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Adopting wisely innovative computer-assisted technologies in prosthodontic care

Asbjørn Jokstad

UiT The Arctic University of Norway

Disclaimer: I have no material interest in products, equipment, publications, or services from any mentioned commercial producers

Current state of computer-assisted dentistry

- **Novel digital technologies** continues to evolve rapidly
- Multiple advanced digital technologies for different purposes: e.g.,
  - **Customizing dento-orofacial devices**, **3D-** e.g., restorations (CEREC), orthodontic aligners (Invisalign), implant components, endo-/exo-grafts auto-/allo-/xeno-, tissue scaffolding.
  - **Communication** ("Smile-design"), **Diagnostics** ("TMJ-tracking"), **Treatment** interventions
- **Open file formats** enable **data exchange** between different **digital tracking and recording** devices, **CA design (CAD) softwares** and **CA manufacturing (CAM) devices**.
- New **additive and subtractive CAD-CAM technologies** that enables the use of **new injectable and machinable biomaterials**
- **<u>Challenges:</u>** Professionals need to **adapt and assimilate best technologies** and recognize their **strengths, limitations and benefits for all stakeholders**. Which criteria to apply among:

  1. the current spectrum of **latest technologies**
  2. the **novel biomaterials developed for CAM** - which remain largely untested clinically

- Have we **prepared wisely** to address the two challenges and adopted the best technologies?

World-Renowned Scholar Joins U of T's Faculty of Dentistry

2005

Left to right: David Naylor (President, University of Toronto), Asbjørn Jokstad, David Mock. Seated: Heliane Canepa

The long-standing relationship between the University of Toronto and Nobel Biocare has brought Professor Asbjørn Jokstad from the University of Oslo, Norway, to join U of T's Faculty of Dentistry as the Nobel Biocare Chair in Prosthodontics. The Chair, created in 2004 through a $2-million gift from the Swedish-based company, promotes significant contributions to prosthodontics scholarship.

The prestige associated with the Nobe Biocare Chair allowed the Faculty to attract interest from international scholars of the highest calibre to the position, resulting in Jokstad's recruitment. U of T is the only Canadi university with endowed chairs in dentistry, and the Faculty's three such positions attest to its pervasive commitment to research and teaching excellence.

"Dr. Jokstad is among the most highly regarded academic prosthodontists in the world," says Professor David Moc Dean of Dentistry. "He is devoted to improving the scientific basis for clini research and teaching in dentistry. His skill in evidence-based dentistry and applying electronic tools to dental education is a welcome addition to ou already world-class faculty."

Jokstad replaces the Chair's inaugural holder, retiring Professor George Zarb, North America's foremost expert in implant dentistry. Zarb's research and innovative teaching programs for Canadian dental faculty members initially brought Professor Per-Ingvar Brånemark, the founder of Nobel Biocare and inventor of modern dental implants, to work with U of T in the early 1980s.

"We need to partner with universities because we need the dental profession to tell us what patients need," says Heliane Canepa, president and CEO of Nobel Biocare. "We provide and the dental profession, as the experts, decides. Together we are strong!"

Prosthodontics Clinic & Research CHALLENGES:

- No focus on all-ceramic prosthetics
  No focus on CAD-CAM
  No digital intraoral / desktop scanners
- Sole implant manufacturer use over 25 yrs.
  Multiple rigid treatment dogmas
  No implant surgery planning software
  Very limited hard & softtissue grafting
- No established funding support

(1) IMPLEMENT NOVEL&DIVERSIFIED TREATMENT PRINCIPLES
(2) ACQUIRE «FAIL-FREE» DIGITAL TECHNOLOGIES &
(3) BREAK UP A BUSINESS PARTNERSHIP WITHOUT HURTING ANYONE'S FEELINGS UNINTENTIONALLY

Prioritized acquisitions:

2006

- Laptop computers for all residents
- Simplant v.6 (Surgical guidance) (Materialise)

2008

- MagnaVu & DVD (surgery operatory)
- iTero (IO impression) (Cadent)

2010

- D810 desktop scanner (3Shape →Diadem USA →Diadem Canada →Delivery 2011

2011

- Implant planning software for all residents
  - co-Diagnostics (Straumann)
  - Facilitate (Astra Tech)
  - NobelClinician / Procera (Nobel Biocare)
- Navident (dynamic implant surgery navigation prototypes (Claron) (project)

2012

- iTero Laboratory (planning software) (Align)
- 3Shape Convince (metrology / QC) (project)

ITI International Team for Implantology

Using intra oral scanning and CAD-CAM technology to create accurate and esthetic restorations

ITI Canadian Section Meeting, Montreal

May 7, 2011

EAO, København, 2012

Future perspectives of implant prosthetics

Asbjørn Jokstad
University of Toronto, Canada
& University of Tromsø, Norway

ITI Education Week,
Bloorview-Macmillan Hospital,
[illegible], Canada. Oct 28 2012

The benefits and caveats of using computer technologies in the fabrication process to make supra-constructions

Asbjørn Jokstad
University of Toronto, Canada

DOI 10.1002/cre2.56

WILEY Clinical and Experimental Dental Research

EDITORIALS

Dentists and new digital appliances - to buy or delay until the next model?

Three years after dental school graduation in 1979, I signed up for graduate studies in information technology at the University of Oslo. The impetus was the Norwegian success story variant of the Finnish "Nokia" cell phone chronicle: a company named "Norsk Data" who managed for a short while in the 80ies to dominate the global market for what was then termed "mini-computers". The studies didn't secure me a job in Norsk Data, but landed me instead at the Department of

semiconductors can be placed on an integrated electronic circuit every second year. The effect is a continuous increase of the capacity of microprocessors in terms of speed and memory and invariably also in better stability and lower price versus performance. The second is that innovative software programs will harness these improvements in performance. The net effect is that the product life cycle of a new digital product is worryingly unknown, but is in general short-lived.

[illegible]ence, manufacturers choose di[illegible]
[illegible]n their R&D investments as f[illegible]

Holland Bloorview ITI Education Week, 2013

ITI International Team for Implantology

CAD / CAM Technology for Implant Abutments, Crowns and Superstructures

Asbjørn Jokstad
University of Toronto, Canada
UiT The Arctic University of Norway

DOI: 10.1002/cre2.66

WILEY Clinical and Experimental Dental Research

EDITORIAL

Accuracy of digital appliances for use in [illegible]nics

The world's largest dental fair, the Internationale Dental-Schau (IDS) promoted as "The Greatest Dental Show on Earth" ended just a few days ago in Cologne. The claim is probably true since this year, there were 155.000 visitors over the 5 days that scrambled amongst the 2,305 exhibitors. As expected, the array of new equipment, tools, materials, and appliances on display was daunting. A conspicuous element was the presence of numerous digital hardware and software technologies. The consequences of digitalization to compress work

Imagine that you have obtained a permanent parking space for your car. Your spot is between two other cars in an area that is confined by concrete walls. Thirty centimeters has been allotted on each side of the cars for opening doors. Both your neighbors park their cars consistently on the same spot every time, meaning that their parking is "precise". A few occasional deviations from their spot occur, and these represent what are termed "random errors." Unfortunately, you are a bit annoyed because even if their parking is precise, the two cars are

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

EPA. 41st. Annual Conference,
Bucharest, Romania. 28 Sep 2017

Professor Asbjørn Jokstad
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[illegible]lium of Oral Rehabilitation (CORE) August, 2016

PEKING UNIVERSITY
SCHOOL OF STOMATOLOGY

Digital prosthodontics – limitations and future of current concepts

Professor Asbjørn Jokstad
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Tromsø, Norway

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International Dental Show (IDS) Cologne, Germany

INTERNATIONAL VISITORS

2019	
Total	160,095
Abroad	91,886
2017	
Total	155,132
Abroad	86,685

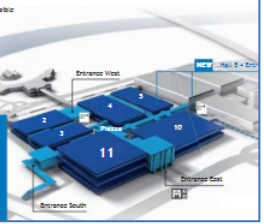
INTERNATIONAL EXHIBITORS

2019	
Total	2,328
Abroad	1,703
2017	
Total	2,305
Abroad	1,657

EXHIBITION FOCUSES

Number of exhibitors:	Domestic	Abroad	Total
Dental section	507	1,369	1,876
Dental technology section	333	817	1,150
Infection protection and maintenance	122	330	452
Services, information, communication and organisation systems and means	161	329	490

Multiple answers are possible



170,000 m²
of gross exhibition space
(2017: 163,000 m²))

Digital innovations for dental clinicians

What are the likely successful purchases today?

1. What should I acquire?
Why?

2. What should I not buy?
Why?

If you purchased a new digital technology in 2013

Good investments, e.g.,

- TRIOS IO scanner (3Shape)
- DWings EO scanner (DentalWings/Straumann)
- DentalCAD (Exocad)

Bad investments, e.g.,

- Densys3D IO scanner
- Clõn3D IO-scanner
- ShadePilot tooth-shade-matching
- IGI Surgical navigation system
- Expert Ease implant planning software
- DentCa CAM-dentures
- 3dMDVultus 3D facial scanning
- DWOS Smile Maker
- ++++

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- ++++
- 3M Lava Ultimate CAM crown (3M ESPE)

Even major companies make mistakes and may launch a bad product!

3M Lava Ultimate Dental Crowns Settlement—Updated

Settlement Structure: Claims Made

Active: Closed

Closed Settlement Statement:

According to court documents, the claim submission deadline has passed. Please contact the claims administrator if you have any questions.

Case Summary:
Update: The court has decided to extended the Supplemental Claim Period to December 8, 2020. Claims may now be filed for debonds fixed between May 10, 2019 and September 7, 2020. A new Supplemental Notice and Supplemental Claim Form will be distributed between September 7 and September 22, 2020. Note that the deadline for debond repairs that occurred earlier than this period has now passed. For details, see the Supplemental Notice at the settlement website.

Original Settlement Summary: 3M is paying $32.5 million to settle a class action brought against it by a group of dentists and dental practices. The complaint alleged that 3M's ESPE Lava Ultimate CAD/CAM Restorative blocks, when made into dental crowns, had a much higher rate of debonding than other crowns, due to the materials of the Lava Ultimate crowns.

Docket Number:
0:16-cv-01304

Company: 3M

Filing Deadline: December 8, 2020

Class Period: June 15, 2020

Considerations before purchasing a new digital technology

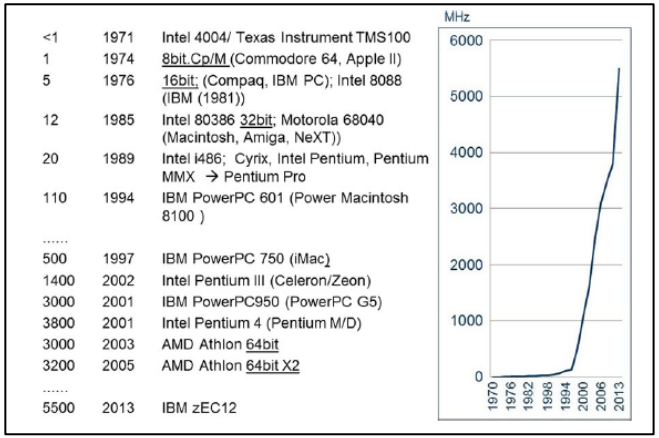
1. The existing scientific clinical documentation should be the major consideration

Journal of Oral Rehabilitation
doi: 10.1111/joor.12483
Journal of Oral Rehabilitation 2017 44; 261–290

Review

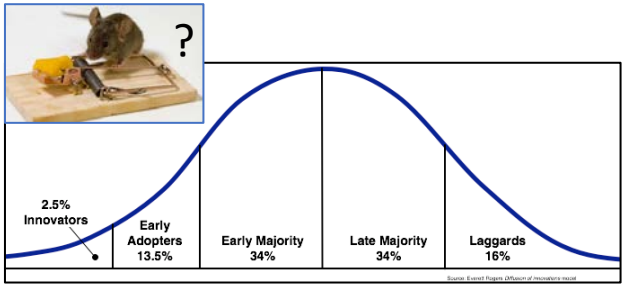
Computer-assisted technologies used in oral rehabilitation and the clinical documentation of alleged advantages – a systematic review

A. JOKSTAD *Department of Clinical Dentistry, UiT The Arctic University of Norway, Tromsø, Norway*



<1	1971	Intel 4004/ Texas Instrument TMS100
1	1974	8bit Cp/M (Commodore 64, Apple II)
5	1976	16bit; (Compaq, IBM PC); Intel 8088 (IBM (1981))
12	1985	Intel 80386 32bit; Motorola 68040 (Macintosh, Amiga, NeXT))
20	1989	Intel i486; Cyrix, Intel Pentium, Pentium MMX → Pentium Pro
110	1994	IBM PowerPC 601 (Power Macintosh 8100)
.....		
500	1997	IBM PowerPC 750 (iMac)
1400	2002	Intel Pentium III (Celeron/Zeon)
3000	2001	IBM PowerPC950 (PowerPC G5)
3800	2001	Intel Pentium 4 (Pentium M/D)
3000	2003	AMD Athlon 64bit
3200	2005	AMD Athlon 64bit X2
.....		
5500	2013	IBM zEC12

Fig. 1. The clock rate of the central processing unit in select computers. Clock rate is the frequency of the clock in any synchronous circuit.

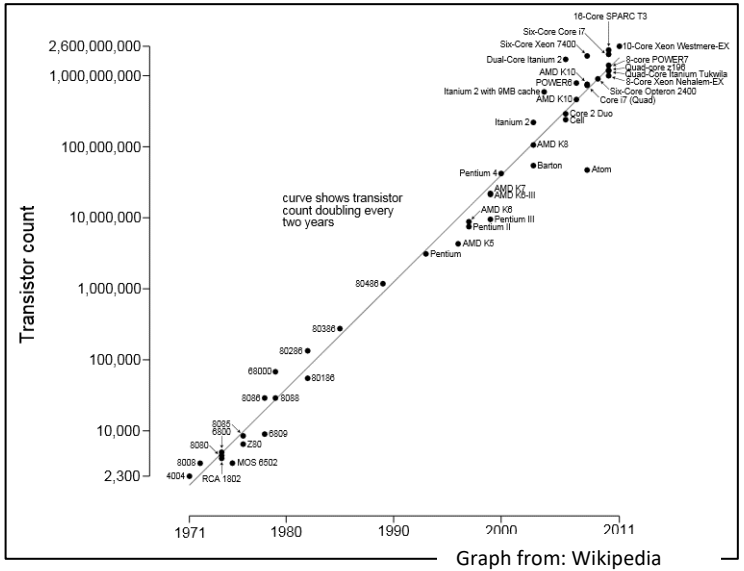


5 categories of people with different levels of readiness for adopting new innovations (acc. to Everett Rogers (1962))

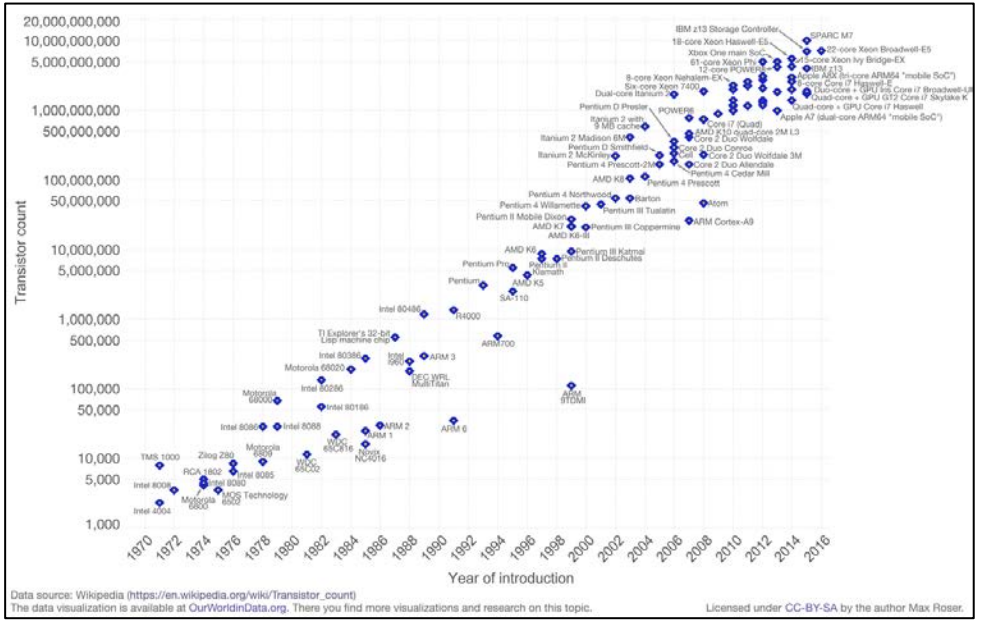
Considerations before purchasing a new digital technology

Moore's law: the number of transistors on integrated circuit chips doubles ~two years

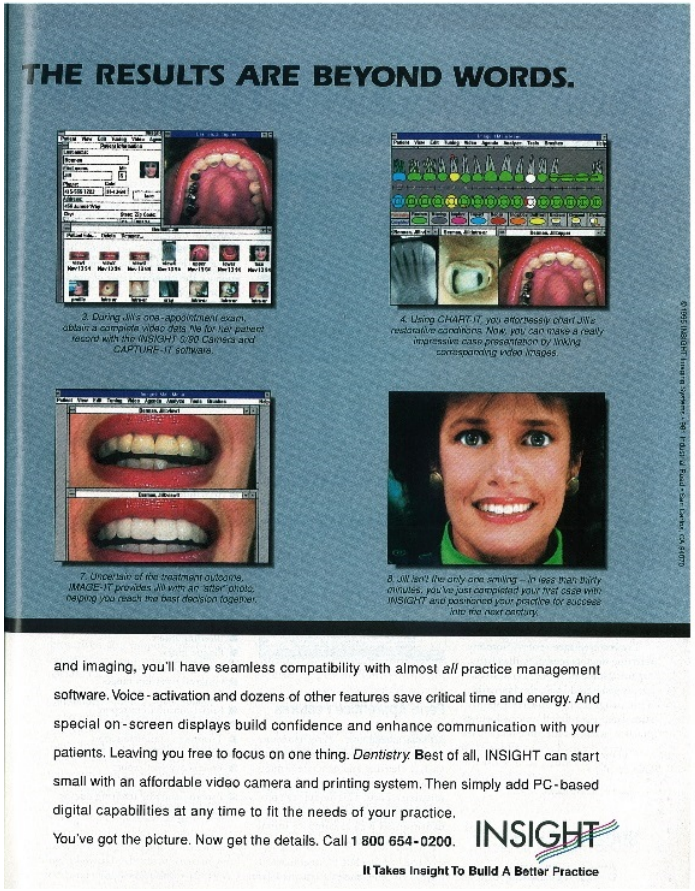
1. Computers will continue to be **faster and with lower cost** per performance unit.
2. **Innovative software algorithms** will harness these improvements in performance.



Graph from: Wikipedia

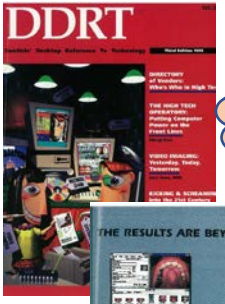


Moore's law → Amazing display / demonstration on standard computers

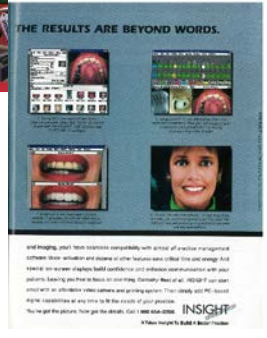


WOW!
…1996
STATE-OF-THE-ART

Moore's law → Amazing display / demonstration on computer screens

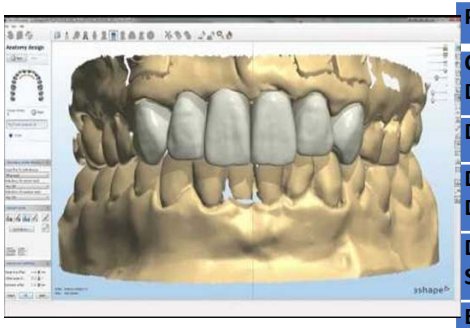


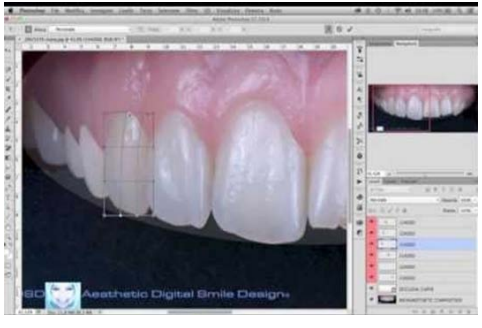
WOW!
…1996
STATE-OF-THE-ART

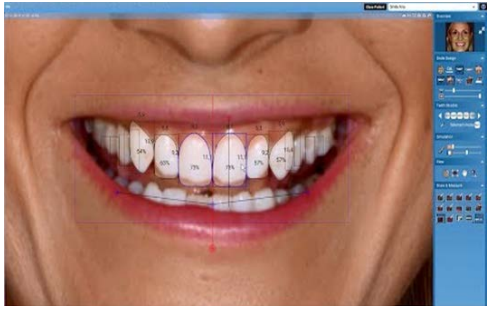


WOW!
…2021

Youtube videos







Product	Manufacturer
CEREC Smile Design	Sirona, Germany
Digital Dentist	Digident, USA
Digital Smile Design	DSD, Spain
Digital Smile System	DSS, Italy
Envisionasmile	EnvisionASmile, USA
G Design / D Pack	HackDental, Rumania
GPS Digital Smile Design	Dental GPS, Canada
Insignia Advanced Smile Design	Ormco, USA
Romexis Smile Design	Planmeca, Finland
Smile Composer	3Shape, Denmark
Smile Designer Pro	Tasty Tech, Canada
Smile-Vision System	Smile-Vision, USA
SNAP Instant Dental Imaging	SNAP Imaging Systems, USA

Moore's law → Short depreciation time & decreased cost recovery period















Chromacan (Sterngold)

Castor (Nordmeditech)

ShadeEye (Shofu) EX →NCC

Dental Color Analyzer(Wolf)

SpectraScan (PhotoResearch)

DigitalShadeGuide DSG4(A.Rieth)

dcm-ikam (DigitalcolorMeasurement)

ShadeScan(Cynovad)

ClearMatch(Clarity→Smart Technology)

ShadeScanSystem(CortexMachia

ShadeVision (X-rite)→Shade-Rite→Colortron II→Shade-X

iKam(Metalor)

Spectroshade(MHT) → SpectroshadeMicro

EasyShade(VITA)→ …Compact→…Advance → …Advance 4.0

iDen ShadePilot(Degudent)

CrystalEye(Olympus)

BeyondInsight(BeyondDental)

ZfX Shade(ZfX)

3Shape Trios

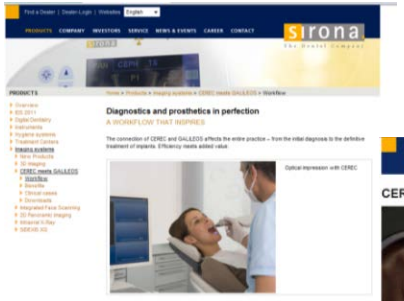
Terminated products

Existing products

1990 1995 2000 2005 2010 2015 2020

MOORE'S LAW APPLIED TO:

Intraoral scanning devices ~2010



CEREC (Switzerland) (1990/1996/2000/2004)

Per 2010: 4 products (+E4D for intracoronal restorations)

Technology

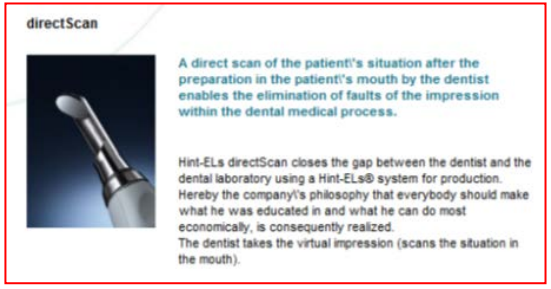
Laser Triangulation

Confocal light

LAVA COS (USA) (2004/2008)

Closed file formats

Open file format



Hint-Els (Germany) (2008)

Cadent iTero (Israel) (2006)

MOORE'S LAW APPLIED TO:

Intraoral scanning devices

4 new products/ manufacturer

CEREC Bluecam

LAVA COS

Cadent Itero

Hint-Els

Densys3D: MIA3d (Israel)

Intellidenta/ Clõn3D: IODIS (USA)

MHT: Cyrtina/ 3DProgress (Italy)

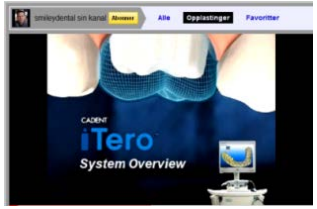
3Shape: TRIOS / (Dentaswiss) (Denmark)

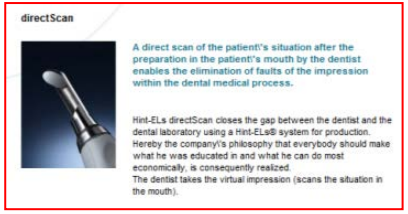
MOORE'S LAW APPLIED TO:

Intraoral scanning devices

IDS 2015

3 new products





Zfks / Intrascan (Germany)

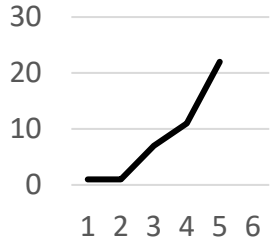
Bluescan /a.tron3D (Austria)

IOS: Fastscan USA

Intraoral scanning devices

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

2020: ≥22 products



MOORE'S LAW RULES!

YET – technology still at its infancy?

- Movement (saliva flow)
- Direct vision required
- Full jaw (voxel size vs algorithm)

Future technologies combined with a tomography technology?

Same content but different labels

MOORE'S LAW APPLIED TO:

Dynamic navigation dental implant surgery

1. Computer capacity is important
   but at least important is:
   SMARTEST SOFTWARE ALGORITHM

"VISIT" System
Vienna, Austria

Photo: Wanschitz ea
Clin Oral Implants Res 2002

MOORE'S LAW APPLIED TO:

Dynamic navigation dental implant surgery

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

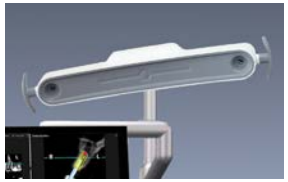
Yet - another technology still at its infancy?

MOORE'S LAW APPLIED TO:

Optoelectronic technology – Infra-red light

Active diode

IGI-System (2001)

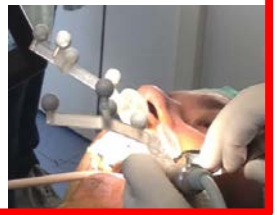


OLD technology
Algorithms maybe new

Introduced	Device
2017	Adens-NAVI
2014	AQ Navi Surgical Navigation System
2016	DENACAM
2001	IGI-System (AKA DenX)
2016	ImplaNav
2015	Inliant
2015	IRIS-100 Implant Real-time Imaging System
2014	Navident
2014	X-Guide Dynamic 3D Navigation

Passive reflectors

- AQ Navi (2014)
- IRIS-100 (2015)
- ImplaNav (2016)



Yet - another technology still at its infancy?

Direct line-of-vision required
Interruption effects?

MOORE'S LAW APPLIED TO:

Optoelectronic technology– optical light

Yet - another technology still at its infancy?

NEW technology
Algorithms new

Blue light

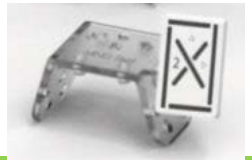
X-Nav (2014)

Polychromatic light

Navident (2014)

Inliant (2015)

DENACAM (2016)



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2014	Navident
2014	X-Guide Dynamic 3D Navigation

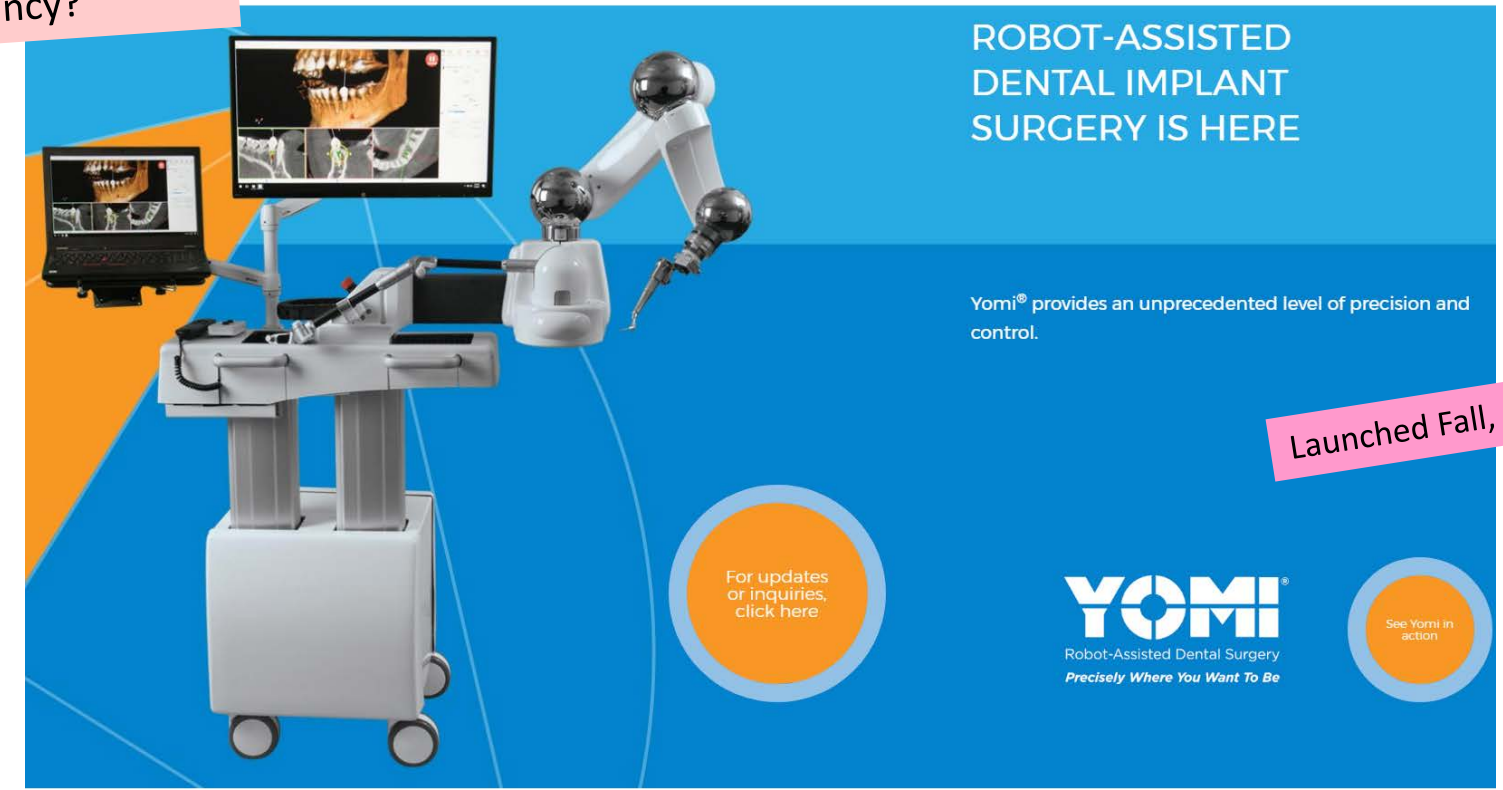
Direct line-of-vision required
Interruption effects?

MOORE'S LAW APPLIED TO:

Dynamic navigation dental implant surgery

Mechanical - haptic

Yet - another technology still at its infancy?



Considerations before purchasing a digital technology

1. The existing scientific clinical documentation should be the major consideration

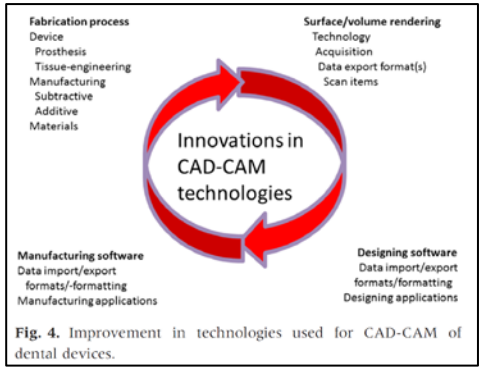


Fig. 4. Improvement in technologies used for CAD-CAM of dental devices.

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Review

Computer-assisted technologies used in oral rehabilitation and the clinical documentation of alleged advantages – a systematic review

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Per Nov. 2016

- 225 commercial digital products for use in oral rehabilitation
- ~⅓ of the products described in ~350 scientific articles reporting from clinical human studies

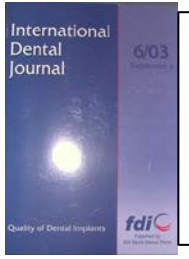
Fig. 6. Milling machines described in advertisements for dental professionals or described in the dental research literature. Desktop size machines can mill softer types of materials, while heavy machines can mill everything. Software algorithms are required for materials that are milled in a pre-sintered state and subsequently undergo shrinkage upon sintering.

Considerations before purchasing a digital technology

1. The existing scientific clinical documentation should be the major consideration

Given that several technologies seem comparable, other factors should be considered:

- Is the manufacturer represented locally and can be consulted easily?
- Can the manufacturer deliver required components timely and reliably in extraordinary situations?
- Is the manufacturer's ethical reputation persuasive and their promotion exact, fair and comprehensive?
- Does the manufacturer provide service and training possibilities?
- Ease of use. Are the training requirements for using the digital technology intricate?
- Is the technology flexible to apply for a wide selection of alternative uses?
- Hardware stock inventory. Is it necessary to acquire an extensive supply of components to meet different clinical treatment situations and thereby induce high inventory costs?
- Hardware engineering design. Since mechanical defects will occur sooner or later, are elaborate and/or time-consuming tasks required to adjust or repair?
- Costs. The cost of the technology, the cost per usage / data export, costs per component, and the course/training costs.
- The accumulated time required for chair-side adjustments and complications management needs to be considered, since such situations involves concerns such as patient trust and opportunity costs



Comparable to considerations for implant produtcs & manufacturers. (Jokstad et al. Int Dent J 2003

Thank you for your kind attention

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