Adopting computer-assisted technologies in patient care – to be or not to be a prosthodontist of the future

Professor Asbjørn Jokstad
UiT The Arctic University of Norway

asbjorn.jokstad@uit.no
LOOKING WEST: Kvaløy island

THE ISLAND OF TROMSØ

LOOKING EAST: The Mainland

UoT43.7°N
Toronto, Canada

UoT69.7°N
Tromsø, Norway

2013

Tromsø, Norway
Innovations in digital technologies has influenced the career decisions of many.

Dentistry student
U. of Oslo
1974-1979

Military dentist
North Norway
1979-1982

Professor Jon Ørstavik
(1937-†2003)
One of the co-founders of EPA in 1977
Innovations in digital technologies has influenced the career decisions of many.

Dentistry student
U. of Oslo
1974-1979

Military dentist
North Norway
1979-1982

Computer Science, U. of Oslo
General biology graduate studies
Dental faculty, clinic instructor
1982-

NORSK DATA
1967 to 1992

• CERN Nuclear Accelerator Project
• International F-16 pilot training simulator program
• French aerospace agency
• ++…

ND-100 32-bit minicomputer

“The Norwegian version of the cell phone adventure”

Object-Oriented Programming - “O.O.P.-language”: SIMULA
(Today: Java, C++, etc.)
Innovations in digital technologies has influenced the career decisions of many.

Dentistry student
U. of Oslo
1974-1979

Military dentist
North Norway
1979-1982

Computer Science, U. of Oslo
General biology graduate studies
Dental faculty, clinic instructor
1982-1984
1984 -

University of Oslo
Faculty of Dentistry
Anatomy Department
~1980: Electron microscopy went digital
Innovations in digital technologies has influenced the career decisions of many.

- Dentistry student, U. of Oslo. 1974-1979
- Military dentist, North Norway. 1979-1982
- Oslo Dental Faculty, Anatomy Dept. SEM / TEM microscopy. 1984 -

Then: 8” → 5.25” → 3.5” floppy disks (250Kb→9Mb)

Today: USB sticks (Gb) / External harrddisk (Tb)
Innovations in digital technologies has influenced the career decisions of many.

Dentistry student, U. of Oslo 1974-1979

Military dentist, North Norway 1979-1982

Computer Science, U. of Oslo
General biology graduate studies
Dental faculty, clinic instructor 1982-1984
1984 -

Oslo Dental Faculty, Anatomy Dept.
SEM / TEM microscopy

Jeol 1200 EXII
Transmission Electron Microscope

Philips SEM 515
Scanning Electron Microscope

Computer-Network infrastructure
An early packet switching network (FTP)

Transmission Protocols: Kermit →
TCP + Internet Protocol (IP) →
TCP/IP 1983-01-01 →
WWW (Mosaic 1993)
An early packet switching network (FTP)

Transmission Protocols: Kermit →
TCP + Internet Protocol (IP) →
TCP/IP 1983-01-01 →
WWW (Mosaic 1993)

Norway - of all places!?
1969

1970

1971

1972

1973

Michael Caine as spy in the film "Billion Dollar Brain"
Dentistry student, U. of Oslo

Military dentist, North Norway

Computer Science, U. of Oslo
General biology graduate studies
Dental faculty, clinic instructor

1974-1979
1979-1982
1982-1984

Oslo Dental Faculty, Anatomy Dept.
SEM / TEM
Computer-Network infrastructure
&
Nordic Institute of Dental Materials

1984-

1985-
October 1985:

- The computer collapsed!
- All datafiles were corrupted and required tedious reconstruction!!
- All clinical data accumulated over 10 years since the inception of NIOM were in a disarray!!!(….backup routines are only for the cowards..)

**URGENT need for a computer geek with a dentistry background!!!**
Innovations in digital technologies has influenced the career decisions of many.

Dentistry student, U. of Oslo

Military dentist, North Norway

1974-1979

General biology graduate studies

1979-1982

Dental faculty, clinic instructor

1982-1984

Oslo Dental Faculty, Anatomy Dept.

1984-

SEM / TEM

1985-

Computer-Network infrastructure

Nordic Institute of Dental Materials

Clinical trials

Clinical studies program

Restorative materials

(Amalgam-)Toxicology
Thesis. 1986:
How will a restoration perform as a function of the qualities of the cavity prepared by the dentist?

Cavity designs for class II amalgam restorations
A literature review and a suggested system for evaluation

Asbjørn Jokstad and Ivar A. Mjör
Department of Anatomy, School of Dentistry, University of Oslo, and NIOM, Scandinavian Institute of Dental Materials, Oslo, Norway

A classification system for variations in cavity design and finish has been developed for application on models of teeth with class II cavities for amalgam restorations. The system was based on a review of the literature, on principles for clinical studies, and on examination of models of 623 teeth in which routine class II cavity preparations had been made. Preliminary data on the agreement of rating of evaluators indicated that the classification system can be used with good consistency for assessment of variations in cavity preparations. Longitudinal clinical studies on the performance of restorations will be decisive for the validity of the selected criteria and for a relevant differentiation between acceptable and unacceptable preparation features. [Conservative dentistry; failure of restorations; longevity of restorations; operative dentistry]

A. Jokstad & I. A. Mjör.

NOT FEASIBLE IN 1986
Stereo-photogrammetry
Computer Stereo Vision

Philips SEM 515 Scanning Electron Microscope
Restoration performance followed 10 years

Class 2 Cavity Preparations and Restoration Performance

Asbjørn Jokstad

The thesis

Submitted in partial fulfillment of the requirements for the degree of Doctor Odontologaie at the University of Oslo, 1992

COST-PROHIBITIVE IN 1992: Stereo-photogrammetry Computer stereo vision

Epoxy models – Qualitative appraisal & quantitative measurements of preparations + covariates

Bulk fracture

Secondary caries

Tooth fracture
Innovations in digital technologies has influenced the career decisions of many

Dentistry student
U. of Oslo
1974-1979

Military dentist
North Norway
1979-1982

Computer Science, U. of Oslo
General biology graduate studies
Dental faculty, clinic instructor
1982-1984

Oslo Dental Faculty, Anatomy Dept.
SEM / TEM
Computer / Network infrastructure
&
Nordic Institute of Dental Materials
Clinical trials
Restorative materials
(Amalgam-) Toxicology
1984-1992

Dept. Prosthodontics and
Stomatognathic Function
1995-

Prosthodontics Graduate Program
&
Private Practice

Professor
Jon Ørstavik
(1937-†2003)
EPA President, 1988-1989
EPA meeting organizer, Oslo, 1988
Digital Motion Capture System + ElectroMyoGraphy (EMG)

Meeting surplus 1988 EPA Oslo → Purchase of $$$ equipment

Professor Stig Karlsson
Interim Department Head
Digital Motion Capture System + ElectroMyoGraphy (EMG)

Meeting surplus 1988 EPA Oslo → Purchase of $$$ equipment

HOWEVER - The user complexity was too high!
Need for a computer geek with a background in prosthodontics!!!
Digital Motion Capture System + ElectroMyoGraphy (EMG)

2xIR cameras - 40Hz

Graphic controller
EMG

Analogue x-y & y-z video screens

Calibration frame for 3D recording

Fiducial markers (IR reflectors)

MacReflex software:
Triangulation of centre points (40 Hz)
MacIntosh computer
Chewing Movements in TMD Patients and a Control Group Before and After Use of a Stabilization Splint

Una Soboleva, DDS, MSc^a
Asbjørn Jokstad, LDS, Dr Odont^b
Thomas Eckersberg, LDS, MSc^c
Bjørn L. Dahl, LDS, Dr Odont^d

Purpose: This study assessed the effect of using an occlusal stabilization splint in the maxilla for 6 weeks on certain parameters of chewing movements in subjects with and without temporomandibular disorder symptoms. Materials and Methods: Twelve male and 30 female temporomandibular disorder patients with and without a prior whiplash incidence, and individuals without signs and symptoms of temporomandibular disorders participated. The participants formed three groups matched according to gender and age (n = 3 × 14). A maxillary stabilization splint was used during sleep for 6 weeks. An optoelectronic system (MacReflex, Qualisys) was used to record chewing movements at baseline, before using the splint, and after 6 weeks’ use of the splint. Calculated parameters were the duration of the chewing cycles, the spatial displacement, and the mean velocity of the mandible while chewing paraffin wax for 20 seconds. Results: On a group basis, the use of an occlusal stabilization splint for 6 weeks did not change the jaw movement parameters in a predictable pattern as recorded under the conditions of this study. On an intraindividual basis, large variations in changes of chewing parameters over time were observed. Conclusion: The use of an occlusal stabilization splint for 6 weeks did not alter the jaw movements when chewing a substance with a soft consistency. Int J Prosthodont 1998;11:158–164.
Digital Motion Capture Systems in the 90’ies

40 Hz

...a few years later...

200 Hz
Computer performance in 1996

The clock rate is the frequency of the clock in any synchronous circuit, such as a central processing unit (CPU).

Clock speed (MHz)

<table>
<thead>
<tr>
<th>Clock speed</th>
<th>Year</th>
<th>Processor/Operating System</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1</td>
<td>1971</td>
<td>Intel 4004 / Texas Instrument TMS100</td>
</tr>
<tr>
<td>1</td>
<td>1974</td>
<td>Motorola / Intel8008 / ZilogZ80 8bit.Cp/M (Commodore 64, Apple II)</td>
</tr>
<tr>
<td>4.77</td>
<td>1976/8</td>
<td>Intel 8086 16bit; (Compaq, IBM PC) / Intel 8088 (IBM (1981))</td>
</tr>
<tr>
<td>8</td>
<td>1978</td>
<td>Motorola 68000 (Macintosh128k, Amiga1000)</td>
</tr>
<tr>
<td>12 – 40</td>
<td>1985-90</td>
<td>Intel 80386 / 32bit; Motorola 68040 (Macintosh, Amiga, NeXT))</td>
</tr>
<tr>
<td>20 – 100</td>
<td>1989-94</td>
<td>Intel i486; Cyrix</td>
</tr>
<tr>
<td>110</td>
<td>1993-95</td>
<td>Intel Pentium / Pentium MMX → Pentium Pro</td>
</tr>
<tr>
<td></td>
<td>1994</td>
<td>IBM PowerPC 601 / Power Macintosh 8100</td>
</tr>
</tbody>
</table>

From: www.old-computers.com/museum
Computer performance in 1996 and innovations in digital technologies in dentistry

Clock speed (MHz)

<1  1971 Intel4004/ Texas Instrument TMS100

110  1994 IBM PowerPC 601 (Power Macintosh 8100)
Digital technology innovations~1996

- Virtual smile
- Digitized intraoral camera
- Chairside patient education / communication
- Digital radiography
Use of the Internet for educational applications in prosthodontics

Meade C. van Putten, Jr., DDS, MS
The Ohio State University, College of Dentistry, Columbus, Ohio

Internet is the common term for the information superhighway. The Internet has become a major information resource for educational, governmental, and business institutions. This article reviews the current operation of the Internet as a background for discussing educational opportunities for instruction in prosthodontics. Electronic mail, news groups, file transfer protocol, Gopher, and network navigators are discussed. The use of the World Wide Web for educational purposes by The Ohio State University College of Dentistry Department of Restorative and Prosthetic Dentistry is described. (J Prosthet Dent 1996;76:200-8.)

Health education institutions are undergoing significant changes in the delivery of information. One of the most notable technologic changes is the evolution of computerized network systems that allow storage and dissemination of information in a variety of multimedia formats. The Internet is undoubtedly the most significant of these systems. This powerful, universal network will have a significant impact on how health educators process and present information in the coming decades. As of August 1995, the Internet has provided worldwide access to information for more than 30 million users. This complex of networks forms the initial pathway for the global information revolution that currently provides a link for

Table I. Computer equipment and software requirements for Internet access

<table>
<thead>
<tr>
<th>Hardware</th>
<th>Software</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer (486, Pentium, Mac II, PowerPC.)</td>
<td>Windows, Windows 95, UNIX, MacOS 7.04</td>
</tr>
<tr>
<td>RAM 8 metabyes or greater</td>
<td>Navigator software (Mosaic, Netscape etc.)</td>
</tr>
<tr>
<td>Internet access device (Ethernet card or modem 14.4 bps or greater)</td>
<td>TCP/IP connection software (InterCon Syst Corp., Herndon, Va.)</td>
</tr>
<tr>
<td>Storage device (hard drive)</td>
<td>HTTP gateway software (MacHttp, Webstar)</td>
</tr>
</tbody>
</table>
Mikroprosessoren i tannklinikken

Jaw-registrering

Kamera

Video

Digitalisering

Røntgen

CT/MRI

Digital kamera/video

Modem/ISDN

Teletransmisjon

E-mail

Internet

Dataasst. diagnostikk

Skjerm

Printer

DAK-DAP

Asbjørn Jokstad
Oslo 1996
Computer performance today

Different benchmarking tests provide different performance indicator
Clock rate is no longer considered as a reliable benchmark since there are different instruction set architectures & different microarchitectures – “MIPS” is more common)

<table>
<thead>
<tr>
<th>Clock Rate</th>
<th>Year</th>
<th>Model Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1</td>
<td>1971</td>
<td>4 bit</td>
</tr>
<tr>
<td></td>
<td>1974</td>
<td>8 bit</td>
</tr>
<tr>
<td>4.77</td>
<td>1976</td>
<td>16 bit</td>
</tr>
<tr>
<td>12 – 40</td>
<td>1985</td>
<td>32 bit</td>
</tr>
<tr>
<td>20 – 100</td>
<td>1989-94</td>
<td>Pentium Pro</td>
</tr>
<tr>
<td>110</td>
<td>1994</td>
<td>IBM PowerPC 601 / Power Macintosh 8100</td>
</tr>
<tr>
<td></td>
<td>1997</td>
<td>IBM PowerPC 750 (iMac)</td>
</tr>
<tr>
<td>1400</td>
<td>2002</td>
<td>Intel Pentium III (Celeron/Zeon)</td>
</tr>
<tr>
<td>3000</td>
<td>2001</td>
<td>IBM PowerPC950 (PowerPC G5)</td>
</tr>
<tr>
<td>3800</td>
<td>2001</td>
<td>Intel Pentium 4 (Pentium M/D)</td>
</tr>
<tr>
<td>3000</td>
<td>2003</td>
<td>AMD Athlon 64bit</td>
</tr>
<tr>
<td>3200</td>
<td>2005</td>
<td>AMD Athlon 64bit X2</td>
</tr>
<tr>
<td></td>
<td>2013</td>
<td>IBM zEC12</td>
</tr>
</tbody>
</table>
Computer-assisted technologies in dentistry

Jaw/joint-tracking -> virtual articulator

Perio-probe

Voice input

T-Scan

Patient admin -> Big data

Patient education / communication / cosmetic simulation

Virtual patient student training

Screen

Printer

CAD-CAM

Surgery Guidance / Navigation

Medical device manufacturing
Subtractive (Milling)
Additive (3D print / Stereolithography)

3D Acquisition intraoral

3D Acquisition extraoral

Digital camera/video +/- expert-software (e.g. Velscope)

cbCT/MRI

Digitalization

Scanner

Video

Camera

Video

Digitalization

X-ray

Teledentistry
Diagnosis
Clinical decision support

Modem/ISDN

Tele-transmission
E-mail
Internet (www)

STL

DICOM

Screen

CAD-CAM

Microscope

Teledentistry
Diagnosis
Clinical decision support
Computer performance today

Moore’s* law: The number of transistors in a dense integrated circuit doubles approximately every two years (*Gordon Moore, co-founder of Intel)

1. New microchips are faster and have lower cost per performance unit

2. Innovative software programs that may harness the improvements in performance

→ Digital devices with better performance at a lower price

Digital Electron Microscopes life range

MOORE’S LAW RULES!
DEPRECIATION TIME DECREASES!
Moore’s law & digital tooth shade acquisition

- Chromacan (Sterngold)
- Castor (Nordmeditech)
- ShadeEye (Shofu) EX → NCC
- SpectraScan (PhotoResearch)
- DigitalShadeGuide DSG4 (A. Rieth)
- dcm-ikam (DigitalcolorMeasurement)
- ShadeScan (Cynovad)
- ClearMatch (Clarity → Smart Technology)
- ShadeScanSystem (CortexMachina)
- ShadeVision (X-rite) → Shade-Rite → Colortron II → Shade-X
- iKam (Metalor)
- Spectroshade (MHT) → SpectroshadeMicro
- EasyShade (VITA) → EasyshadeCompact → EasyshadeAdvance
- iDentacolor II (iDenta)
- ShadePilot (Degudent)
- CrystalEye (Olympus)
- BeyondInsight (BeyondDental)
- ShadeWave
- ZfX Shade (ZfX)

MOORE’S LAW RULES!

The diffusion of innovations

• People have different levels of readiness for adopting new innovations

• The characteristics of a product affect overall adoption

• Individuals can be classified into five groups*

*according to Everett Rogers (1962)
2008/2009:
Objective: Develop a protocol for digital impression of implants

Verification jig for checking accuracy intraorally

iTero impression

Returned: Polyurethane model – with no implant analogues!

Are the early adopters like the first mouse that try to eat the cheese in the trap? -1

2nd clinical check for intraoral fit

1st generation two-piece impression copings (PEEK) for digital impressions of Straumann Implants
Are the early adopters like the first mouse that try to eat the cheese in the trap? -2

In-vitro accuracy ≠ in-vivo accuracy
# Dynamic Navigation

## market 2017: 10 products

<table>
<thead>
<tr>
<th>Intro</th>
<th>Brand name</th>
<th>Company</th>
<th>FDA</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>Adens-NAVI</td>
<td>U&amp;I Adens Dental Clinic, Taiwan</td>
<td>-</td>
</tr>
<tr>
<td>2014</td>
<td>AQ Navi Surgical Navigation System</td>
<td>Taiwan Implant Technology Company, Taiwan</td>
<td>-</td>
</tr>
<tr>
<td>2016</td>
<td>DENACAM</td>
<td>Mininavident AG, Switzerland</td>
<td>-</td>
</tr>
<tr>
<td>2001</td>
<td>IGI-System (AKA DenX)</td>
<td>DenX Advanced Dental systems, Israel</td>
<td>Yes</td>
</tr>
<tr>
<td>2016</td>
<td>ImplaNav</td>
<td>BresMedical, Australia</td>
<td>-</td>
</tr>
<tr>
<td>2015</td>
<td>Inliant</td>
<td>Navigate Surgical Technologies Technologies, Canada</td>
<td>-</td>
</tr>
<tr>
<td>2015</td>
<td>IRIS-100 Implant Real-time Imaging System</td>
<td>EPED Incorporated, Taiwan</td>
<td>-</td>
</tr>
<tr>
<td>2014</td>
<td>Navident</td>
<td>ClaroNav Inc., Canada</td>
<td>Yes</td>
</tr>
<tr>
<td>2014</td>
<td>X-Guide Dynamic 3D Navigation</td>
<td>X-Nav Technologies, PA, USA</td>
<td>Yes</td>
</tr>
</tbody>
</table>

---

**MOORE’S LAW RULES!**
<table>
<thead>
<tr>
<th>Company Name</th>
<th>Location</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adens-NAVI U&amp;I</td>
<td>Taiwan</td>
<td>2014</td>
</tr>
<tr>
<td>AQ Navi Surgical Navigation System</td>
<td>Taiwan/Implant Technology Company, Taiwan</td>
<td>2016</td>
</tr>
<tr>
<td>DENACAM Mininavident AG</td>
<td>Switzerland</td>
<td>2001</td>
</tr>
<tr>
<td>IGI-System (AKA DenX)</td>
<td>Israel</td>
<td>2001</td>
</tr>
<tr>
<td>ImplaNav BresMedical</td>
<td>Australia</td>
<td>2015</td>
</tr>
<tr>
<td>Inliant Navigate Surgical Technologies</td>
<td>Canada</td>
<td>2015</td>
</tr>
<tr>
<td>IRIS-100 Implant Real-time Imaging System</td>
<td>Taiwan</td>
<td>2014</td>
</tr>
<tr>
<td>Navident ClaroNav Inc.</td>
<td>Canada</td>
<td>2014</td>
</tr>
<tr>
<td>X-Guide Dynamic 3D Navigation</td>
<td>PA, USA</td>
<td>2016</td>
</tr>
</tbody>
</table>

Launched Sep 19, 2017
Are the early adopters like the first mouse that try to eat the cheese in the trap? -3

Perforated PMMA stent on original stone model → Intraoral scan (iTero) → STL-file
+ Desktop scan (D810, 3Shape) of a cleaned FDP → STL-file

= STL-files compared by use of an industrial metrological software (Convince Premium, 3Shape)

New 3D technologies applied to assess the long-term clinical effects of misfit of the full jaw fixed prosthesis on dental implants

FDPs 12-32 years (mean 19 yrs)

History of screw issues
<table>
<thead>
<tr>
<th>Patient administration</th>
<th>Patient communication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electronic charting → “Big data”</td>
<td>Visualization of procedures</td>
</tr>
<tr>
<td></td>
<td>Virtual treatment outcome</td>
</tr>
<tr>
<td><strong>Education</strong></td>
<td></td>
</tr>
<tr>
<td>Student learning / assessment</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Patient management</strong></td>
<td><em><em>Medical device</em> production</em>*</td>
</tr>
<tr>
<td>Detect/diagnose pathology</td>
<td>Shade-matching</td>
</tr>
<tr>
<td>Radiography / tomography</td>
<td><strong>Designing “CAD”</strong></td>
</tr>
<tr>
<td>Jaw-/TMJ-joint-tracking → “virtual</td>
<td><strong>Manufacturing “CAM”</strong></td>
</tr>
<tr>
<td>articulator”</td>
<td>*Intra- / Extra- -oral / -tissue /-tooth or interface constituents</td>
</tr>
<tr>
<td>Decision support system (AKA expert</td>
<td>Tissue-engineering constructs</td>
</tr>
<tr>
<td>system)</td>
<td></td>
</tr>
<tr>
<td>Treatment (surgery) planning</td>
<td></td>
</tr>
<tr>
<td>Surgery guidance (dynamic /static)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Other applications</strong></td>
<td></td>
</tr>
<tr>
<td>Quality assurance “Registration”</td>
<td></td>
</tr>
<tr>
<td>Tele-dentistry</td>
<td></td>
</tr>
</tbody>
</table>
Innovations in CA additive / subtractive manufacturing methods ~1987

W. Mörmann / M. Brandestini
University of Zurich

CONCEPT:
Intraoral data acquisition by structured light
→ Point cloud (polygon mesh)
→ Surface reconstruction
→ Milled inlays/onlays from blocks of ceram

Product commercialized as:
CEREC by Siemens, Germany

First generation
CEREC from 1987
Innovations in CA additive / subtractive manufacturing methods ~1997

Cerec 2, Siemens→Sirona, Germany (1994)
Cicero, Elephant, Netherlands
DENStech, Dens, Germany
Decsy, Media Corp., Japan
Precident-DCS, DCS-Dental, Switzerland (1989)
Procera, Nobel Biocare, Sweden (1993)

“Closed systems”

“Milling centres”

Compact unit: Surface rendering + Design- & manufacturing-software + CNC-Milling (Al$_2$O$_3$ -ceramic)
Innovations in CA additive / subtractive manufacturing methods ~2007

DECIM system (cad-esthetics)(1997)
Cercon smart ceramics®(2001)
Cynovad Pro50 (1997)
Digident (1999)
KaVo Everest® (2002)
Lava® system (2002)
Procera Zirconia (2002)

“Intraoral scanner
CEREC 2003
(iTero 2007)
(Lava COS 2008)

“Open system (.stl)”
stand-alone scanners
BEGO (2002):
Etkon es1 (2000)
Innovations in CAD-CAM technologies

Fabrication process
- New methods
- New materials
- New designs

Restorative dentistry:
- Zirconia
- Hybrids
- Tissue-engineering
- Tissue constructs (stress vs seeding)

"Open systems"

Surface / volume rendering
- Merging of surface (.stl) and volumetric (DICOM*) data

Manufacturing software
- Designing software

Innovations in CA additive / subtractive manufacturing methods ~2017 and beyond

*Digital Imaging and Communications in Medicine
Innovations in CA additive / subtractive manufacturing methods ~2016 and beyond

Fabrication process

Innovations in CAD-CAM technologies

Surface / volume rendering
Technology Acquisition
Data export format(s)
Scan items

Manufacturing software
Designing software
<table>
<thead>
<tr>
<th>Technology</th>
<th>Acquisition</th>
<th>Scan Items</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Surface</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mechanical-electric +/- laser-adjusted</td>
<td>Intraoral</td>
<td>Antagonist</td>
</tr>
<tr>
<td>Optical-structural light</td>
<td>Extraoral</td>
<td>Bite registration</td>
</tr>
<tr>
<td>Optical-laser/video</td>
<td>Intra- &amp; Extraoral</td>
<td>Die</td>
</tr>
<tr>
<td>Optical-laser-triangulate/confocal</td>
<td></td>
<td>Full arch</td>
</tr>
<tr>
<td>Optical conoscopic holography</td>
<td></td>
<td>Implant Abutment</td>
</tr>
<tr>
<td><strong>Volumetric:</strong></td>
<td>Scan export format</td>
<td>Model</td>
</tr>
<tr>
<td>X-ray Tomography</td>
<td>“Open system” format</td>
<td>Prostheses</td>
</tr>
<tr>
<td>Magnetic res. Tomo.</td>
<td>Closed systems</td>
<td>Wax-up</td>
</tr>
<tr>
<td>Optical coher. Tomo.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ultrasound Tomo.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Apart from DICOM*, there are no ISO-standards specific to digital dentistry**

*Digital Imaging and Communications in Medicine*
Intraoral surface scanning – pre 2010

- **CEREC**
- **BlueCam**
- **LAVA COS** (2008)
- **Cadent Itero** (2006)
- **Laser Triangulation**
- **Confocal light**
- **Per 2010;**
  - **4 systems**
  - (+E4D)
- **Hint-Els** (2009)
Intraoral surface scanning

2010/2011: 4 new systems

CEREC
Bluecam
LAVA COS
Cadent Itero
Hint-ElS

REMEmBER MOORE’S LAW

Densys3D: MIA3d
Intellidenta/ Clõn3D: IODIS
MHT: Cyrtina/3DProgress
3Shape: TRIOS /(Dentaswiss)
Intra oral surface scanning

2012: 3 new systems

REMEMBER MOORE’S LAW

Zfx / Intrascans

Bluescan /a.tron3D

IOS: Fastscan
## Intraoral surface scanning

### 2017: 22 products+

<table>
<thead>
<tr>
<th>Product name</th>
<th>Manufacturer</th>
<th>Refs</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D Progress MHT</td>
<td>MHT (Medical High Technologies, Italy / Switzerland)</td>
<td>#</td>
</tr>
<tr>
<td>Aadva iOS ← Bluescan-I ← a.tron 3D</td>
<td>GC, Belgium ← 2016 a.tron 3D, Klagenfurt, Austria</td>
<td>0</td>
</tr>
<tr>
<td>Apollo DI</td>
<td>Sirona Dental Systems, Germany</td>
<td>#</td>
</tr>
<tr>
<td>CEREC OmniCam / BlueCam</td>
<td>Sirona Dental Systems, Germany</td>
<td>2</td>
</tr>
<tr>
<td>Condor</td>
<td>Condor International, Belgium</td>
<td>0</td>
</tr>
<tr>
<td>CS3500 / CS3600</td>
<td>Carestream Dental, USA</td>
<td>0</td>
</tr>
<tr>
<td>Dentium rainbow iOS</td>
<td>Dentium, Korea</td>
<td>0</td>
</tr>
<tr>
<td>Detection Eye</td>
<td>Zirkonzahn, Italy</td>
<td>0</td>
</tr>
<tr>
<td>directScan</td>
<td>Hint-Els, Germany</td>
<td>0</td>
</tr>
<tr>
<td>DWIO ← DigImprint Steinbichler</td>
<td>Dental Wings, Canada ← 2013 Steinbichler</td>
<td>#</td>
</tr>
<tr>
<td>IntraScan Zfx</td>
<td>zfx, Germany</td>
<td>0</td>
</tr>
<tr>
<td>i/s/canoral</td>
<td>Goldquadrat, Germany</td>
<td>0</td>
</tr>
<tr>
<td>IOS Fastscan</td>
<td>Glidewell Laboratories, USA ← 2015 IOS technologies, USA</td>
<td>0</td>
</tr>
<tr>
<td>Itero Element / Itero</td>
<td>Align Technology, USA ← 2011 Cadent, Israel</td>
<td>3</td>
</tr>
<tr>
<td>KaVo Lythos</td>
<td>KaVo, Germany ← 2015 Ormco Corp.</td>
<td>0</td>
</tr>
<tr>
<td>MIA3D</td>
<td>Densys, Israel</td>
<td>0</td>
</tr>
<tr>
<td>Organical Scan Oral</td>
<td>R+K CAD/CAM Technologie, Germany</td>
<td>0</td>
</tr>
<tr>
<td>PlanScan ← E4D</td>
<td>PlanMeca, Finland ← 2015 E4D Tech, USA</td>
<td>1</td>
</tr>
<tr>
<td>Progress IODIS</td>
<td>Clon 3D / IODIS / Intellidenta (USA?)</td>
<td>0</td>
</tr>
<tr>
<td>TRIOS 3 / TRIOS Color / Standard</td>
<td>3Shape, Denmark</td>
<td>3</td>
</tr>
<tr>
<td>True Definition Scanner ← Lava COS (Chairside Oral Scanner)</td>
<td>3M ESPE, USA ← 2006 Brontes Technology</td>
<td>4</td>
</tr>
</tbody>
</table>
Intraoral surface scanning 2017: 22 products+

<table>
<thead>
<tr>
<th>Product name</th>
<th>Manufacturer</th>
<th>Refs</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D Progress MHT</td>
<td>MHT (Medical High Technologies, Italy / Switzerland)</td>
<td>#</td>
</tr>
<tr>
<td>Aadva IOS ← Bluescan-I ← a.tron 3D</td>
<td>GC, Belgium ← 2016 a.tron 3D, Klagenfurt, Austria</td>
<td>0</td>
</tr>
<tr>
<td>Apollo DI</td>
<td>Sirona Dental Systems, Germany</td>
<td>#</td>
</tr>
<tr>
<td>CEREC OmniCam / BlueCam</td>
<td>Sirona Dental Systems, Germany</td>
<td>2</td>
</tr>
<tr>
<td>Condor</td>
<td>Condor International, Belgium</td>
<td>0</td>
</tr>
<tr>
<td>CS3500 / CS3600</td>
<td>Carestream Dental, USA</td>
<td>0</td>
</tr>
<tr>
<td>Dentium rainbow iOS</td>
<td>Dentium, Korea</td>
<td>0</td>
</tr>
<tr>
<td>Detection Eye</td>
<td>Zirkonzahn, Italy</td>
<td>0</td>
</tr>
<tr>
<td>directScan</td>
<td>Hint-Els, Germany</td>
<td>0</td>
</tr>
<tr>
<td>DWIO ← DigImprint Steinbichler</td>
<td>Dental Wings, Canada ← 2013 Steinbichler</td>
<td>#</td>
</tr>
<tr>
<td>IntraScan Zfx</td>
<td>zfx, Germany</td>
<td>0</td>
</tr>
<tr>
<td>i/s/canoral</td>
<td>Goldquadrat, Germany</td>
<td>0</td>
</tr>
<tr>
<td>IOS Fastscan</td>
<td>Glidewell Laboratories, USA ← 2015 IOS technologies, USA</td>
<td>0</td>
</tr>
<tr>
<td>Itero Element / Itero</td>
<td>Align Technology, USA ← 2011 Cadent, Israel</td>
<td>3</td>
</tr>
<tr>
<td>KaVo Lythos</td>
<td>KaVo, Germany ← 2015 Ormco Corp.</td>
<td>0</td>
</tr>
<tr>
<td>MIA3D</td>
<td>Densys, Israel</td>
<td>0</td>
</tr>
<tr>
<td>Organical Scan Oral</td>
<td>R+K CAD/CAM Technologie, Germany</td>
<td>0</td>
</tr>
<tr>
<td>PlanScan ← E4D</td>
<td>PlanMeca, Finland ← 2015 E4D Tech, USA</td>
<td>1</td>
</tr>
<tr>
<td>Progress IODIS</td>
<td>Clon 3D / IODIS / Intellidenta (USA?)</td>
<td>0</td>
</tr>
<tr>
<td>TRIOS 3 / TRIOS Color / Standard</td>
<td>3Shape, Denmark</td>
<td>3</td>
</tr>
<tr>
<td>True Definition Scanner ← Lava</td>
<td>3M ESPE, USA ← 2006 Brontes Technology</td>
<td>4</td>
</tr>
<tr>
<td>COS (Chairside Oral Scanner)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Innovations in CAD-CAM technologies

Fabrication process

Surface or volume rendering

Innovations in CA additive / subtractive manufacturing methods ~2016 and beyond

Manufacturing software
Data import/export formats / formatting
Manufacturing applications

Designing software
Data import/export formats / formatting
Designing applications
Open (data / file / system) formats- ("free files")

**STL (Standard Tessellation Language)**
- a format native to stereolithography
- widely used for rapid prototyping and CAM
- only surface geometry - no representation of color, texture or other common CAD model attributes
- describes a raw unstructured triangulated surface by the unit normal and vertices of triangles using a three-dimensional Cartesian coordinate system

**OBJ (Object files)**
- include surface texture/color - developed originally for 3D graphics animation applications

**AMF (Additive Manufacturing File)**
- describe color, materials, lattices, and constellations of objects for additive manufacturing processes (e.g., acellular scaffold manufacturing by printing)
Data / file / system formats

- **Skeletal volumetric**
  - Denture w/ markers volumetric

- **DICOM***

- **Implant planning**

- **Prosthesis design**

- **Static surgery guide design**

- **Dynamic surgery**

- **Intraoral surface scan**
  - .STL
  - .OBJ
  - .AMF

- **Object surface scan**
  - .STL
  - .OBJ
  - .AMF

- **Fabrication**
  - Data / file / system formats
    - *Digital Imaging and Communications in Medicine
Design / Manufacturing software - Parameters

Import & export format(s)
Open system (.stl, .obj, .amf)
CAD-CAM bundled (Closed)

Prosthodontic applications
Wax-up / temporary
Inlay / Onlay
Single-unit coping
Crown / monolithic crown
3 → 16 unit / (4 → 7 cm) FDP
Removable Dental Prosthesis
(Partial / Full)

Top 3 O.S. market leaders:
3shape
exocad
dental wings

Implant “customised” abutment
Implant-suport. meso-structure
Implant-suport. super-structure
Innovations in CAD-CAM technologies ~2016 and beyond

Fabrication process
Manufacturing
- Subtractive
- Additive
Device
- Prosthesis
- Tissue-engineering

Surface or volume rendering

Designing software

Manufacturing software
Fabrication process- parameters

Manufacturing
Subtractive
3 / 3.5 / 4 / 5 / 6-axes –milling --- +/- Sintering-furnace
Additive
Solid freeform fabrication, stereolithography, powder-fusion printing, bioprinting

Device
Prosthesis
• In-/Onlay/Veneer
• Single-unit coping
• Crown
• Monolithic Crown
• 3 →16unit(/4 →7cm)-FDP
• Implant abutment
• Implant bars / Meso-structure
• (Endosseous dental implant)
• Surgical guidance stent
• Partial / Full Removable Prosthesis
• Wax-up / Provisional / Splint

Tissue-engineering
• Scaffolds +/- cells
Milling in dentistry – From 3→5→5+5 axes

Milling machines have moved from manually operated to mechanically to digitally automated via computer numerical control (CNC) re. e.g., torques, feed-rate, nature of cutters, etc.
Software algorithm compensation for errors introduced during milling processes

• Geometrical compensation

• Force compensation

• Thermal compensation

• Errors in the final dimensions of the machined part are determined by the accuracy with which the commanded tool trajectory is followed, combined with any deflections of the tool, parts/fixture, or machine caused by the cutting forces.

• The effect of geometric errors in the machine structure is determined by the sophistication of the error compensation algorithms.

• The cutting tools’ trajectories are subject to performance of the axis drives and the quality of the control algorithms.
# Additive manufacturing technologies

Multiple ambiguous terms: 3D printing / Additive (freeform) fabrication / Layered manufacturing / Rapid prototyping /-manufacturing, etc.

<table>
<thead>
<tr>
<th>Tissue-engineering</th>
<th>Prosthodontics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anisotropic scaffolds</td>
<td>Extensive</td>
</tr>
<tr>
<td>Precision scaffolds</td>
<td>Semi-permanent</td>
</tr>
<tr>
<td>Rigid scaffolds</td>
<td>Experimental</td>
</tr>
<tr>
<td>Cellularized constructs</td>
<td>Soft-tissues</td>
</tr>
</tbody>
</table>

- Solid freeform fabrication (SFF)*
- Stereolithography (SLA)
- Powder-fusion printing (PFP)
- Bioprinting (Laser/Inkjet/Extrusion)

3D geometries physically constructed directly from 3D CAD.

**“Fused deposition modelling”, “Laminated object modelling”, “Direct Metal Printing”, “Selective laser sintering”, “Solid ground curing”, “Robocasting”**
CAM – subtractive manufacturing

Model fabrication & articulation

Model digitized (scan)

CA design

Mill Blank

Oven sinter

Separate & trim

Polish & prepare for veneer

Desktop size, e.g.
- Bien Air
- Carestream
- CEREC
- Degudent
- Flussfisch
- KaVo
- Kutaz
- Planmeca
- Robocam
- ZirkonZahn

Mid-size,
- CEREC
- Charlyrobot
- DentMaster
- Dental Plus
- Lycodent
- Roland Noritake
- Rübeling
- Sisma
- Upcera
- VHF
- Wieland
- Yena Dent

Heavy duty, e.g.
- Agie Charmilles
- Datron
- DMG
- iCM
- Isel
- Mikron
- Röders
- Röders
- Sisma
- Upcera
- VHF
- WilleminMacodel
- Wissner
- Witech

MOORE’S LAW RULES!
Additive manufacturing in prosthodontics

CA design – “virtual wax”

3D Print

Oven Sinter

Separate & trim

Polish & prepare for veneer

CA design

3D Print

Invest

Burnout

Cast

Laser melt / sinter powder

Separate & trim

Polish & prepare for veneer
Additive manufacturing in Tissue Engineering

Stereolithographic printing technique and exemplary tissue engineering scaffold composed of poly(d-l lactic acid)

Powder-fusion printing technique and exemplary tissue engineering scaffolds composed of calcium phosphate–poly(hydroxybutyrate-cohydroxyvalerate,

Solid freeform fabrication and exemplary tissue engineering scaffold composed of poly(ethylene glycol) diacrylate;, nanosilicates, and alginate

From: Sears ea. Tissue Engineering, 2015
Innovations in CAD-CAM technologies

Fabrication process
Subtractive
Additive

Materials
Prosthesis
Tissue-engineering

Manufacturing software
Designing software

Surface or volume rendering

Innovations in CA additive/subtractive manufacturing methods ~2016 and beyond
Manufacturing methods - parameters

**Additive fabrication**
- Laser sintering
- Printing

**Subtractive fabrication**
- 3 / 3.5 / 4 / 5 / 6-axes -milling
- with / without
- Sintering-furnace

**Device**
- In-/Onlays/Veneers
- Single-unit copings
- Crowns
- Monolithic Crowns
- 3 → 16unit(/4 → 7cm)-FDPs
- Implant abutments
- Implant bars / Meso-structures
- (Endossous dental implants)
- Surgical guidance stents
- Partial / Full Removable Prosthesis
- Wax-ups / Provisionals / Splints

**Materials - Restorative**
- Base alloys
- Gold alloys
- Non-precious alloys
- Titanium / - alloys
- Composite resins
- Casting Resins / Wax
- Polymers (PEEK, PMMA)

**Hi/low-glass content ceramics**
- Feldspathic
- Glass-ceramics, e.g., Li₂Si₂O₅
- In-Ceram (Porous Alumina)

**No glass content**
- Alumina (sintered)
- Zirconia (porous/green state)
- Zirconia (pre-sintered state)
- Zirconia (sintered)
- Zirconia (sintered & HIP-ed state)
Restorative materials for CAM

Photos: Song et al. (2013)
FPD substructure dimensions?

Photos: Mahmood et al. (2015)

Polymers
- High Temperature
- Lava Ultimate
- Cerasmart
- Shofu block-HC
- Light cured
- Paradigm
- MZ100
- VITA Enamic
- Polymer-infiltrated Ceramic Network (PICN)

Glassy Ceramics
- Feldspatic
- Mica
- Leucite
- Li-Ox
- Al/Zr-Infiltrate

Poly-crystalline
- Aluminium
- PSZ Ce Mg Yt
- 3Y-TZP Zirconia

Monolithic
- Veneer
Zirconia milling substrates are not all alike!

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Composition</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>TZP*</td>
<td>ZrO$_2$ / Y$_2$O$_3$</td>
<td>95 / 5</td>
</tr>
<tr>
<td>TZP-A</td>
<td>ZrO$_2$ / Y$_2$O$_3$ / Al$_2$O$_3$</td>
<td>~95 / ~5 / 0.25</td>
</tr>
<tr>
<td>FSZ</td>
<td>ZrO$_2$ / Y$_2$O$_3$</td>
<td>90 / 10</td>
</tr>
<tr>
<td>PSZ</td>
<td>ZrO$_2$ / MgO</td>
<td>96.5 / 3.5</td>
</tr>
<tr>
<td>ATZ</td>
<td>ZrO$_2$ / Al$_2$O$_3$ / Y$_2$O$_3$</td>
<td>76 / 20 / 4</td>
</tr>
<tr>
<td>Ce-TZP</td>
<td>ZrO$_2$+CeO$_2$</td>
<td>98</td>
</tr>
</tbody>
</table>

Great variations regarding:

- Hardness
- Fracture resistance
- Tension strength
- Elasticity module
- Sintering time
- Grain size
- Opacity
- Opacity

Who do you believe checks:

- Veneering ceramic compatibility?
- Optimal core-veneer layering thickness?

*TZP=(tetragonal zirconia polycrystals)
Zirconia milling substrates are not all alike!

3 point  4 point  biaxial
flexural strength test

Beware when comparing strength data

Fracture toughness may be a better predictor

* dry polishing before sintering or wet polishing after sintering

From: Schatz ea Materials 2016
FUTURE TRENDS IN PROSTHODONTICS?
Computer performance in the future

MOORE’S LAW RULES!

Digital devices will likely continue to be faster and with lower cost per performance unit; and innovative software programs will harness these improvements in performance.

The www of Internet will likely continue to be commercialized, driving other services to VPN-like solutions.

Moore’s law: the number of transistors in a dense integrated circuit doubles approximately every two years.
Digital motion capture systems to appraise and manage patients with oral dyskinesia

“MoCap”: is used extensively in films and cartoons; e.g., Avatar, Planet of the apes, etc.

1990’ies: 3 dim., 40 Hz

Today: Multi-dimensional \(ightarrow\) 4000Hz

Past: 2 dim.

but increasingly also in neuromedicine

"Technology for Assessment of Motor Disorders in Parkinson’s Disease: A Review"
The pace of technological developments compress the learning curve time for

- operating new devices for surface or volumetric rendering
- mastering CA designing software
- handling CA manufacture numerical control programs
- controlling new additive and subtractive manufacturing technologies
- optimal handling of new CAD-CAM-biomaterials

→ Brokers & “bundle package industries”
Patient

Dentist

Prosthesis designing

Biomaterial selection

Fabrication process

Dental Technician

😊
Patient

Dentist

«Broker»

Prosthesis designing

Biomaterial selection

Fabrication process
ESSENTIAL:
1. It is always a **responsibility of a doctor** to maintain the control of the choice of biomaterial and chain of fabrication method.
2. The choice of biomaterial and CAM method may not be compatible – time will tell.
3. Stay with a validated concept or upgrade your knowledge about properties of new material & new CAM methods.

Example, Customized abutments with CAM

Who decides whether the interface is in ceramic or metal? The clinician or the CAM owner?
Virtual patients – already feasible today

Planmeca  Cerec4.2(Sirona) 3dMDvultus

Conebeam Rx  √  √  √
Facial scan  √  √  √
<table>
<thead>
<tr>
<th>Product</th>
<th>Price</th>
<th>Mesh Quality</th>
<th>Texture Quality</th>
<th>Synthesis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Intel RealSense 3D</strong></td>
<td>$99</td>
<td>4/5</td>
<td>2/5</td>
<td>The mesh quality is really good. Dense and detailed.</td>
</tr>
<tr>
<td><strong>Shining 3D EinScan-Pro</strong></td>
<td>$3,999</td>
<td>4/5</td>
<td>4/5</td>
<td>High mesh quality, hair tends to degrade the performance.</td>
</tr>
<tr>
<td><strong>Fuel3D SCANIFY</strong></td>
<td>$1,500</td>
<td>3/5</td>
<td>5/5</td>
<td>The mesh is really good in the center, the cheeks have less details and are approximate.</td>
</tr>
<tr>
<td><strong>Artec Space Spider</strong></td>
<td>$27,600</td>
<td>5/5</td>
<td>5/5</td>
<td>Excellent mesh resolution and accuracy.</td>
</tr>
</tbody>
</table>

**Synthesis:**
- Intel: The 3D scans took a very long time to obtain. A decent result at an affordable price, however necessitates a lot of practice to get good results.
- Shining 3D EinScan-Pro: The scan process takes some time. The Einscan-pro is not specifically designed for face scanning but is a very versatile portable scanner.
- Fuel3D SCANIFY: Delivers an excellent performance. The capture is instantaneous and the user can even keep his eyes open. The marker is the only constraint.
- Artec Space Spider: A product made for metrology and reverse engineering but capable of producing amazing face 3D scans. Its price puts it in an entirely different category.

From: aniwaa.com

Intel on Amazon
Virtual patients – already feasible today

Planmeca  Cerec4.2(Sirona) 3dMDvultus

Conebeam Rx  √  √  √
Facial scan  √  √  √
Jaw tracking  √  √
CA jaw recording $\rightarrow$ (Virtual) articulator

- WinJaw (Zebris) JMA20
- ARCUSdigma II (KaVo)
- Axioquick Recorder (SAM)
- Myotronics
- Ultrasound
- Opto-electronic
- Cadiax
- Freecorder BlueFox (DDI-Group)
A virtual articulator may replace the mechanical in complex treatment cases.
Virtual patients – already feasible today

Planmeca | Cerec4.2(Sirona) | 3dMDvultus
---|---|---
Conebeam Rx | ✓ | ✓ | ✓
Facial scan | ✓ | ✓ | ✓
Jaw tracking | ✓ | ✓ | ✓
Smile design | ✓ | ✓ | ✓
Great visual impact by use of the state-of-the-art technology in 1996
Virtual smile designing in 2017 - an even more impressive visual impact

<table>
<thead>
<tr>
<th>Product name</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEREC Smile Design</td>
<td>Sirona, Germany</td>
</tr>
<tr>
<td>Digital Dentist</td>
<td>Digident, USA</td>
</tr>
<tr>
<td>Digital Smile Design</td>
<td>DSD, Spain</td>
</tr>
<tr>
<td>Digital Smile System</td>
<td>DSS, Italy</td>
</tr>
<tr>
<td>Envisionasmile</td>
<td>EnvisionASmile, USA</td>
</tr>
<tr>
<td>G Design / D Pack</td>
<td>HackDental, Romania</td>
</tr>
<tr>
<td>GPS Digital Smile Design</td>
<td>Dental GPS, Canada</td>
</tr>
<tr>
<td>Insignia Advanced Smile Design</td>
<td>Ormco, USA</td>
</tr>
<tr>
<td>Romexis Smile Design</td>
<td>Planmeca, Finland</td>
</tr>
<tr>
<td>Smile Composer</td>
<td>3Shape, Denmark</td>
</tr>
<tr>
<td>Smile Designer Pro</td>
<td>Tasty Tech, Canada</td>
</tr>
<tr>
<td>Smile-Vision System</td>
<td>Smile-Vision, USA</td>
</tr>
<tr>
<td>SNAP Instant Dental Imaging</td>
<td>SNAP Imaging Systems, USA</td>
</tr>
</tbody>
</table>
Thank you for your kind attention