Robotic Prosthodontics

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Whom do you prefer as your Dentist?

Older?

Younger?

Whom do you prefer as your Dentist?

Older

- Experienced
- Knowledgeable

But

- Possibly medically compromised (sight)
- Tired

Whom do you prefer as your Dentist?

Younger

- Limited experience
- Limited knowledge

But

- Perfect health incl. sight
- Sexy…sometimes…☺

Ideal

Me… (Middle age)

- Enough experience
- Relatively good health (sight is already compromised)
- Definitively sexy! ☺

But,

- Number of possible dentists is very limited due to age interval which is 35-50? 55?

I prefer robots.

- Works 24/7/365
- Sight multiple times better than human
- No unintentional movements
- Expensive for purchase but less costly over a longer time period
- I would choose him as a potential employee

Why are humans insufficient?

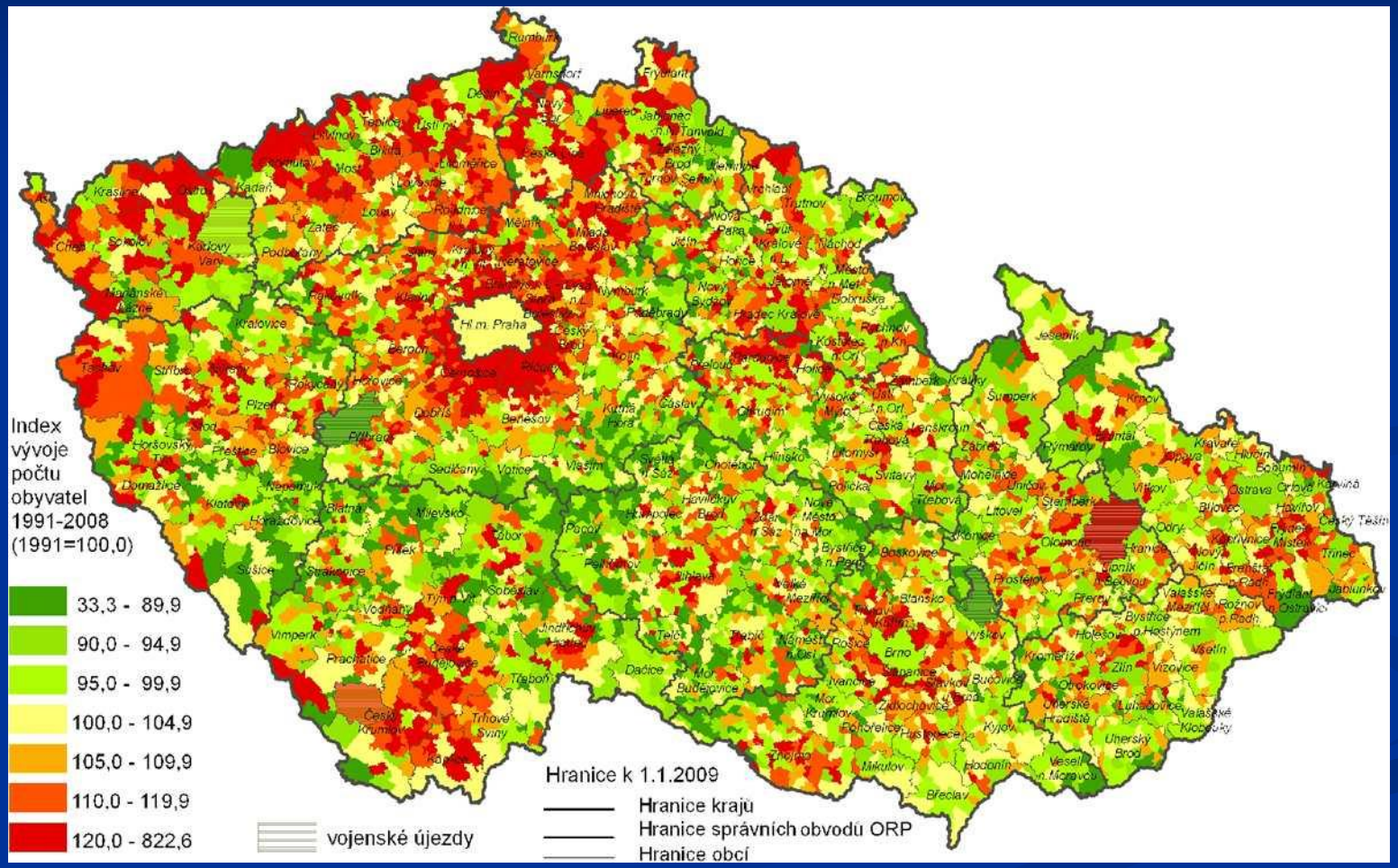
Human

- Reaction time 0.1 s
- Max. precision 0.1 mm
- Good in qualitative tasks
- Bad in repetitive and boring tasks

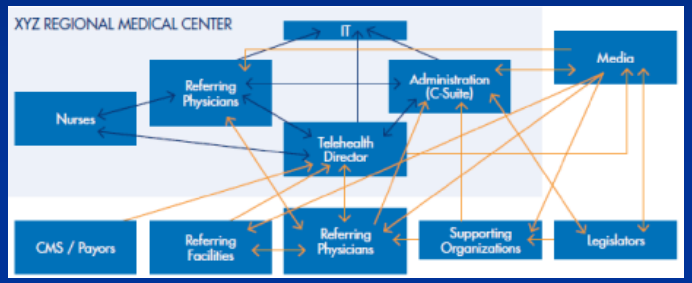
Robot

- Reaction time under 1 ms (some femtoseconds)
- Max. precision under 1um
- Excellent in quantitative tasks
- Excellent in repetitive and boring tasks

People redistribution Czech Republic



Live where you want to live!



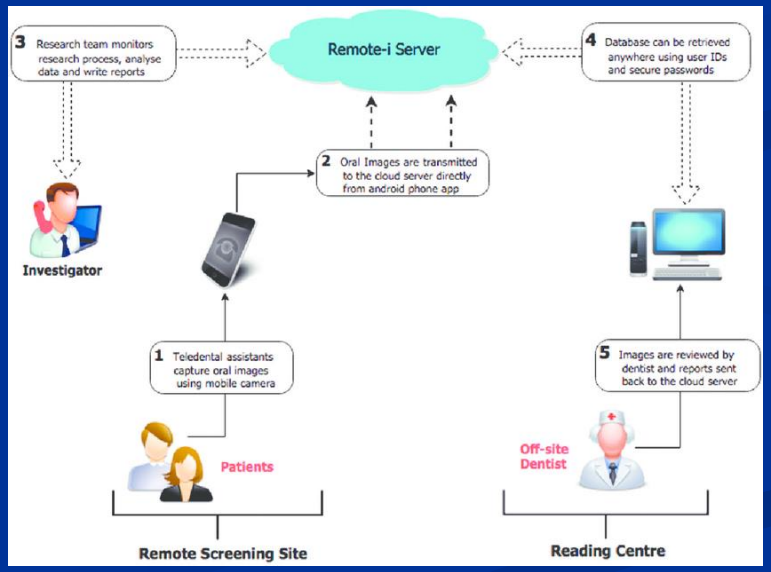
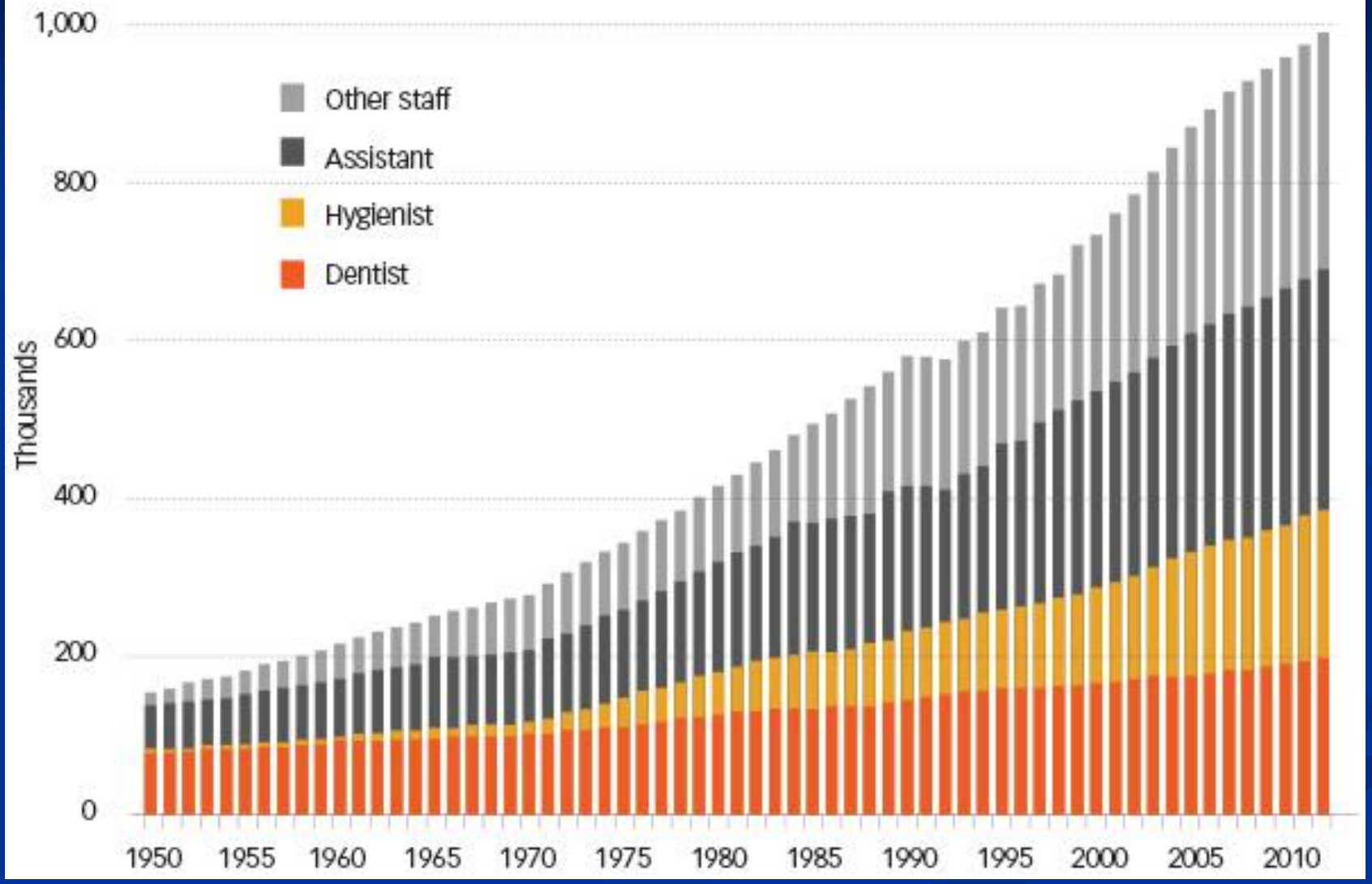
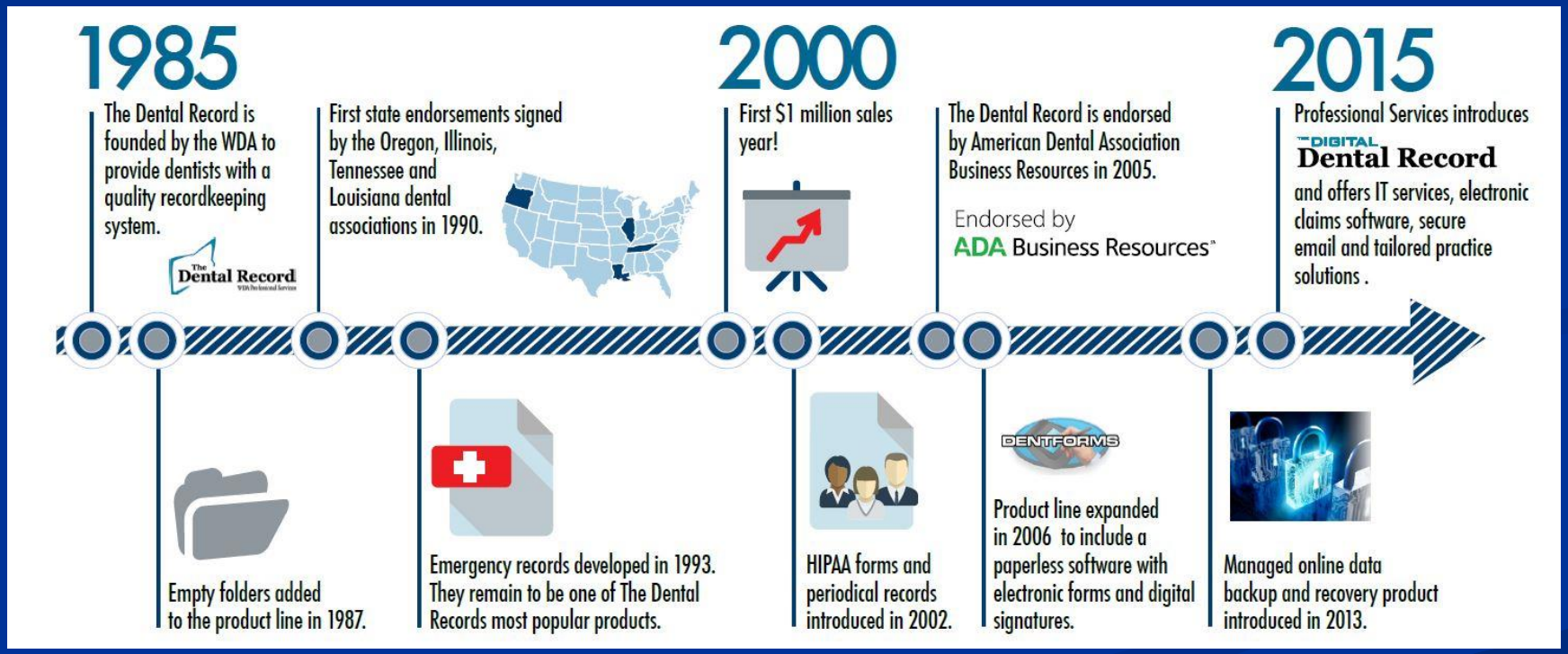


FIGURE 1—Dental personnel in the labor force[1]



Teledentistry- more than just medical records



Teledentistry

Teledentistry

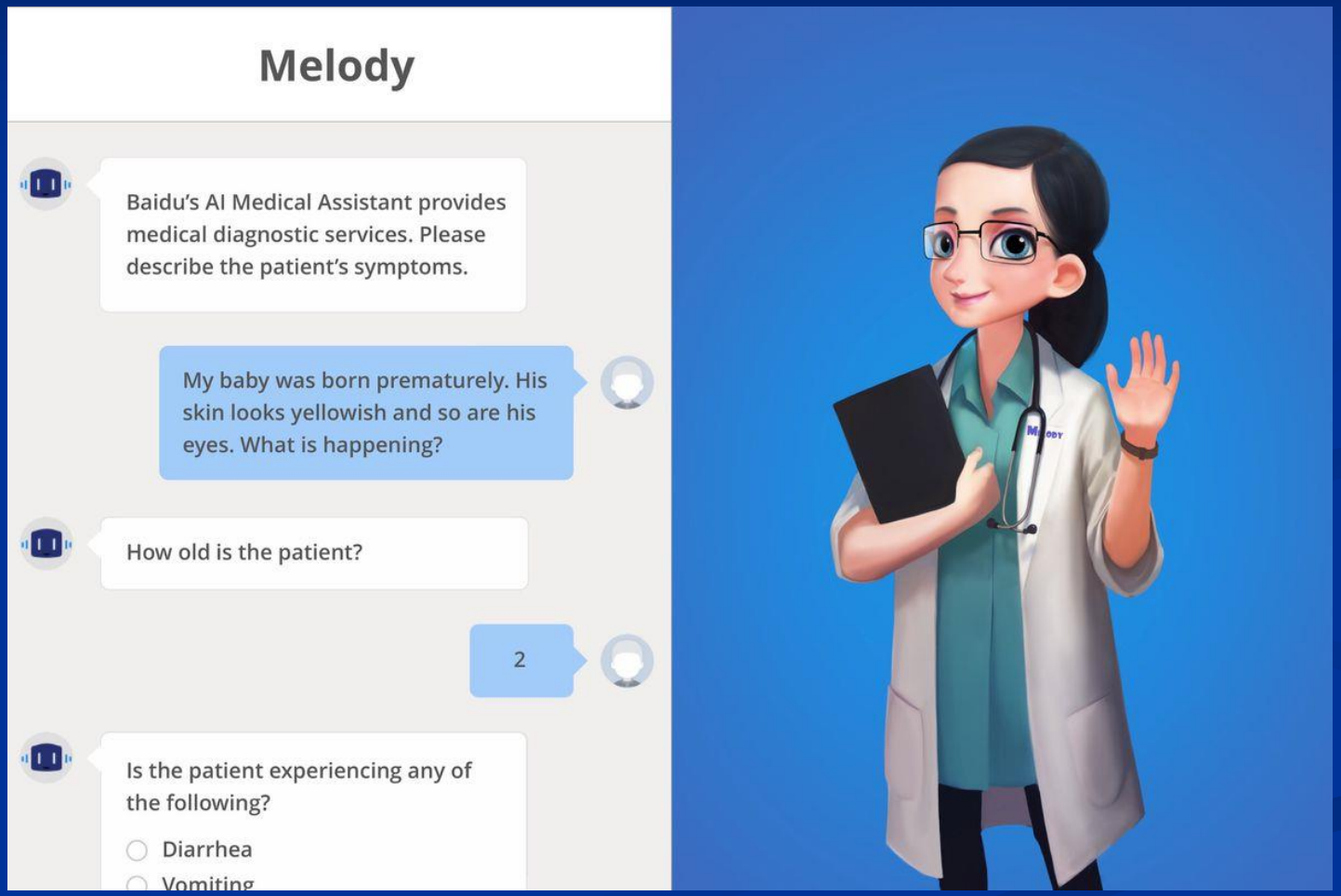
Teledentistry

Teledentistry

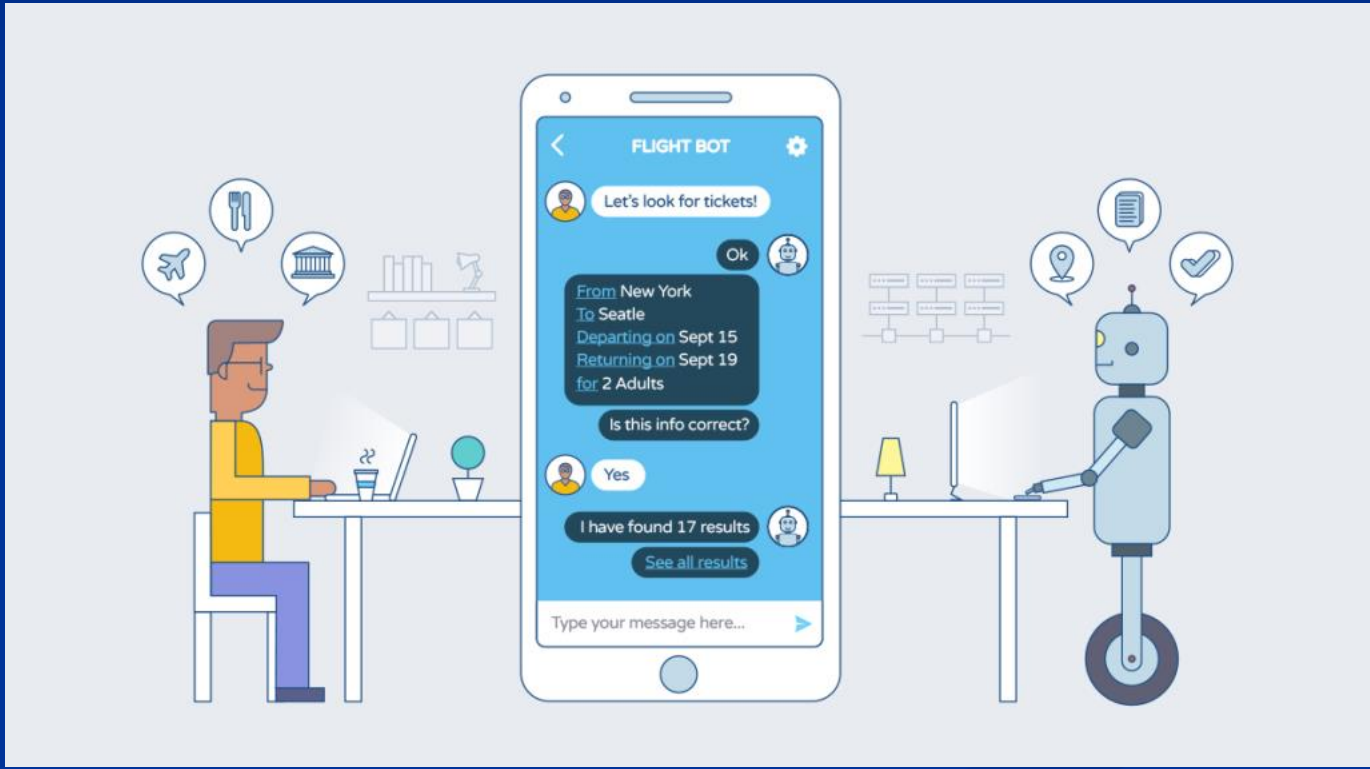
Teledentistry

Teledentistry Assistant

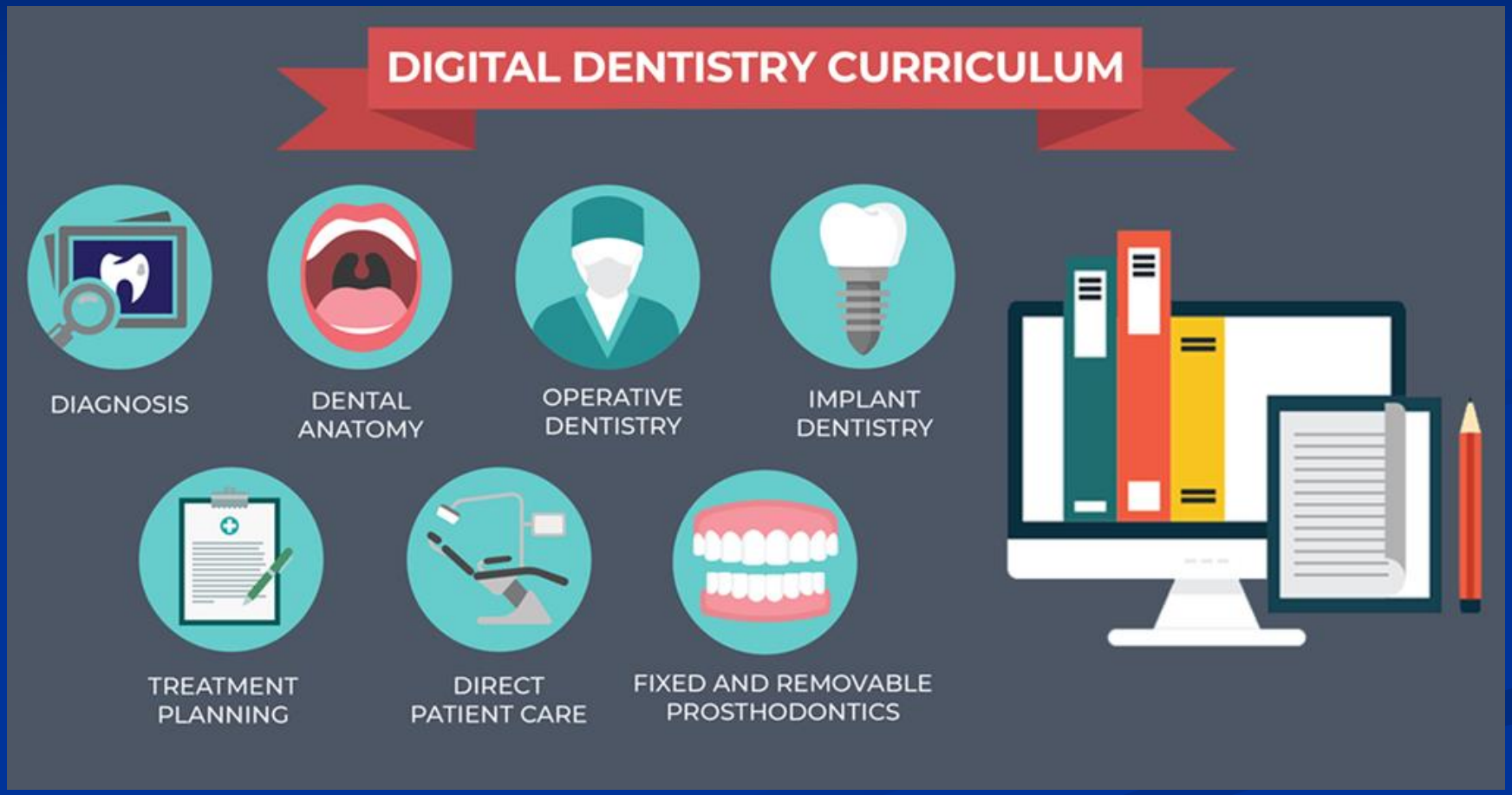
Teledentistry with AI



Teledentistry with AI



New Curriculum – Reeducate Dentists or ITs?



OK, Robot. But What it Means?

Da Vinci is not a robot

Digital smile design

Where are we today?

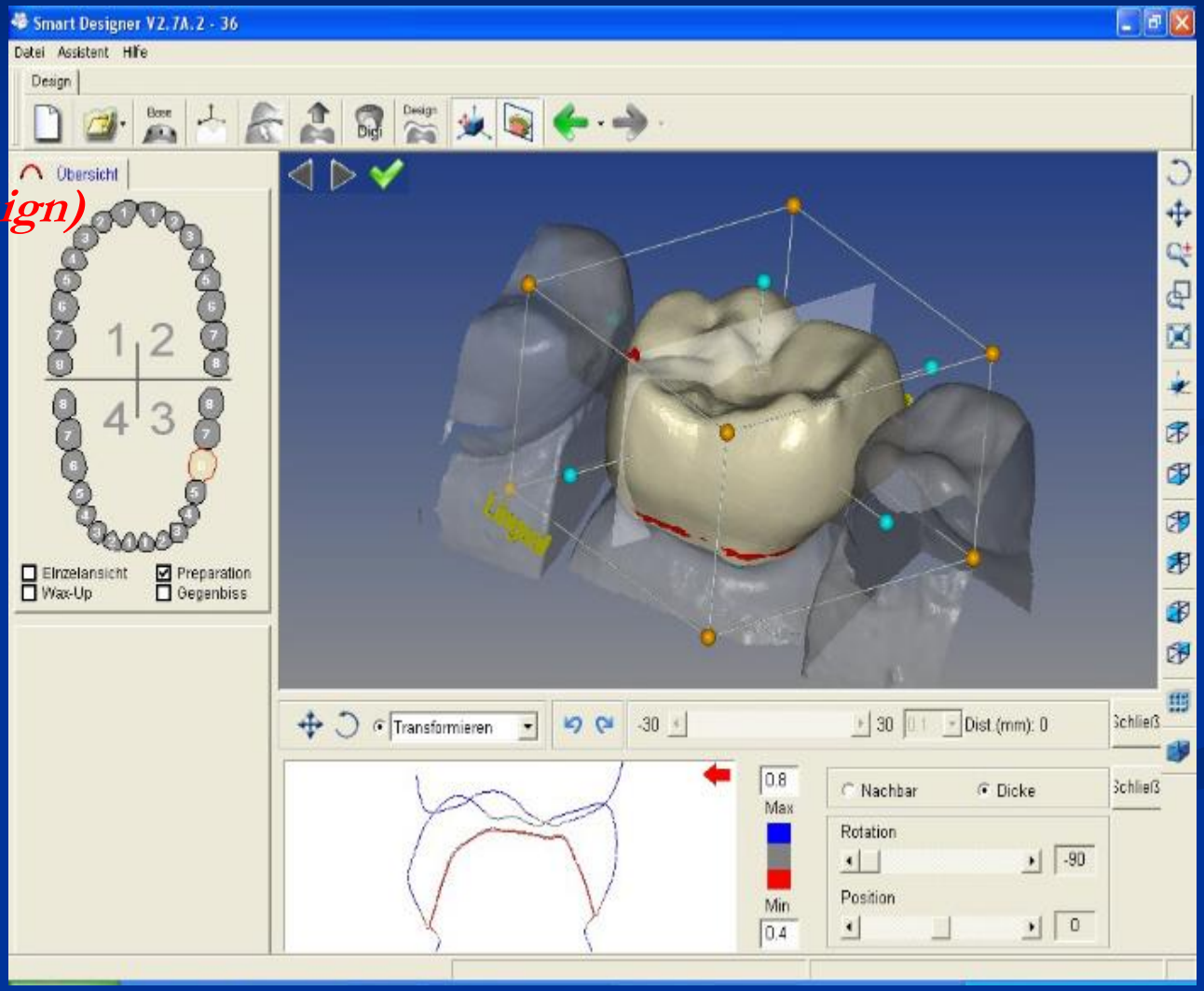
CAD-CAM

CAD\CAM IN DENTISTRY

CAD/CAM DENTISTRY

CAD

(Computer-Aided Design)



CAM

(Computer-Aided Manufacturing)

HISTORY OD CAD-CAM IN DENTISTRY

- **1950s** U.S Air Force
- **1971** Dr.Duret- Sopha System (crowns)
- **1985** Dr. Moermann- CEREC® system (inlay)
- **1980s** Dr. Andersson- Procera® system (titanium copings and composite veneered restorations)

This system, later developed as a processing center, networked with satellite digitizers around the world for the fabrication of all-ceramic frameworks.

Types of CAD/CAM Restorations

- Inlays & onlays.
- Veneers.
- Coping.
- Substructures.
- Full coverage crowns.

CAD/CAM SYSTEMS

- *In office- scan*, fabricate and seat within the same appointment.
- *CAD/CAM dental lab models-* scan a stone ast of prepared tooth in lab. Produce coping and poreclain is then added.
- *CAD/CAM for outsourcing-* network machining centre

ADVANTAGES

Eliminates second visit	No casting errors
Accuracy of impression and restoration	No layering errors
Opportunity to view, adjust, rescan	Cost effective
No physical impression for the patient	Cross infection control
Saves time and labor	No Temporization
View occlusion digitally	Esthetic

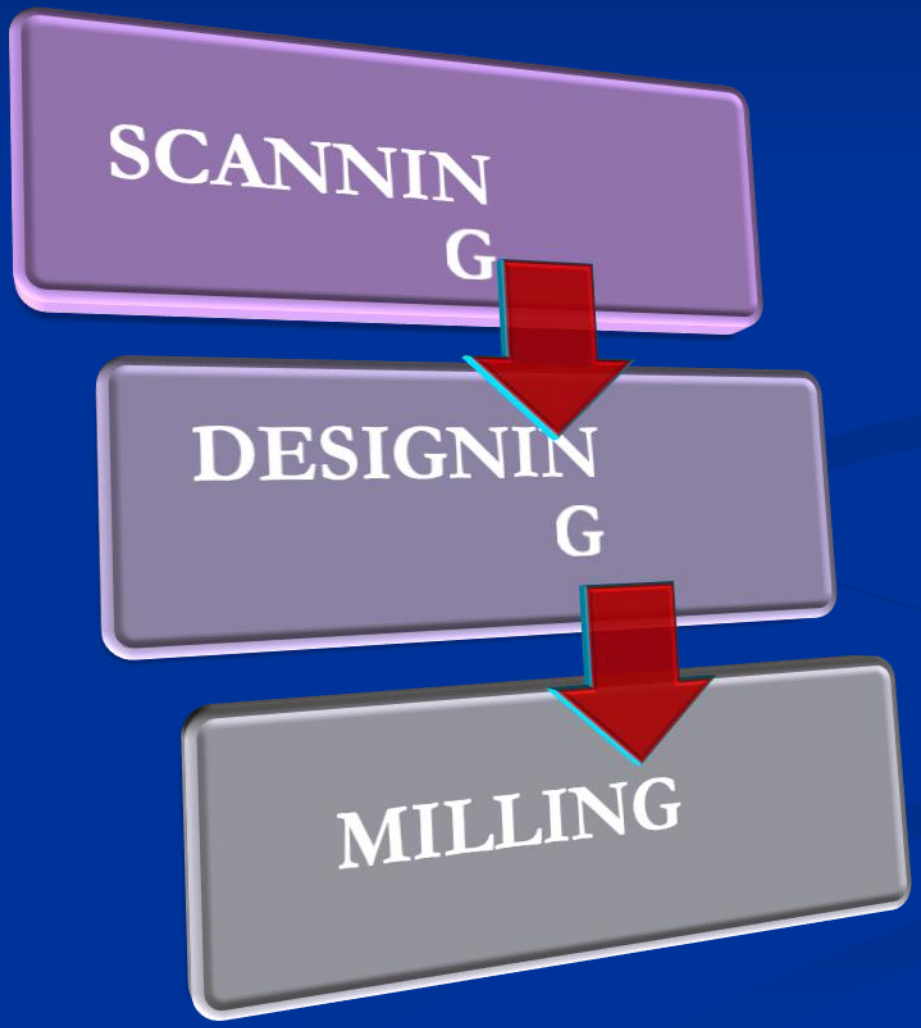
DISADVANTAGES

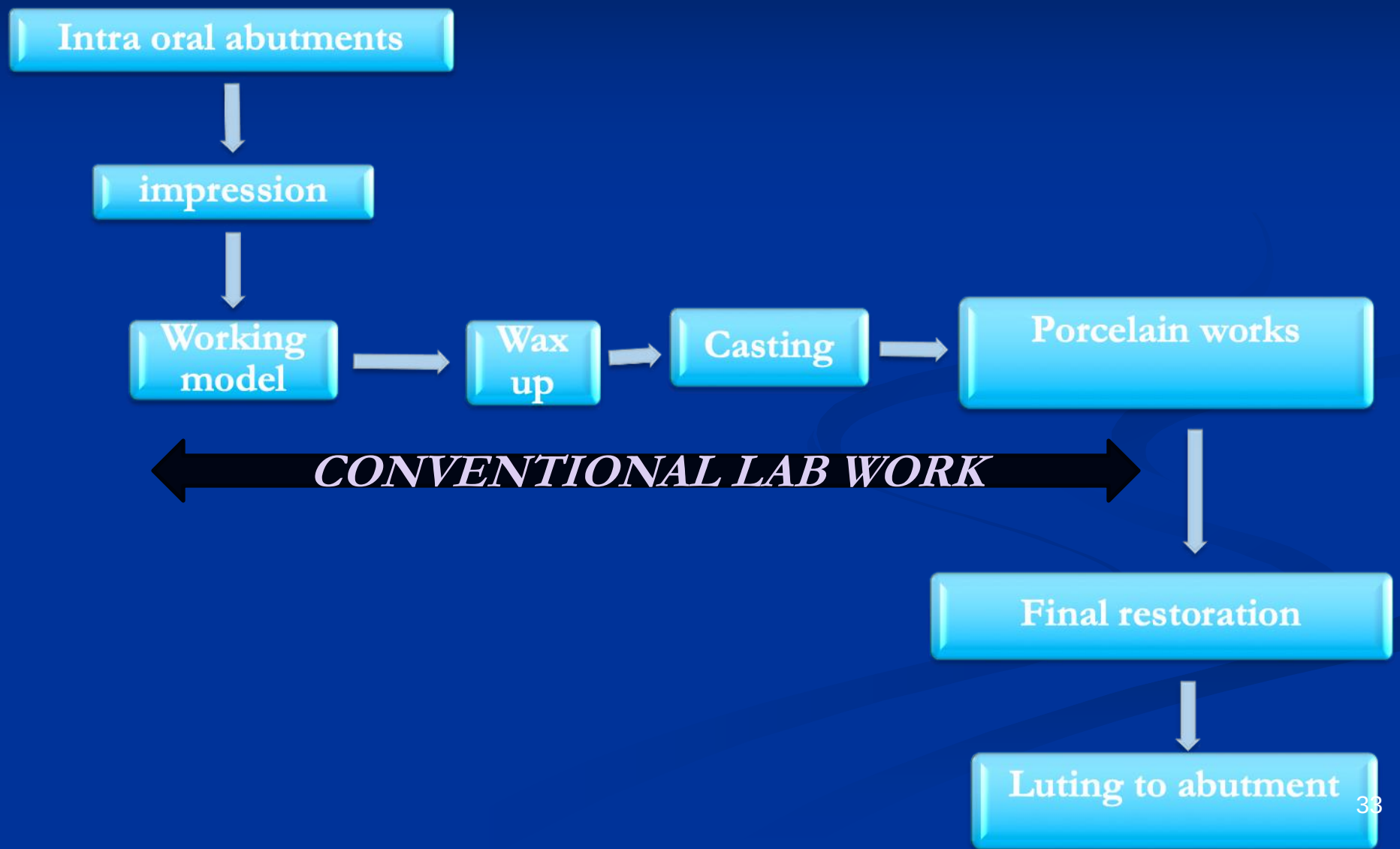
Initial equipment cost

Capturing errors

Color- customization

PROCESS




Intra oral abutments
impression
Working model
Wax up
Casting
Porcelain works
CONVENTIONAL LAB WORK
Final restoration
Luting to abutment

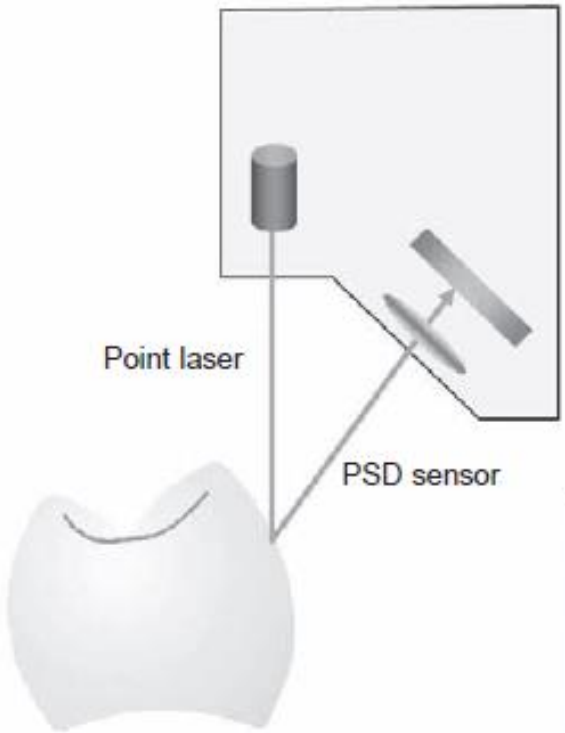
DIGITIZERS/SCANNERs

Surface of stone models is measured by tools, called digitizers and scanners, to obtain digital data that represents morphology of target tooth.

Contact probe

Fig. 2 Currently available digitizing method using a contact probe.

Laser beam with Position Sensing Device sensor



GN-1 (GC Co., Japan)

CEREC inLab (Sirona Dental of system GmbH, Germany)

Fig. 3 Currently available digitizing method using a laser displacement gauge.

Laser with CCD camera

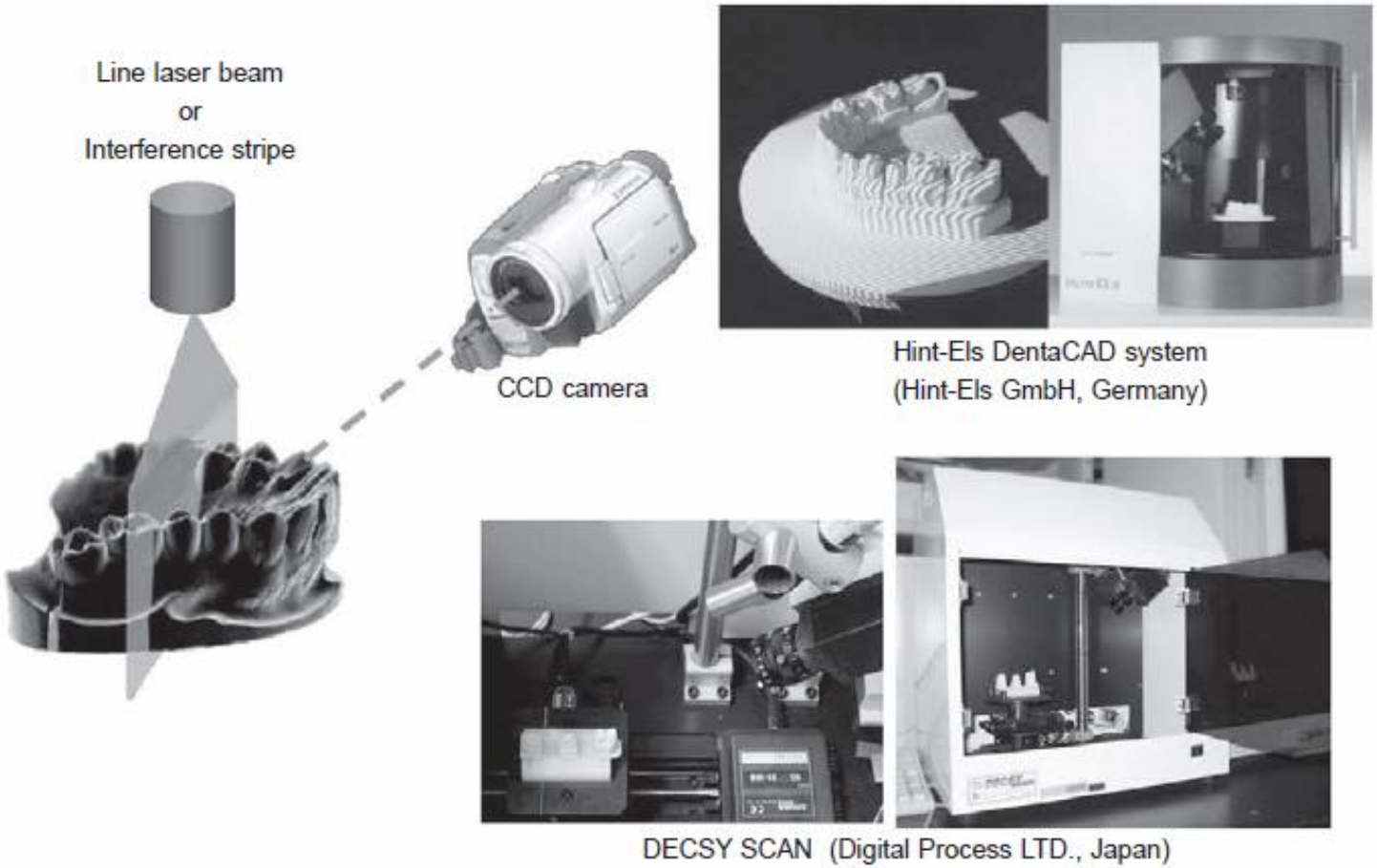


Fig. 4 Currently available digitizing method using a line laser beam or interference stripe with a CCD camera.

Intraoral digitizers

Figure 2. CEREC (upper image) and LAVA COS (lower image)

Different CAD/CAM Systems

- CEREC 123
- DCS Precident
- Cercon
- Procera All Ceram 1994
- Cicero 1999
- LAVA 2002
- Everest
- Katana
- iTero
- …and hundreds others…

Mcenter digitalisation

Digital Dentistry

TYPES OF MANUFACTURING

- ***Subtractive manufacturing-*** power driven machine tools as lathes, milling machines, drill press.

- ***Additive manufacturing-*** series of cross sectional slices layered on top of one another.

Alternatives for teeth preparations

- **Lasers**
- Air abrasion

Lasers for “Hard tissue”

Applications for treatment of hard tissues – carious enamel (tooth decay) and for operating on soft tissues (gums and mouth cavity)

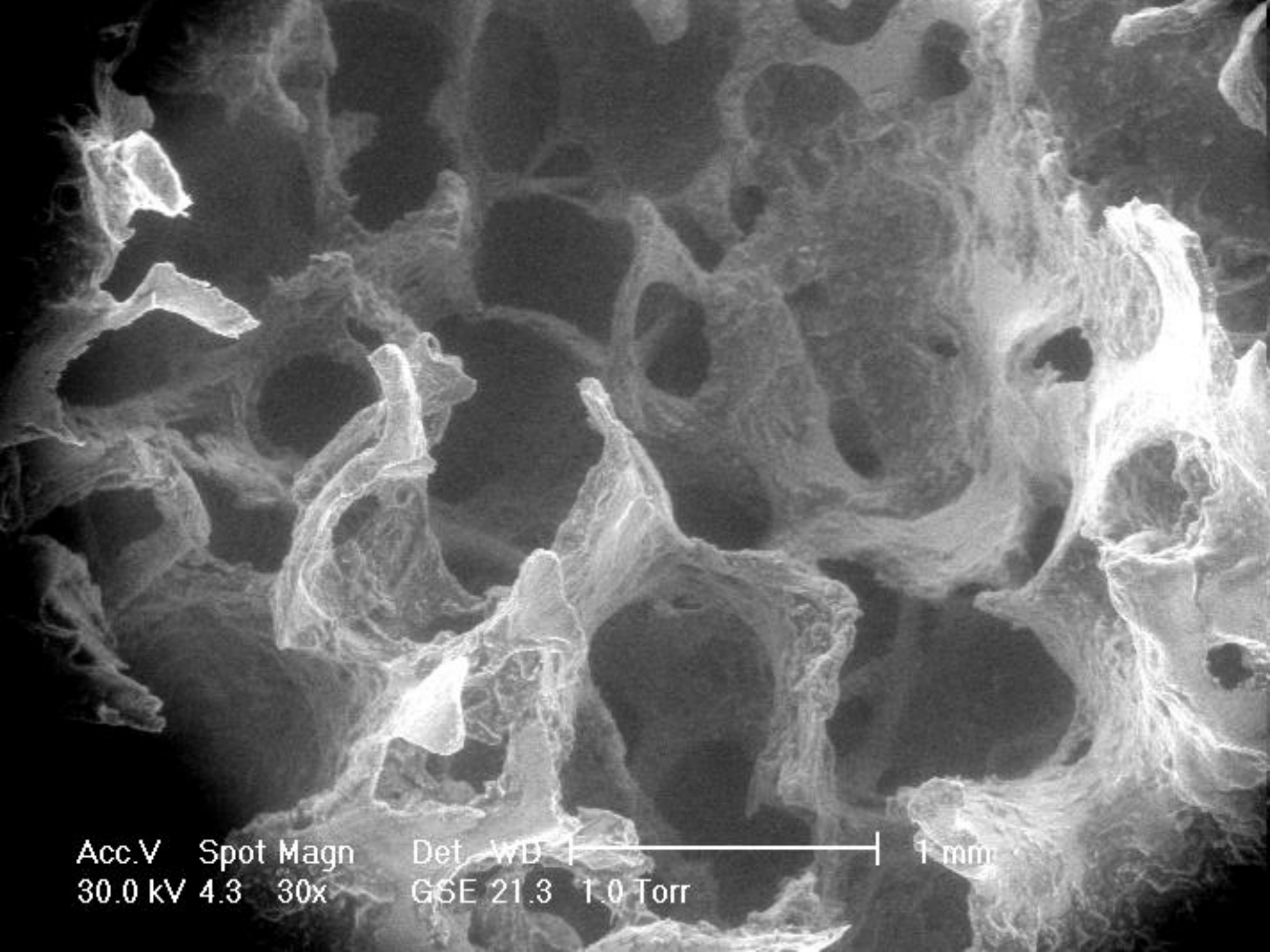
Potentially no pain because there is no vibration (compared with mechanical drill)

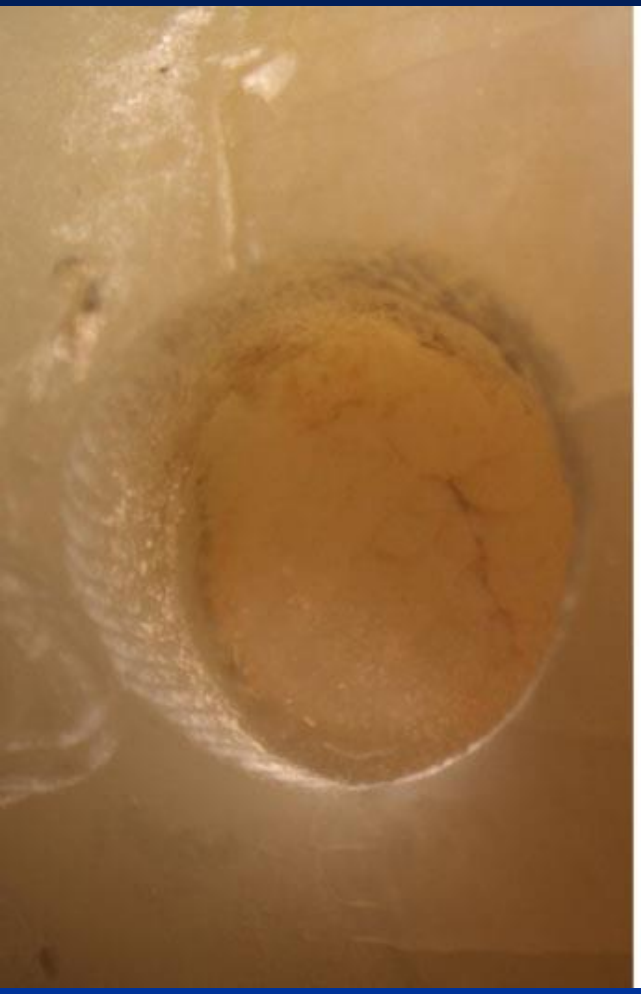
Can target tooth decay or damaged tissue accurately (optical control)

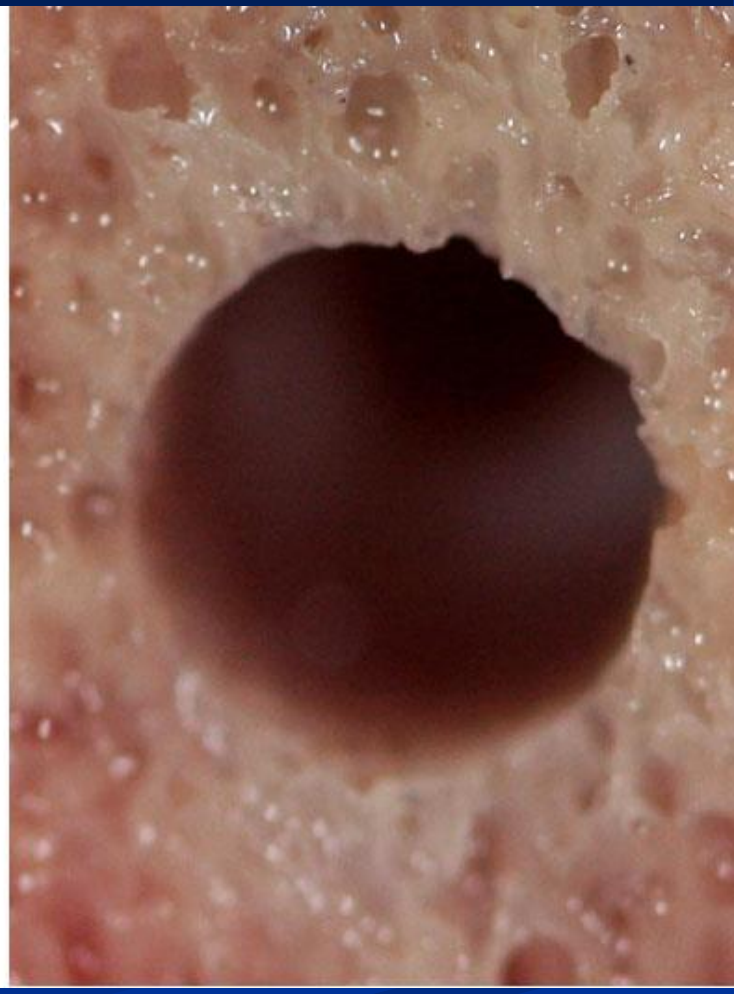
Delivery by optical fiber for ease of access to the patient’s mouth

Conventional Laser Ablation (Er:YAG, Er:Glass)

- Ablation with long laser pulses requires water cooling to minimise heating of the nerve in the tooth and avoid collateral damage.
- Material removal occurs by heating, which then vaporises the tooth surface.


Acc.V Spot Magn Det WD
30.0 kV 4.3 30x GSE 21.3 1.0 Torr
1 mm





Laser as Dental drill

Pulsed lasers with high absorption in water (Er: YAG)

Pros

- High accuracy (considerate preparation)
- Preparation itself is painless (but not whole treatment)
- Alternate preparation bones and "soft tissue"

Cons

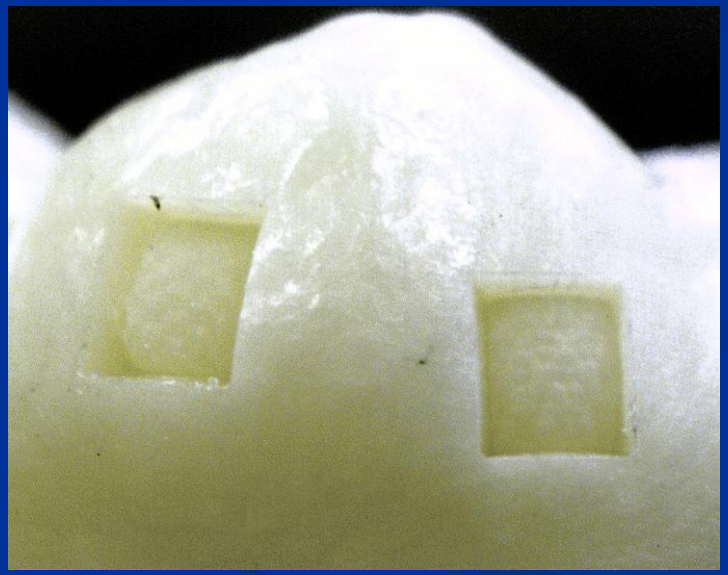
- Need of micromotors (another system in office)
- The general risks of working with lasers
- Slower
- High purchase investment
- Special training needed

Tips

- Perfect for primary dentition and minimally invasive Dentistry
- Some iatrophobic patients like it some not…
- Tool in marketing
- It is necessary to use it full time (soft and hard tissues)
- Realistic expectations

Hope for future?
Use Femtosecond (10^{-13} s pulse width) Laser Ablation

- Excellent surface preparation to enable permanent attachment of fillings, with no microcracking (to avoid infection) and precise ablation.
- Minimise heating effects. Only 5.5°C temperature rise damages the nerve.
- Femtosecond laser ablation of teeth can give cleaner features with no collateral damage, and negligible heating of tooth.

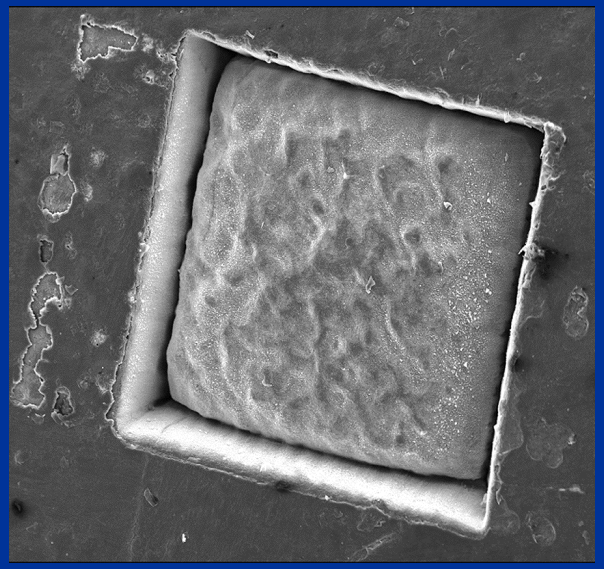


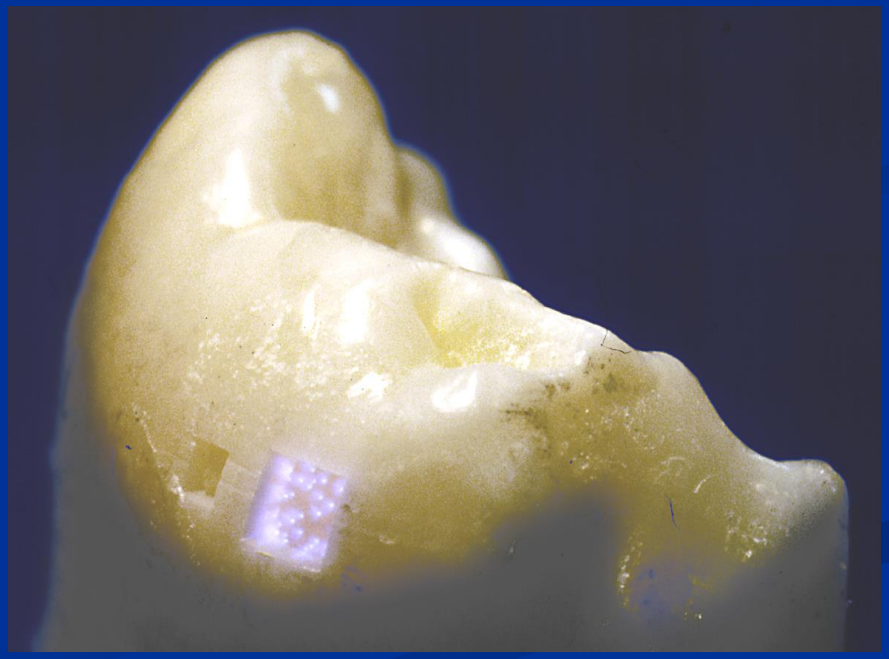
Results

Sharp crater edges, no collateral damage.

Ablation rate ~ $1x10^{-3}$ mm^3s^{-1}

Temperature rise less than 2 ^oC.





How to design robots for dentistry? Does it work on the same principle as in surgery?

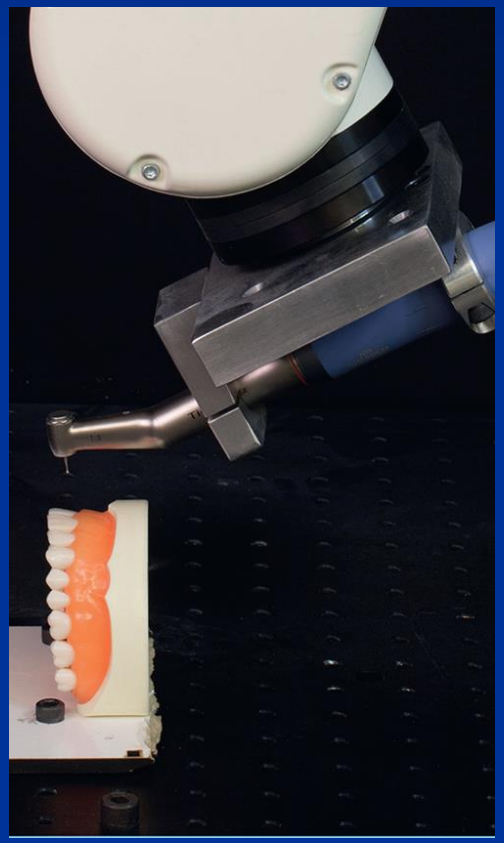
What is different?

- Patient is not stabilized
- Economy is more tight
- Freehand preparation is very cheap
- Great penetration of CAD-CAM

In vitro evaluation of accuracy and precision of automated robotic tooth preparation system for porcelain laminate veneers

- Takafumi Otani, DDS, MSD, PhD, Ariel J. Raigrodski, DMD, MS, Lloyd Mancl, PhD, Ikuru Kanuma, and Jacob Rosen, PhD
- J Prosthet Dent 2015;114:229-235)

In vitro evaluation of accuracy and precision of automated robotic tooth preparation system for porcelain laminate veneers



In vitro evaluation of accuracy and precision of automated robotic tooth preparation system for porcelain laminate veneers

ROBOTIC PREPARATION

FREEHAND HUMAN PREPARATION

ABSTRACT

Statement of problem. Controlling tooth reduction for porcelain laminate veneers (PLVs) in fractions of millimeters is challenging. The purpose of this study was to assess an automated robotic tooth preparation system for PLVs for accuracy and precision compared with conventional freehand tooth preparation.

Material and methods.

Twenty maxillary central incisor tooth models were divided into 2 groups. Ten were assigned to a veneer preparation with a robotic arm according to preoperative preparation design-specific guidelines (experimental group). Ten were assigned to conventional tooth preparation by a clinician (control group). Initially, all tooth models were scanned with a 3-dimensional (3D) laser scanner, and a tooth preparation for PLVs was designed on a 3D image. Each tooth model was attached to a typodont. For the experimental group, an electric highspeed handpiece with a 0.9-mm-diameter round diamond rotary cutting instrument was mounted on the robotic arm. The teeth were prepared automatically according to the designed image. For the control group, several diamond rotary cutting instruments were used to prepare the tooth models according to preoperative preparation design guidelines. All prepared tooth models were scanned. The preoperative preparation design image and scanned postoperative preparation images were superimposed. The dimensional difference between those 2 images was measured on the facial aspect, finish line, and incisal edge. Differences between the experimental and the control groups from the 3D design image were computed. Accuracy and precision were compared for all sites and separately for each tooth surface (facial, finish line, incisal). Statistical analyses were conducted with a permutation test for accuracy and with a modified robust Brown-Forsythe Levene-type test for precision (a=.05).

Results.

For accuracy for all sites, the mean absolute deviation was 0.112 mm in the control group and 0.133 mm in the experimental group. No significant difference was found between the 2 (P=.15). For precision of all sites, the standard deviation was 0.141 mm in the control group and 0.185 mm in the experimental group. The standard deviation in the control group was significantly lower (P=.030). In terms of accuracy for the finish line, the control group was significantly less accurate (P=.038). For precision, the standard deviation in the control group was significantly higher at the finish line (P=.034).

Conclusions. For the data from all sites, the experimental procedure was able to prepare the tooth model as accurately as the control, and the control procedure was able to prepare the tooth model with better precision. The experimental group showed better accuracy and precision at the finish line.

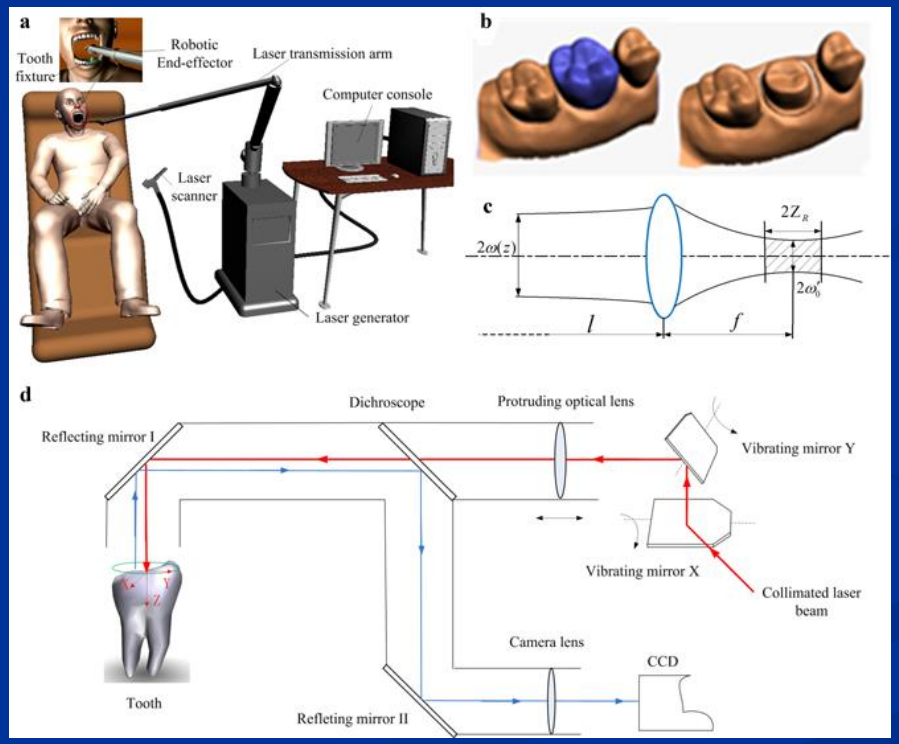
An Automatic Robotic System for Three-Dimensional Tooth Crown Preparation Using a Picosecond Laser

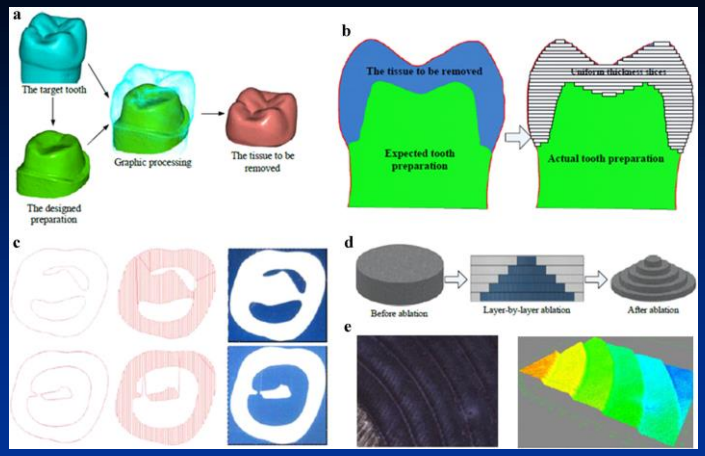
Lei Wang, MSc,1 Dangxiao Wang, PhD,1 Yuru Zhang, PhD,1 Lei Ma, MSc,1 Yuchun Sun, MD,2 and Peijun Lv, MD2

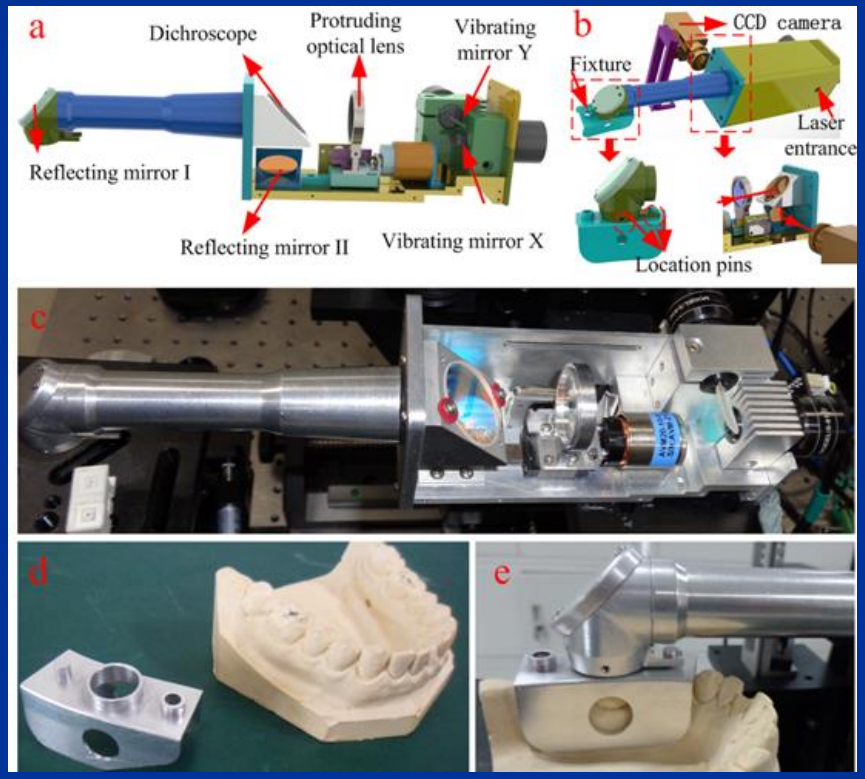
1State Key Lab of Virtual Reality Technology and Systems, Beihang University, Beijing, China

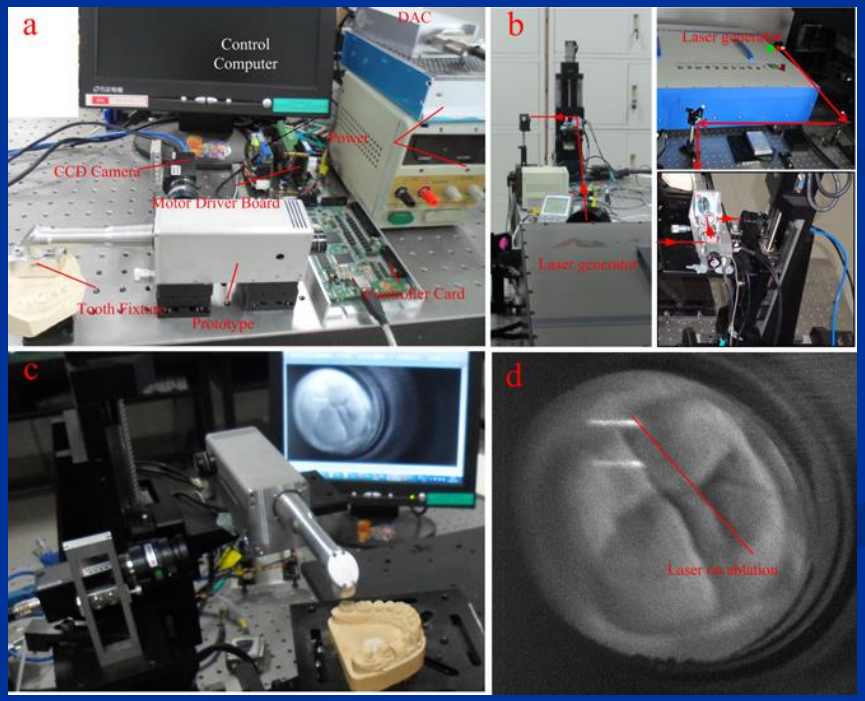
2School and Hospital of Stomatology, Peking University, Beijing, China

Lasers in Surgery and Medicine 46:573–581 (2014)




a
The target tooth
The designed preparation
Graphic processing
The tissue to be removed
b
The tissue to be removed
Expected tooth preparation
Uniform thickness slices
Actual tooth preparation
c
d
Before ablation
Layer-by-layer ablation
After ablation
e


a
Dichroscope
Protruding optical lens
Vibrating mirror Y
Reflecting mirror I
Reflecting mirror II
Vibrating mirror X
b
CCD camera
Fixture
Laser entrance
Location pins
c
d
e


a
Control Computer
DAC
Power
CCD Camera
Motor Driver Board
Controller Card
Tooth Fixture
Prototype
b
Laser generator
Laser generator
c
d
Laser on ablation

Economy

- Robotic prosthodontics need significant investment.
- Robotic dentistry has to be significantly less time consuming, or it has to allow work on multiple patients simultaneously. If it would be possible, we should have cost savings in a high volume dental office. It can start industrialization of dentistry.

Conclusion

- We have all the technologies needed for the robotic prosthodontics- no need of a breakthrough invention
- There is no medical indication today– accuracy and precision are comparable to the preparation by human (today!)
- Potential for the economy of scale. It can be a game changing technology but it has to be proven

Future – manufactured tissues

Thank you for your attention

- Contact:

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