Working Group name: Digital restorative dentistry working group

I.   Group members:
  - leader: János Vág
  - PhD students: Dániel Borbola, Ákos Mikolicz
  - External collaborations:
    i.   Zsolt Nagy, Differental, Budapest, Magyarország
    ii. Walter Renne, Modern Optimized Dentistry Institute, Charleston, South Carolina, USA
    iii. Clinton D. Stevens, Downtown Tulsa Dental, Tulsa, Oklahoma, USA
    iv. Francesco Guido Mangano, Department of Pediatric, Preventive Dentistry and Orthodontics, Sechenov First Moscow State Medical University, Moscow, Russia
    v.   György Sersli, László Románszky, Artifex Dentis Kft., Budapest, Hungary

II. Brief description:
The main research area of the Digital Dentistry Working Group is to track the rapid development of digital technologies in dentistry, to investigate and estimate their accuracy and reliability through scientific methods.

The CAD-CAM (computer aided-design/manufacturing) workflow consists of three main parts, intraoral scanning, digital restorative design and the physical restoration itself. Our working group tests the accuracy of the sub-processes and the overall process using advanced digital engineering measurement techniques.

  - **Scanner reproducibility studies.** In our clinic we are testing the accuracy of newer and newer intraoral scanners. The scanners are compared to a high accuracy industrial optical scanner (Zeiss ATOS) or to other intraoral scanners. The accuracy of the intraoral scanners compared to conventional impression taking techniques (VPS impression or conventional plaster cast) and the reproducibility of different scanners compared to each other are investigated. As newer intraoral scanners appear on the market, we consider it important to investigate their accuracy and reproducibility.

- **Testing the accuracy of a digital jaw movement registration device (Modjaw device).** Accurate registration of jaw relationships and movements is essential for the digital design of dental prostheses in order to ensure that the prosthesis is biomechanically as correct as possible. In addition, it is also important to create the most accurate bite and jaw movement relationships to protect the temporomandibular joint. Our team is conducting various in vitro and vivo studies to explore the accuracy of this device.

- **By examining the complete chairside CAD-CAM process,** we have the possibility to scan and finish digital restorations accurately solely in the dental chair using Planmeca scanners and milling machines in the clinic. Chairside digital technology is based on three main pillars. The first pillar is the intraoral scanning itself, the second is the computer-aided design (CAD) and finally the manufacturing process (CAM) itself. At the end of this workflow, the final restoration is fixed. Since the accuracy of all three sub-processes plays a major role in the accuracy of the final restoration, we will examine each of these processes separately and then look at how they affect the accuracy of the overall workflow, giving an overall picture of the whole process.

- During the **investigation of the CAD-CAM process**, special attention is paid to the **accuracy of intraoral scanners**. In vitro full arch scans corresponding to clinical situations are performed to digitally create virtual prostheses by adjusting different cementation thicknesses and widths. These digital restorations are virtually mapped back onto the original dental arch scanned by the reference scanner using three-dimensional analysis software (Zeiss Inspect). This gives the accuracy of the marginal occlusion of the virtual prosthesis set at different cement widths and, indirectly, the accuracy of the intraoral scanner itself. With this method, it is possible to estimate the accuracy of the CAD process in a fully digital way (without the need for a physical restoration).

III. Awarded proposals:
- EFOP-3.6.3-VEKOP-16-2017-00009. János Vág, Zsolt Nagy. Support for a new PhD thesis: characterisation, significance and mapping of individual characteristics in the oral cavity using advanced digital methods. 2.340.000HUF
- Semmelweis University Dental Faculty Tender 2019: Zsolt Nagy, János Vág Investigation of the accuracy of intraoral scanning based on a new measurement methodology. 500.000HUF
- Semmelweis University Dental Faculty Tender 2020: Zsolt Nagy, János Vág Intraoral scanning of ceramic crowns produced by CADCAM system 500eFT
- Semmelweis University Dental Faculty Tender 2022: Ákos Mikolicz, János Vág, Klaudia Lipták, Laura Lipták, 500.000HUF
- Semmelweis University Dental Faculty Tender 2023: Investigation of the wind loosening of solo restorations fabricated with chairside CAD-CAM technology. Dániel Borbola, János Vág, 500.000HUF

IV.   Congress participation on the topic:

1.   Zsolt Nagy (Vág J). The role of intraoral scanning technique in 3D modelling based on a new measurement methodology. Semmelweis University, Faculty of Dentistry, Department of Conservative Dentistry. Research in oral cavity from basic science to clinical use. 2018. nov. EFOP-3.6.2.-16-2017-00006

2.   János Vág: Digital impression and design as the new form of magnification. Dental World 2018

3.   Zsolt Nagy, János Vág, Anthony Mennito, Walter Renne. Comparison of distortion of seven intraoral scanners caused by stitching mechanism. Digital Dentistry Society Global Conference, Baden Baden, Germany 2019.

4.   János Vág, Evelin Kövér, Ákos Mikolicz, Zsolt Nagy. Assessment of distortion caused by stitching during full arch intraoral scanning. Digital Dentistry Society Global Conference, Baden Baden, Germany 2019.

5.   János Vág: The science of intraoral scanning and its clinical relevance. Pécs, summer training for dentists 2019

6.   János Vág: Accuracy of intraoral scanners (IOS). Accuracy in Digital Dentistry: Where do we Stand? The Third Digital Dentistry Society Consensus Conference, Serralunga d'Alba, Italy, October 2nd-3rd 2020. Invited speaker and discussion panel leader

7.   János Vág: CADCAM The science of today's intraoral scanners and its clinical relevance. Digital imaging and odontotechnology in practice and Intraoral Scanner Show - organized by MERT, 2020, Budapest

8.   János Vág: The machine revolution in dentistry. Researchers' Night, online. 2020.

9.   Akos Mikolicz, Orsolya Gaspar, Botond Simon, Arvin Shahbazi, Janos Vag. Digital reproducibility of the palate utilizing intraoral scanners and its significance in human identification. Semmelweis Symposium 2022, Budapest

10.   Daniel Borbola, Janos Vag. Comparison of the accuracy of five dental laboratory scanners. Semmelweis Symposium 2022, Budapest

11.   Ákos Mikolicz: Chairside CAD/CAM restorations in everyday practice. Upgrade Congress, Budapest, 2023

12.   Dániel Borbola, János Vág: Comparison of the Accuracy of Two Intraoral Scanners by a Novel Method PhD Scientific Days, Semmelweis University. 2023

13.   Akos Mikolicz, Orsolya Gaspar, Botond Simon, Arvin Shahbazi, Janos Vag: Digital reproducibility of the palate utilizing intraoral scanners and its significance in human identification. IOFOS, Dubrovnik, 2023.

14.   Dániel Borbola, János Vág: Trueness of two intraoral scanners measured by a novel method. CED/NOF IADR, Rhodes, 2023.

15.   Dániel Borbola, János Vág: Trueness of intraoral scanners measured by a virtual fit method. Digital Dentistry Society Global Conference, Casablanca, 2023.

16.   Vág János: ...Because digital is much better. The limits of digital prosthetics today. Hungarian Society of Aesthetic and Restorative Dentistry Congress, Budapest, 2023.

17.   János Vág: Chairside CADCAM and digital prosthetics. Where are we now? ColgateTalks   Webinar,   2023.

V.   Publications:

[1] J. Vag, C. Stevens, M.H. Badahman, M. Ludlow, M. Sharp, C. Brenes, A. Mennito, W. Renne, Trueness and precision of complete arch dentate digital models produced by intraoral and desktop scanners: an ex-vivo study, J. Dent. (2023) 104764 DOI: 10.1016/j.jdent.2023.104764.

[2] J. Vag, L. Romanszky, G. Sersli, M. DeFee, W. Renne, F. Mangano, D. Borbola, Application of the virtual-fit method for fixed complete denture cases designed on intraoral scans: Effect of cement spacing, J. Dent. (2023) 104780 DOI: 10.1016/j.jdent.2023.104780.

[3] B. Simon, F.G. Mangano, A. Pal, I. Simon, D. Pellei, A. Shahbazi, J. Vag, Palatal asymmetry assessed by intraoral scans: effects of sex, orthodontic treatment, and twinning. A retrospective cohort study, BMC Oral Health 23(1) (2023) 305 DOI: 10.1186/s12903-023-02993-1.

[4] Z. Nagy, A. Mikolicz, J. Vag, In-vitro accuracy of a novel jaw-tracking technology, J. Dent. 138 (2023) 104730 DOI: 10.1016/j.jdent.2023.104730.

[5] A. Mikolicz, B. Simon, O. Gaspar, A. Shahbazi, J. Vag, Reproducibility of the digital palate in forensic investigations: a two-year retrospective cohort study on twins, J. Dent. 135 (2023) 104562 DOI: 10.1016/j.jdent.2023.104562.

[6] D. Borbola, G. Berkei, B. Simon, L. Romanszky, G. Sersli, M. DeFee, W. Renne, F. Mangano, J. Vag, In vitro comparison of five desktop scanners and an industrial scanner in the evaluation of an intraoral scanner accuracy, J. Dent. 129 (2023) 104391 DOI: 10.1016/j.jdent.2022.104391.

[7] J. Vag, G. Freedman, E. Szabo, L. Romanszky, G. Berkei, Cervical tooth anatomy considerations for prefabricated anatomic healing abutment design: A mathematical formulation, J. Prosthet. Dent. 127(6) (2022) 852-859 DOI: 10.1016/j.prosdent.2020.11.023.

[8] G. Revell, B. Simon, A. Mennito, Z.P. Evans, W. Renne, M. Ludlow, J. Vag, Evaluation of complete-arch implant scanning with 5 different intraoral scanners in terms of trueness and operator experience, J. Prosthet. Dent. 128(4) (2022) 632-638 DOI: 10.1016/j.prosdent.2021.01.013.

[9] J. Vag, W. Renne, G. Revell, M. Ludlow, A. Mennito, S.T. Teich, Z. Gutmacher, The effect of software updates on the trueness and precision of intraoral scanners, Quintessence Int. 52(7) (2021) 636-644 DOI: 10.3290/j.qi.b1098315.

[10] J. Vag, Z. Nagy, C. Bocklet, T. Kiss, A. Nagy, B. Simon, A. Mikolicz, W. Renne, Marginal and internal fit of full ceramic crowns milled using CADCAM systems on cadaver full arch scans, BMC Oral Health 20(1) (2020) 189 DOI: 10.1186/s12903-020-01181-9.

[11] B. Simon, L. Liptak, K. Liptak, A.D. Tarnoki, D.L. Tarnoki, D. Melicher, J. Vag, Application of intraoral scanner to identify monozygotic twins, BMC Oral Health 20(1) (2020) 268 DOI: 10.1186/s12903-020-01261-w.

[12] Z. Nagy, B. Simon, A. Mennito, Z. Evans, W. Renne, J. Vag, Comparing the trueness of seven intraoral scanners and a physical impression on dentate human maxilla by a novel method, BMC Oral Health 20(1) (2020) 97 DOI: 10.1186/s12903-020-01090-x.

[13] J. Vag, Z. Nagy, B. Simon, A. Mikolicz, E. Kover, A. Mennito, Z. Evans, W. Renne, A novel method for complex three-dimensional evaluation of intraoral scanner accuracy, Int. J. Comput. Dent. 22(3) (2019) 239-249