis, and ensure the partial framework fits without any occlusal interference. It is recommended that patient education regarding the insertion of the prosthesis begin at this point, so the wax try-in and delivery appointments are of increasing instructional value. Wax rims should be fabricated and tested after confirming the metal-only framework is satisfactory. Teeth should be set, either on-site, or by an off-site lab technician and the processing and delivery of the final rRPD should proceed as in any other RPD case.

*2.5.1. Delivery & Patient Education*

Since the rRPD should not be inserted or removed along a straight-line path, it is important to educate the patient in the importance of maintaining the contour of the abutment teeth by ensuring that removal of the prosthesis does not grind the anterior abutment teeth. In other words, and especially in the cases of milder anterior mesial undercuts, the patient must always remove the prosthetic along the arc path of insertion to avoid wearing down the undercuts. Additionally, it is vital that the patient is informed that s/he must inform other providers (e.g. hygiene) that the prosthesis is an rRPD, and ideally remove it him/herself. In this case, the patient was extremely pleased with the results which are shown in Fig. 7. She was able to achieve a very natural looking smile that provided her the desired form and function and increased her self-confidence. Due to the financial constraints, a result at this level of esthetics would have been all but impossible without the rRPD concept. It is fair to say that without using a rotational path, the treatment would have fallen short on its most fundamental goal to restore not only the biomechanical but the psychosocial function of the dentition.

**2.6. Additional Benefits and Considerations**

Some authors have also suggested that the claspless and flush anterior design promotes better periodontal health [9]. Given the association of partial edentualism and poor periodontal health, this is a noteworthy consideration.

Here are clear psychological benefits of the claspless appearance of the rRPD, both in how it looks and in that it is "different" from a traditional RPD.

In this case, the clinician made the decision to add a pin to retain the distal molar which was also replaced by the maxillary prosthesis. It is possible to add such retention features to the entirety of the anterior segment. This is particularly useful in cases where the residual ridge is more posteriorly located relative to the mandible. This will provide additional reinforcement where the denture teeth are retained by very thin acrylic embedded in the framework only. However, while pins are encouraged if needed, "bead retention" is discouraged by lab technicians as it may complicate the fabrication process and provides relatively little benefit [10].

## 3. Learning Summary Points

The case presented here should serve as a prototype for both the clinical decision tree that should be used to evaluate the potential rRPD case, as well as the steps to designing the prosthesis. The following learning points should help guide the clinician.

1. A highly aesthetic, claspless RPD can be designed easily and quickly, yielding a removable prosthesis that rivals its fixed counterparts and is a sound financial proposition.
2. The ideal case is a Kennedy Class IV or similar situation of a single space of anterior edentulism, such as Class I or II with only one modification space.
3. Smile analysis should have precluded the use of infrabulge clasps or fixed solutions.
4. Standard equipment for RPD design can be used with little additional knowledge, namely a standard surveyor with analyzing rod. The lack of familiarity with this technique is unfortunate and readily remedied by its use in simple, but effective treatments.
5. Canines with mesial undercuts are ideal abutment teeth, but enameloplasty or addition of RBC can be used to quickly modify deficient teeth.
6. Long anterior rests are used on the mesial abutment teeth, and traditional rests, retentive elements and clasps are used on the posterior teeth.
7. Additional benefits may include psychological and periodontal advantages over traditional prostheses.
8. Patient education is important to ensure that the mesial undercuts are protected and that the patient and any other clinicians with whom s/he interacts can comfortably insert or remove the appliance.

## 4. Conclusion

In a world increasingly dominated by fixed implant restorations, the RPD is often regarded as the unaesthetic last resort for the patient who is not a candidate financially or physiologically for more popular restorative techniques.

This case study shows that not only can highly aesthetic results be achieved using rotational path of insertion RPDs, but that these cases are accessible to the modern clinician without significant investment in time or any new equipment.

It is the author's hope that adding this case to the modern literature serves to encourage others to explore and utilize this technique to benefit patients for whom this treatment is appropriate.

## Acknowledgments

The author would like to thank the faculty of the University of Florida, College of Dentistry, Prosthodontics Department; in particular, Dr. Luis Rueda, for his encouragement to learn about and pursue this treatment modality.

## References

1. Osada H, Shimpo H, Hayakawa T, Ohkubo C. Influence of thickness and undercut of thermoplastic resin clasps on retentive force. *Dent Mater J*. 2013;32(3):381-389. [Full Text Links] [Pubmed] Google Scholar(22) Scopus(8)
2. Tannous F, Steiner M, Shahin R, Kern M. Retentive forces and fatigue resistance of thermoplastic resin clasps. *Dent Mater*. 2012;28(3):273--278. [Full Text Links] [Pubmed] Google Scholar(93) Scopus(44)
3. Alikhasi M, Monzavi A, Gramipanah F, et al. Rotational path removable partial denture: A literature review. *J Indian Prosthodont Soc*. 2007;7(3):143-146. [Full Text Links] Google Scholar(2) Scopus(0)
4. Jacobson TE. Rotational path partial denture design: A 10-year clinical follow-up--Part I. *J Prosthet Dent*. 1994;71(3):271-277. [Full Text Links] [Pubmed] Google Scholar(27)Scopus(15)
5. Jacobson TE. . Rotational path partial denture design: A 10-year clinical follow-up--Part II. *J Prosthet Dent*. 1994;71(3):278-282. [Full Text Links] [Pubmed] Google Scholar(18) Scopus(9)
6. Wiener RC, Wiener MA, McNeil DW. Comorbid depression/anxiety and teeth removed: behavioral risk factor surveillance system 2010. *Community Dent Oral Epidemiol*. 2015;43(5):433-443. [Full Text Links] [Pubmed] Google Scholar(11) Scopus(4)
7. Donovan TE, Derbabian K, Kaneko L, Wright, R. Esthetic considerations in removable prosthodontics. *J Esthet Restor Dent*. 2001;13(4):241-53. [Full Text Links] [Pubmed] Google Scholar(50) Scopus(18)
8. Jacobson TE, Krol AJ. Rotational path removable partial denture design. *J Prosthet Dent*. 1982;48(4):370-376. [Full Text Links] [Pubmed] Google Scholar(61) Scopus(41)
9. Goncalves LM, Bezerra-Junior JR, Benatti BB, Santana IL. Improving the esthetic replacement of missing anterior teeth: interaction between periodontics and a rotational path removable partial denture. *Gen Dent*. 2011;59(3):190-194. [Full Text Links] [Pubmed] Google Scholar(5) Scopus(2)
10. Ivanhoe JR. Laboratory considerations in rotational path removable partial dentures. *J Prosthet Dent*. 2000;84(4):470-472. [Full Text Links] [Pubmed] Google Scholar(8) Scopus(3)

**Adam Perry TOW**
MBA, DMD Candidate
Department of Restorative Dental Sciences
College of Dentistry, University of Florida
Gainesville, FL 32610, USA



## CV

The author is a DMD Candidate at the University of Florida and also earned an MBA 'with distinction' from Cornell University. Prior to dental school matriculation, he founded and served as chairman and CEO of a biomedical robotics startup which produces tissue engineering research equipment. He also holds an issued and several pending US Patents and is licensed to practice patent prosecution before the US Patent and Trademark Office. He has published academic work in business management, biomedical additive manufacturing, and he is approaching publication of a study aid book for dental anatomy.

## Questions

### 1. What are the unique required components of the rRPD?

❑a. Long Anterior Rests;
❑b. Rigid Retainers;
❑c. Mesial Anterior Undercuts;
❑d. All of the Above.

### 2. Where do the rigid retainers lock into the teeth to create retention?

❑a. Anterior Rests;
❑b. Mesial Undercuts;
❑c. Buccal Undercuts;
❑d. Conventional Posterior Clasps.

### 3. What case type(s) is/are appropriate for using the method described in the case report?

❑a. Kennedy Class IV RPD;
❑b. Kennedy Class I Mod I RPD;
❑c. Kennedy Class II Mod I RPD;
❑d. All of the Above.

### 4. How is surveying a rRPD different from a traditional RPD?

❑a. There is no difference;
❑b. Specialized surveyor must be purchased;
❑c. The cast must be surveyed in two planes;
❑d. Surveying is not necessary to fabricate an rRPD.

munich.eaed.org

European Academy of Esthetic Dentistry

# 33rd Spring Meeting

**Hotel Bayerischer Hof, Munich – Germany**

May 23-25, 2019

## DECODING THE CENTER-EFFECT

**In pursuit of better treatment outcomes for more patients**

## SESSIONS

- **The centre-effect: a scientific finding with impact on patient-related treatment outcomes**
- **Where are the limits in restorative dentistry?**
- **The John McLean Honorary Lecture**
- **Where are the limits in periodontal therapy?**
- **The Willi Geller Honorary Lecture**
- **The Peter Schärer Honorary Treatment Planning Session**
- **Where are the limits in hard tissue augmentation?**
- **Interactive podium discussion**
  **The centre-effect: breaking new ground to minimize or completely avoid it**

## SPEAKERS

Giuseppe Allais
Stefano Gracis
Arndt Happe
Endo Jungo
Giulio Rasperini
Isabella Rocchietta
Jean-Francois Roulet
Anton Sculean
Roberto Spreafico
Istvan Urban
Otto Zuhr

## MODERATORS

Rino Burkhardt
Amelie Meyer-Bäumer
Nicola Pietrobon
Deborah Schwartz-Arad
Francesca Vailati
David Winkler
Otto Zuhr

## SCIENTIFIC COMMITTEE

Markus Hürzeler
Otto Zuhr

May 23-25, 2019 **Munich, Germany**

**SIOCMF 2018 - 3rdMemorial Cattabriga**
Date: 14-15 December 2018
Location: Rome, Italy
Event types: Conference, Exhibition
Visit event website: www.siocmf.it/images/eventi_2018/roma.pdf

**7 Decades of Experience**
Date: 10-12 January 2019
Location: Berlin, Germany
Event types: Conference, Exhibition
Visit event website: https://www.7decades.com/

**KDAC 2019 - Kuwait Dental International Conference & Exhibition**
Date: 10-12 January 2019
Location: Kuwait City, Kuwait
Event types: Conference, Exhibition
Visit event website: http://www.kdac-kw.com/

**IDC 2019 - The 72nd Indian Dental Conference**
Date: 18-20 January 2019
Location: Indore,India
Event types: Conference, Workshop, Exhibition
Visit event website: http://idc.org.in/#/scientific_program

**MDA SCATE 2019 - 26th MDA Scientific Convention & Trade Exhibition**
Date: 18-20 January 2019
Location: Kuala Lumpur, Malaysia
Event types: Conference, Workshop, Exhibition
Visit event website: https://www.mda.org.my/mdascate/2019/03-02-program.html

**CIOSP 2019 - The 37th Sao Paulo International Dental Meeting**
Date: 30 January-02 February 2019
Location: São Paulo, Brazil
Event types: Conference, Workshop, Exhibition
Visit event website: http://www.ciosp.com.br/

**Yankee Dental Congress 2019**
Date: 30 January-02 February 2019
Location: Boston, USA
Event types: Conference, Workshop, Exhibition
Visit event website: https://www.yankeedental.com/

**AADGP 2019 - American Academy of Dental Group Practice - Conference and Exhibition**
Date: 30 January-02 February 2019
Location: Las Vegas, NV, USA
Event types: Conference, Workshop, Exhibition-
Visit event website: https://www.aadgp.org/

**Continuing Education AIC 2019 - Accademia Italiana di Odontoiatria Conservativa e Restaurativa**
Date: 04-09 February 2019
Location: Bologna, Italy
Event types: Conference, Workshop, Exhibition
Visit event website: https://accademiaitaliana-adiconservativa.it/

**DWDM 2019 - Dubai World Dental Meeting**
Date: 05-07 February 2019
Location: Dubai, United Arab Emirates
Event types: Conference, Workshop, Exhibition
Visit event website: https://aeedc.com/dubai-world-dental-meeting/

**Dental Review 2019 - 16th Russian Dental Forum & Exhibition**
Date: 11-13 February 2019
Location: Moscow, Russia
Event types: Conference, Workshop, Exhibition
Visit event website: http://www.dental-expo.com/dental-review/

**ICOI Winter Implant Symposium 2019 - International Congress of Oral Implantologists**
Date: 14-16 February 2019
Location: Phoenix, AZ, USA
Event types: Conference, Workshop, Exhibition
Visit event website: https://www.icoi.org/

**IAOCI 2019 - The 8th International Academy of Ceramic Implantology Congress**
Date: 14-17 February 2019
Location: Tampa, FL, USA
Event types: Conference, Workshop, Exhibition
Visit event website: https://iaoci.com/iaoci-world-congress-2019-speakers/

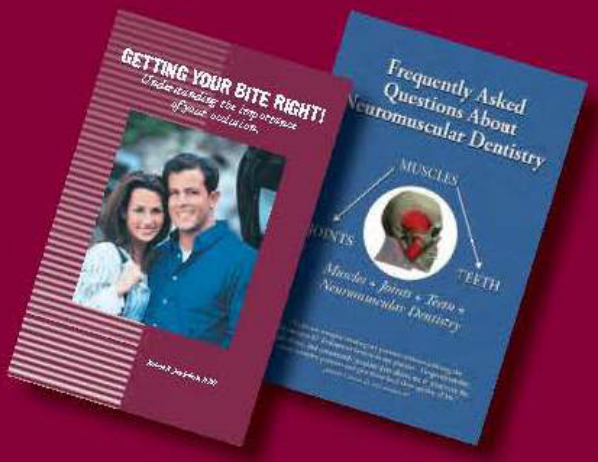
**154th Chicago Midwinter Meeting**
Date: 21-23 February 2019
Location: Chicago, IL, USA
Event types: Conference, Workshop, Exhibition
Visit event website: www.cds.org/meetings-events/midwinter-meeting

**Dental Community 2019**
Date: 22-23 February 2019
Location: Brescia, Italy
Event types: Conference, Workshop, Exhibition
Visit event website: https://it.dental-tribune.com/event/dental-community-2019/

# Neuromuscular Dentistry
## *Powered by Myotronics*

Dentists worldwide are discovering the science and the benefits of Neuromuscular Dentistry with Myotronics technology.

Evaluate and successfully treat occlusal and restorative cases with reliable, reproducible clinical data never seen before.




Contact Myotronics to receive information on upcoming CE courses and complimentary booklets on the benefits of Neuromuscular Dentistry.
800.426.0316 or info@myotronics.com.

MYOTRONICS
*Helping Build the Perfect Bite*
SINCE 1966
www.myotronics.com

# Teledentistry your partner in improving the oral health care of your patients

In this year's first issue, we published "Telemedicine in dentistry as the gold standard of improving access to oral health care" [1].
The Editorial Office has received several readers' requests to provide more information about the telemedicine systems used in dentistry. I have planned this presentation for this year's last issue. In order to make the presentation more compelling, I have asked for an ad page from both Dr. Jerry Herman, DDS, New York City, NY 10022 for *TeleDent* by MouthWatch, and Dr. Robert Clark, DDS of Liverpool, NY 13090 for *DrQuickLook* system. Both had a similar response, teledentistry systems were conceived and promoted only in the US. They are not interested in making their systems known in Europe because they do not know the dental market and have no distributors.
When accessing the American Dental Association website in the ADA Dental Product Guide for the Cameras, Intra and Extra Oral category, among the 17 Product Profile, one comes across DrQuickLook ™ Intraoral Dental Viewer Vendor: DrQuickLook [2].
If we visit https://drquicklook.com/[3]we notice two profile products:
• DrQuickLook SD Plus Intraoral Camera
• DrQuickLook PDA Tablet

**DrQuickLook SD Plus Intraoral Camera**
Intraoral SD and SD Plus cameras allow dentists to capture and save high-quality intraoral images on a standard SD card. The images are viewed and examined together with the patients on a 5-inch touchscreen. They help the patient to become aware of their own clinical condition and to better understand the dental treatment recommended. The cameras are easy to handle, feature an intuitive touch screen and switching buttons. The cameras work without a computer, any external software or a USB cable. SD Plus includes a FaceCam to capture extra-oral images. Images can be easily transferred to the desktop computer and the patient file, regardless of the patient management software. The necessary visual evidence for patient education is thus obtained. An optional patient education package with more than 30 videos and slideshows is available.

**DrQuickLook PDA Tablet**
PDA Tablet is a unique system that combines intraoral imaging and patient education, enhancing patient care and saving time for clinicians. Based on a Microsoft Surface 3 tablet, it can capture high-quality intra- and extra-high quality images that can be saved in the included software and transferred to the current patient management solution. PDA software includes features such as quad viewing as well as draw on screen, making it an ideal show and tell device to help patients understand the diagnosis and say yes to the treatment plan proposed. The system includes the informed consent and post-op videos as well as more than 60 patient education videos.
DrQuickLook ™ systems are recommended to be used in the following specialties: Dental Public Health, Endodontics, General Dentistry, Oral/ Maxillofacial Pathology, Oral/ Maxillofacial Radiology, Oral/ Maxillofacial Surgery, Orthodontics and Dentofacial Orthopedics, Pediatric Dentistry, Periodontics, Prosthodontics .
We look forward to the new edition of IDS 2019 in Cologne to evaluate together what new teledentistry systems are offered to us by the producers.

**References**
[1] http://www.htomaeduj.com/wp-content/uploads/2018/01/Prod_news_v5_1.pdf
[2] https://www.ada.org/en/publications/ada-dental-product-guide/product-category/product-profile?productid=1085&catid=27
[3] https://drquicklook.com/

**Florin - Eugen Constantinescu**
DMD, PhD Student
Editorial Director, Product News

**DOI: https://doi.org/10.25241/stomaeduj.2018.5(4).prodnews.1**

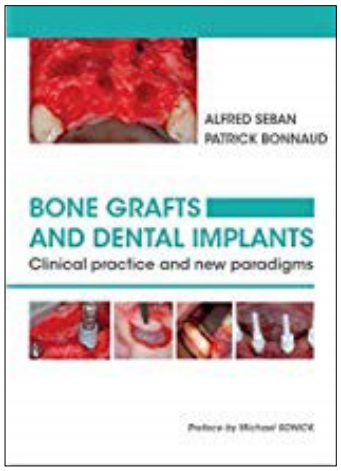
To comparatively analyse the two systems, we have compiled a table presenting the technical specifications of each.

| Item | DrQuickLook SD Plus Intraoral Camera | DrQuickLook PDA Tablet |
|---|---|---|
| Warranty | 1 Year | One Year Full Warranty and Remote Access Support |
| Weight | 23 oz. (652.04 g) | 1.37 lbs (621.42 g) |
| Light Source | LED | 6 LEDs |
| Resolution | up to 1024 x 768 pixels | up to 1024 x 768 pixels |
| Wireless | Viewer is wireless, camera wand connect to Viewer via 37" cord | Wi-Fi (802.11 a/b/g/n/ac), Bluetooth 4.0 |
| CPU Connection | Images saved to standard SD card for transfer to any computer | USB 2.0/3.0; Micro USB; Mini HDMI |
| Capture Card Needed | N/A | No |
| Docking Station Needed | N/A | No |
| Focus | Fixed Focus | Fixed Focus |
| Visual/Viewing Angle | 105° | 80° |
| Software | None needed | PDA Imaging App |
| Undistorted Extraoral / Wide Angle Available | Yes | |

# Bone Grafts and Dental Implants Clinical Practice and New Paradigms

**Marian-Vladimir Constantinescu**
DDS, PhD
Holistic Dental & Medical Institute of Bucharest - ROPOSTURO, Bucharest, Romania
e-mail:
dr.vladimir.constantinescu@gmail.com

Authors: Alfred Seban, Patrick Bonnaud
Publisher: Biotech Dental Group
Language: English
ISSN: 979-10-699-0887-1
Edition: 1/e
Publish Year: 2017
Pages: 431, illustrated
Price: 135.00€




Nowdays, implants and bone grafts are used more frequently in each dental clinic dental, because the jaws and alveolar processes suffer resorption after tooth loss. The book entitled „Bone Grafts and Dental Implants: Clinical Practice and New Paradigms" by Alfred Seban and Patrick Bonnaud presents the experience and research accumulated over the years regarding tbone regeneration .
This textbook has six chapters.
Chapter 1 talks about the influence of systemic diseases, technologies and contemporary practices for bone grafts and implants. The effectiveness of a specific treatment for dental implants in extraction sockets, bone augmentation following dental avulsion and bone quality assessment are presented in chapter 2.
The following chapter speaks about bone augmentation prior to the dental implant, the advantages and disadvanteges of graft materials, autologous bone grafts, corticocancelous allogenic bloc graft and operation technique (segmental osteotomy). Chapter 4 presents the maxillary sinus lift, the lateral and crestal approach, postoperative management and complication of the sinus lift. Chapter 5 approaches the clinical practice guidelines for bone grafting procedures prior to dental implant placement and describes 25 clinical cases.
The last chapter presents the preservation of biological width in implantology, while discussing one by one the concept of bone preservation, conical connection and biological width, narrow implants, short implants, full arch rehabilitation, immediate loading and biological width and immediate implant placement.
The authors succeed to present the most recent useful data in clinical practice as, graft materials, Bone Morphogenic Proteins, computer-guided implant placement, Cone Bean Computed Tomography for a complete approach of the practitioner. The book is an authentic guide to inform oral surgeons in bone graft and dental implants through various clinical cases illustrated with exceptional photos and radiographies associated with particular treatment protocols.

**DOI: https://doi.org 10.25241/stomaeduj.2018.5(4).bookreview.1**

*The Books Review is drafted in the reviewer's sole wording and illustrates his opinions.*

## 1. Submitting the Article

The journal publishes articles written in English. All articles will be accompanied by the signed copyright form which can be returned by e-mail, fax (as scanned documents). All the responsibility for the originality of the material sent belongs to the author(s) alone. Each article will be evaluated by the peer-review committee composed of two independent peer-reviewers, in a blinded fashion, according to the peer-review protocol. All articles will be sent to the editor-in-chief at the following e-mail address: stomatology.edu@gmail.com. The articles will also be sent at the e-mail address of the co-editors-in-chief from your area (Americas, Europe, Asia-Pacific).

## 2. Articles sent for publishing

Stomatology Edu Journal (Stoma Edu J) publishes:
- original articles;
- reviews;
- case reports;
- consensus declaration coming from an association or from a group of specialists;
- letters to the editor.

All articles must be up to 3,000 and 5,000 words for meta-analysis (the word count is for the manuscript text only). Letters to the editor must not exceed 400 words of text and have no more than 3 authors. Letters to the editor can be related to an article already published in the journal or it can represent original scientific contributions or events news/presentations etc. of interest for the reader. If, following the peer-review process, the article requires only minor changes (language changes etc.) then the manuscript is accepted for publication in its revised form without further input from the author. In case the changes are considered more important (scientific errors or an incorrect use of the language that can affect the quality of the scientific message) the author will be contacted by a member of the editorial committee and it will only be published after he approves the changes considered necessary by the peer reviewers. In some cases, based on the written approval of the author(s), the peer-reviewers and the chief-editor or the publisher the article may be published alongside the comments of the reviewer(s).

## 3. Authors

Each author must be able to prove his active participation in the study by contributing to the concept, protocol, data gathering or analysis, their interpretation or by critically revising the manuscript. Any other persons who have contributed to the paper, like study participants or colleagues, will be mentioned in the "Contribution" section.

## 4. Permissions and Ethics

For citations, tables, figures etc. which are not original, these must be accompanied by the written permission for their use and the full reference must be provided. Photographs of identifiable persons must be sent alongside the written permission of the person(s) and all regions that may allow the identification of the subject must be covered.

The author must have obtained, for all studies including human subjects, the permission of the subjects to be part of the study whilst keeping their anonymity. By sending the article, the author declares that he obtained this permission from all his subjects. All studies must respect the Helsinki Declaration (1975).

For human and animal studies, the authors must have obtained the approval of the ethics committee from the University/Institute/etc. where the study was done.

## 5. Writing the article

The article must be written in conformity with the general recommendations of the International Committee of Medical Journal Editors. http://www.icmje.org/icmje-recommendations.pdf

The Stomatology Edu Journal (Stoma Edu J) uses double-blind review, which means that both the reviewer and author name(s) are not allowed to be revealed to one another for a manuscript under review. The identities of the authors are concealed from the reviewers, and vice versa.

To facilitate this, please include the following separately:

**Title page** (with author details): This should include the title, authors' names and affiliations, and a complete address for the corresponding author including an e-mail address.

**Blinded manuscript** (no author details): The main body of the paper (including the references, figures, tables and any Acknowledgements) should not include any identifying information, such as the authors' names or affiliations.

The articles must be sent either as a Microsoft Word 2000 document (*.doc) or as a Microsoft Word 2003 document (*.docx).

The article will be written using Times New Roman font, size 12 for the characters with one and half (1 1/2) spaces between paragraphs. The manuscript must be sent in its final form. The pages will be numbered with the manuscript containing the following sections: title, authors, abstract, keywords, the text of article, contributions, acknowledgments, references, the figures and the tables legend.

Please also check the Author's Guidelines for the Abstract.

**A. The title of the manuscript** will have a maximum of 100 characters without spaces, written in title case, centered capitals, and in 12 point bold Times New Roman font at the top of page. Abbreviations should be avoided within the title.

**B. The author(s)** will send their full name(s) and surname(s), the highest academic position, their full titles and their affiliations. All names are listed together and separated by commas. Provide exact and correct author names as these will be indexed in official archives. Affiliations should be keyed to the author's name with superscript numbers and be listed as follows: Laboratory, Department, Institute, Organization, City, State abbreviation (USA, Canada, Australia), and Country (without detailed address information such as city zip codes or street names).

**The correspondent author** will send his/her full name and surname, the highest academic position, his/her full title, his/her affiliation, his/her institution address, his/her telephone, fax and e-mail. The authors will send this information in the same format as that in the published articles.

**C. The Structured Abstract**

The abstract can have a maximum of 250 words. After the abstract, the author(s) must mention a maximum of 5 keywords. Keywords must be selected from **Medline Mesh**.

The abstract for Original Scientific Articles should be no more than 250 words using the following structure: Introduction; Methodology; Results; Conclusion.

The abstract for Review Articles should be no more than 250 words with the authors covering all the following information regarding the subject presented under the following subheadings: Background, Objective, Data Sources, Study Selection, Data Extraction, Data Synthesis.

The abstract for Case Reports should be no more than 250 words using the following structure: Aim, Summary and Key learning points: provide up to 5 short statements of the report.

The abstract for Clinical Articles should be no more than 250 words using the following structure: Aim, Methodology, Results and Conclusions. Abbreviations are not accepted in the title or the abstract.

**D. The Article Text**

**Headings and Sub-headings**

Except for special names (e.g. GABAergic), capitalize only the first letter of headings and subheadings. Headings and subheadings need to be defined in Times New Roman, 12, bold. You may insert up to 5 heading levels into your manuscript (not more than for example: 3.2.2.1.2 Heading title).

For original articles:

Introduction - a presentation of the most important aspects in the studied domain without doing a review of the literature. The purpose of this part is to present and backup the hypothesis on which the study was based.

Material and Methods - this section will include all required information so that the reader can verify the validity of the study including, but not limited to, subjects, measurements, statistics and ethics. The methods used should be discussed (why the methods have been chosen, which the limitations/advantages). A paragraph about the statistical analysis is required as well.

Results - the results of the study will be presented in a descending order of importance. An interpretation of the results will not be done in this section.

Discussion - the authors will present the way the results backup the original hypothesis, as well as the way in which the results are backed up or contradicted by the published literature. A paragraph must be dedicated to presenting the limitations of the study.

Conclusion - The conclusion presents the implications of this latest work. In addition, authors may consider discussing future plans or recommendations for future research etc.

For all other types of articles we recommend the use of a clear structure based on sections and sub-sections.

**E. Acknowledgments**

Acknowledge persons who have made substantive contributions to the study. Specify grant or other financial support, citing the name of the supporting organization and grant number.

**F. References**

- The references will be written using the Vancouver style (https://www.imperial.ac.uk/media/imperial-college/administration-and-support-services/library/public/vancouver.pdf). All references that are identified with DOI (Digital Object Identifier) must be mentioned.
- For each reference use active links to the full text, free PMC article, PubMed, Google Scholar, and Scopus pages, were they exist, including the number of citations for the last two databases:

Singbartl G. Pre-operative autologous blood donation: clinical parameters and efficacy. Blood Transfus. 2011;9(1):10-18. doi:10.2450/2010.0088-10.
[Full text links] [Free PMC Article] [PubMed] Google Scholar(39) Scopus(23)

- The references will be numbered, in the order they appear in the text, in square brackets, as such: [3], [5,7-9].
- All sources found in the text must be present in the bibliography and all the papers mentioned in the bibliography must appear in the text. For references with more than 5 authors, list the first 3 authors followed by "et al."
- Full-page ranges should be given in expanded form (e.g., 426–429, not 426–9).
- If non-English-language titles are translated into English, bracketed indication of the original language should follow the title.
- All journals will be abbreviated and italicized names of journals according to the style in PubMed; refer to the National Library of Medicine (NLM) Journals Database (http://www.ncbi.nlm.nih.gov/nlmcatalog/journals) if needed. Journal names will be abbreviated according to the List of Title Word Abbreviations
- Information obtained from sources which are not published yet, but accepted for publishing will include at the end of the reference the mention "in print" between round parentheses.
- If the cited results have not been published yet the mention will be "personal communication" written in the text of article between round parentheses.
- Only references read by the authors of the article will be cited.
- An original article will have at most 50 references, a review will have at most 100 references, a letter to the editor 5 references, whilst all other types of articles will have the minimum number of references required.

## 6. Curriculum Vitae – Ultra Short version

Please provide a brief presentation of the first author and his contribution in the field, of maximum 130 words (with a 3.5x4.5 cm color photo).

## 7. Figures, Images, Tables

All illustrations must be numbered and cited in the text in order of appearance.

Figures and Images will be drawn professionally and sent in separate file(s) as jpeg, tiff or png files. Illustrations should preferably fill single column width (54 mm) after reduction, although in some cases 113 mm (double column) and 171 mm (full page) widths will be accepted. See the Image quality specifications chart for details. Image files also must be cropped as close to the actual image as possible.

In the text, each figure must be represented by a number, a title and a description. The authors will indicate where should the figure be placed in the text. All images or figures must come from the author's personal collection or the author must have rights to publish the image or figure. All images must be at or above intended display size, with the following image resolutions: Line Art 800 dpi, Combination (Line Art + Halftone) 600 dpi, Halftone 300 dpi. We do not accept images or figures taken from the Internet.

The Tooth Identification System used in manuscripts must conform to the FDI International System. Units used in manuscripts must conform to the Système Internationale d'Unités (SI).

Tables will be included in the text and each table will have a number and a short description if required.

## 8. Ownership Rights

By sending the article for publication the author(s):

- take full responsibility for the scientific content of the text and for the accuracy of the send data;
- become (co)author(s) of the manuscript (all further plagiarism accusation are addressed solely to the author(s) who signed the manuscript);
- declare they are the rightful owners of the images, figures and/or information sent for publishing and that they have the permission to publish all the materials for which they do not own the intellectual property rights;
- declare that the message/content of the manuscript is not influenced in anyway by commercial interests/ previous engagements/ any sort of relations with other people or companies;
- transfer all rights for the manuscript to the Editorial Council for the Stomatology Edu Journal.

## 9. Other

Previously mentioned limitations can be ignored in special cases with the agreement of the chief-editor and/or the publisher. All published materials cannot be returned.

Not taking into consideration the recommen-dations mentioned before can lead to delay in publishing the materials or may lead to not publishing the article.

# SUBSCRIPTION

## I want to subscribe to stomaedu

- 1 year Subscription (4 issues of the journal) – 280 RON (72 Euro for foreign subscribers)
- 2 years Subscription (8 issues of the journal) – 540 RON (136 Euro for foreign subscribers)
- Single Issue – 80 RON (20 Euro for foreign subscribers)

**Please send the filled subscription at the following e-mail: roposturo@gmail.com.**

**PLEASE COMPLETE ALL THE SUBSCRIPTION FIELDS IN CAPITAL LETTERS!**

Name..... Surname .....
Mrs. ☐ Mr. ☐ Ms. ☐
Home Address
City..... Sector..... District.....
Post office code..... Mobile phone.....
E-mail:..... Web.....
Student ☐ Resident ☐ Specialist doctor ☐ Primary doctor ☐
Competence.....
Institution.....
Activity domain: ☐ Private ☐ Public
Department..... Position.....
Specialty..... Institution address.....
City..... Sector..... District.....
Post office code..... Phone.....
E-mail:..... Web.....
CUI (Institution Unique Registration Code) .....
VAT Payer: ☐ Yes ☐ No
Invoice – please fill all the necessary details for invoice:
Name..... CNP (Personal Identification Number).....
Or
Institution ..... CUI (Institution Unique Registration Code).....

Date..... Signature.....

**After filling the subscription, please send it together with the proof of payment to:**


**ROMANIAN ACADEMY PUBLISHING HOUSE**
13, Calea 13 Septembrie, 5th District
RO-050711 Bucharest, Romania
Tel: +4021 318 81 46, 4021 318 81 06
Fax: +4021 318 24 44
e-mail: edacad@ear.ro
www.ear.ro

**S.C. MANPRES DISTRIBUTION S.R.L.**
1, Piaţa Presei Libere, Corp B
3rd floor, room 301-302, 1st District
RO-013701 Bucharest, Romania
Tel/Fax: +4021 314 63 39
e-mail: abonamente@manpres.ro
www.manpres.ro

New treatments
Old diseases

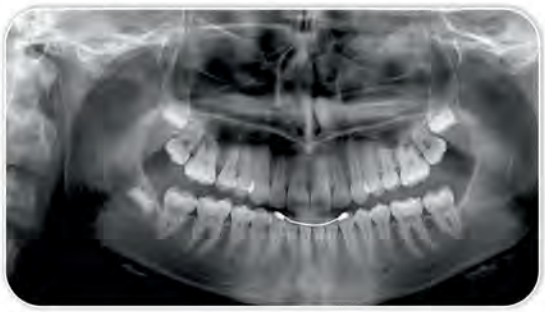
MEDICAL UNIVERSITY OF VIENNA INTERNATIONAL

**The Plevnei Gral Medical Dental Imaging Center** provides dental imaging services dedicated to obtaining a quick and correct dental diagnostic in order to plan an adequate and efficient treatement.

Our state-of-the-art equipment provides dentists, implantologists or maxillofacial surgeons with accurate 2D and 3D images of the structures they will work upon, being of real service to the patients, by practically eliminating all major intervention-associated risks, both due to the use of very low radiation doses and the easy and comfortable positioning of the patient.

**ORTHODONTIC X-RAYS (RADIOGRAPHS)**
Profile (lateral) cephalometric views
Standard OPG (Orthopantomogram) for adults and children (magnification 1.3-1.6)
Orthodontic diagnostic photos

**X-RAYS (RADIOGRAPHS) FOR SPECIAL TREATMENTS**
Standard OPG (Orthopantomogram) for adults and children (magnification 1.3-1.6)
Ortoradial orthopantogram for adults and children (magnification 1.3-1.6)
Orthopantogram with reduced for adults and children
Combination for the same patient
(standard OPG +orthoradial+ reduced shadow)
Four-view TMJ- right to left joint
Anterior maxillary sinus panoramic radiographs
Posterior maxillary sinus panoramic radiographs
Salivary gland panoramic radiographs
Prophile (lateral) cephalometric radiographs
Orthodontic diagnostic photos



**3D CT SCANS**
Full maxilla and mandible CT scan
Maxilla and maxillary sinus CT scan
Mandible and mandible
Mandible and mandibular canal CT scan
Partial maxillary and mandibular CT scan
TMJ CT scan
CT scan of included teeth

**MRI -CT**
Ortho-maxillofacial MRI
Ortho-maxillofacial CT

Examination of the throat using a special protocol for: cavum; oropharynx, oral cavity, tongue, soft palate, salivary glands, larynx and hypopharynx is conducted only at 79-91, Traian Popovici Street, 3rd District, RO-031422 Bucharest, ROMANIA
Tel: 021-323.00.00 | 0731-494.688

GRAL MEDICAL

**The Plevnei Gral Medical Dental Imaging Center**
17 - 21, Calea Plevnei, 1st District, RO - 10221 Bucharest, ROMANIA
Inside the "Dan Theodorescu" Surgery Hospital OMF
Tel: 021 - 313.41.81 | Mob: 0723 - 118.812

www.gralmedical.ro

Dentsply Sirona

Digital x-ray imaging

# Nothing to be afraid of

dentsplysirona.com