

# Fourth Joint Symposium on Nanotechnology

## Nanoparticles in dental materials



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# Nanoparticles - Dental Materials

- Intro Dental Materials
- Regulatory Background
- Exposure scenarios
- Exposure estimates
- Conclusions

# Nanoparticles - Dental Materials

- **Intro Dental Materials**
- Regulatory Background
- Exposure scenarios
- Exposure estimates
- Conclusions

# Nanoparticles - Dental Materials

- Alloys

- Amalgam
- Gold alloys
- Non-precious alloys
- Ti, Ti alloys
- Ni alloys



# Nanoparticles - Dental Materials

- Resin based materials
  - Filling materials
  - Denture materials
- Ceramics



# Nanoparticles - Dental Materials

- Water based cements
- Combinations



- And also:
  - impression materials ...
  - Gypsum compounds



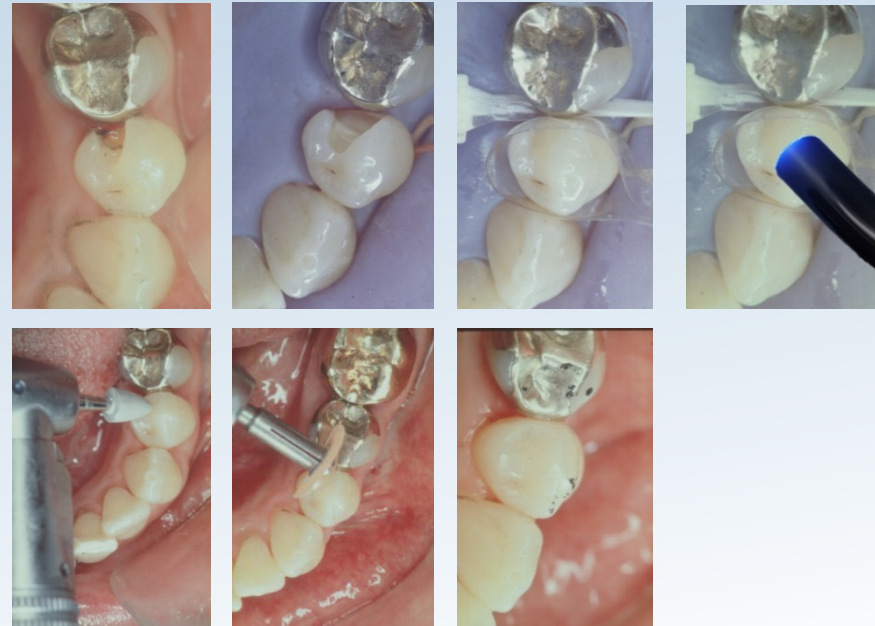
# Nanoparticles - Dental Materials

- Large variety of different materials



# Nanoparticles - Dental Materials

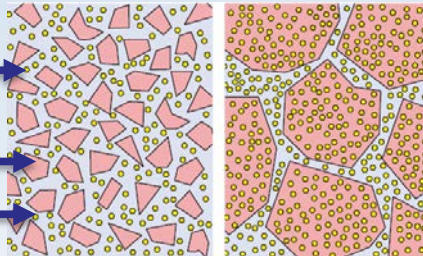
- Large variety of different materials
- Mainly mixtures
- Containing “Fillers”
- Example:
  - Resin composites



Matrix (resin)

Filler

$\mu\text{m}$   
 $\text{nm}$





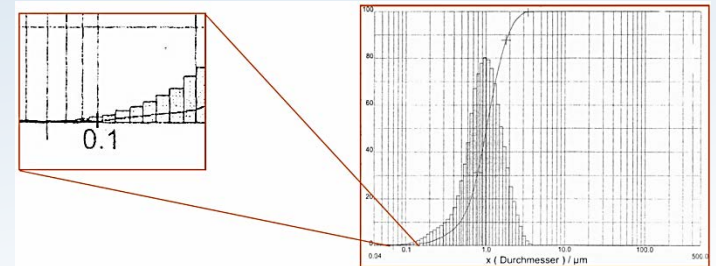
# Nanoparticles - Dental Materials

- Large variety of different materials
- Mainly mixtures
- Containing “Fillers”
- Which?
  - $\text{SiO}_2$ ,  $\text{ZrO}_2\text{-SiO}_2$  (e.g. resin-based composites)
  - Silicate glasses (in cements and Composite resins)
  - $\text{ZnO}$  (e.g. cements),
  - Ag-nanoparticles (e.g. in some adhesives), other antibacterial NPs
  - $\text{TiO}_2$  (e.g. certain resin-based composites, impression materials)
  - Apatite and Ti nanoparticles (on dental implants),
  - Pigments, as coloring agents e.g. iron oxides,  $\text{TiO}_2$  (white), rare earth oxides (fluorescents).
  - Ceramic materials: pigments that are mixtures of different oxides.

# Nanoparticles - Dental Materials

- Large variety of different materials
- Mainly mixtures
- Containing “Fillers”
- Nanoparticles added
  - intentionally or
  - More often unintentionally
  - Low mass, large numbers

**Estimated: 5000 dental materials**



# Nanoparticles - Dental Materials

- Intro Dental Materials
- **Regulatory Background**
- Exposure scenarios
- Risk assessment
- Conclusions

# Nanoparticles - Dental Materials

- Regulatory Background
  - Dental material are (mainly) medical devices
  - MDR 2017
    - Art. 2, Definitions
      - nanomaterial' means a natural, incidental or manufactured material containing particles in an unbound state or as an aggregate or as an agglomerate and where, **for 50 % or more of the particles in the number size distribution**, one or more external dimensions is in the size range 1-100 nm; ...
    - Art. 10.6: ...
      - Special attention shall be given to nanomaterials.

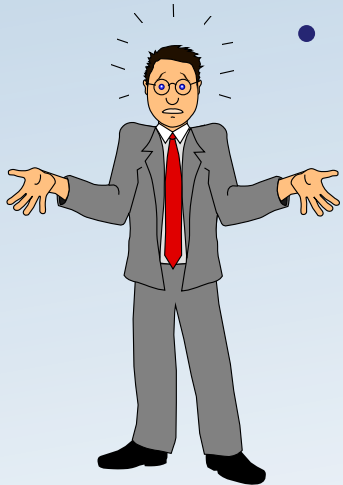
# Nanoparticles - Dental Materials

- Regulatory Background

- Dental material are (mainly) medical devices
- MDR 2017

- Rule 19

- All devices incorporating or consisting of nanomaterial are classified as:
  - » class III if they present a high or medium potential for internal exposure
  - » class IIb if they present a low potential for internal exposure;
  - » class IIa if they present a negligible potential for internal exposure.



# Nanoparticles - Dental Materials

- Intro Dental Materials
- Regulatory Background
- **Exposure scenarios**
- Risk assessment
- Conclusions

# Nanoparticles - Dental Materials

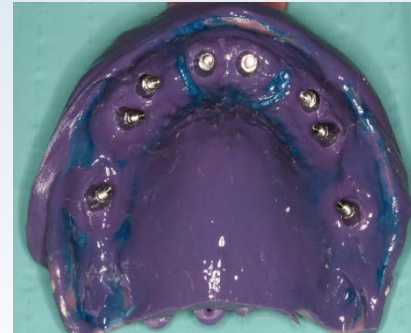
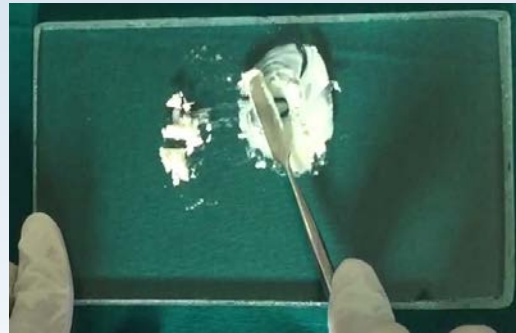
- Exposure scenarios
  - Dental laboratory

- Processing e.g. powdered materials like gypsum
- Grinding/polishing
- Inhalation of dust and chemicals (e.g. Silicate-dust, asbestos, Beryllium): pneumoconiosis and foreign body granuloma in the lung
- THEREFORE: suction apparatus and protective glass
- Occup. Safety regulations (e.g. Arbeitsschutzgesetz (ArbSchG), etc.



# Nanoparticles - Dental Materials

- Exposure scenarios
  - Dental practice office
  - Application of pastes





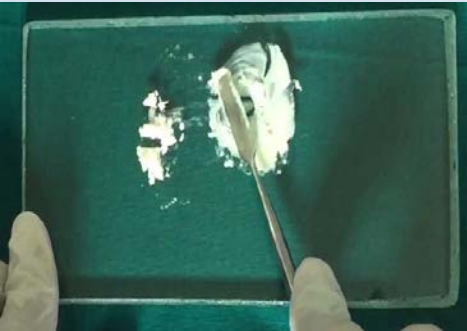
# Nanoparticles - Dental Materials

- Exposure scenarios
  - Dental practice office
    - Application of pastes
    - Release from composites?
    - Filler: silane treatment/wetting by resin
    - Capillary transverse pressure\*
    - No release



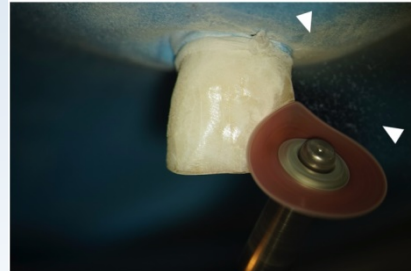
# Nanoparticles - Dental Materials

- Exposure scenarios
  - Dental practice office
    - Release from cements?
    - Only during mixing
    - Today: more capsules



# Nanoparticles - Dental Materials

- Exposure scenarios
  - Dental practice office
    - Adjustment (grinding/polishing): e.g. of Composites



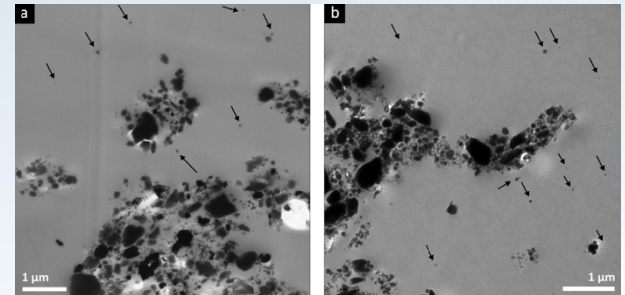
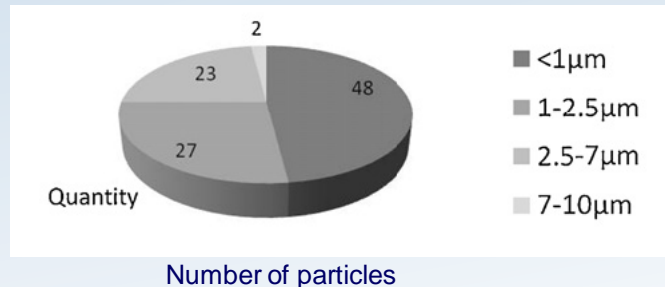
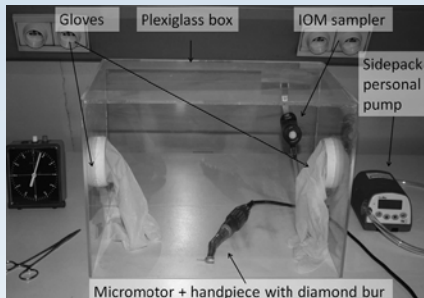
Courtesy Dr. Cokic  
Dr. Widbiller

# Nanoparticles - Dental Materials

- Exposure scenarios

- Dental practice office

- Adjustment (grinding/polishing): e.g. of Composites
    - Blocks ground with a diamond bur; dust collected on 1- $\mu\text{m}$  pore-size filters, quantified and characterized by TEM
    - Materials: Resin based composites

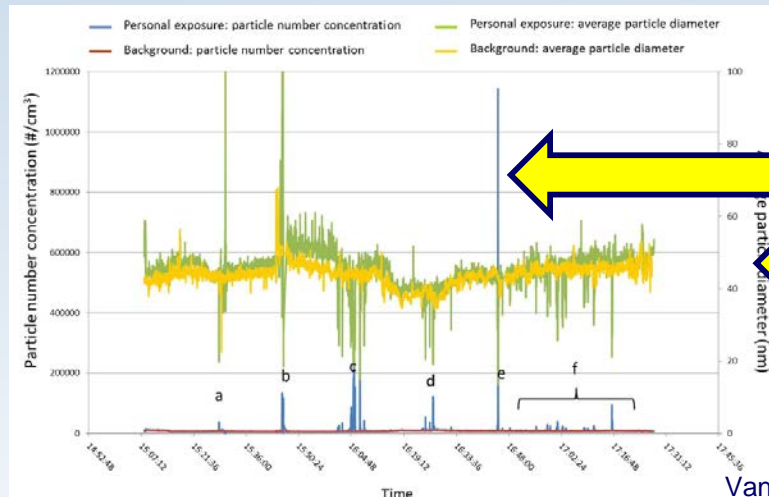
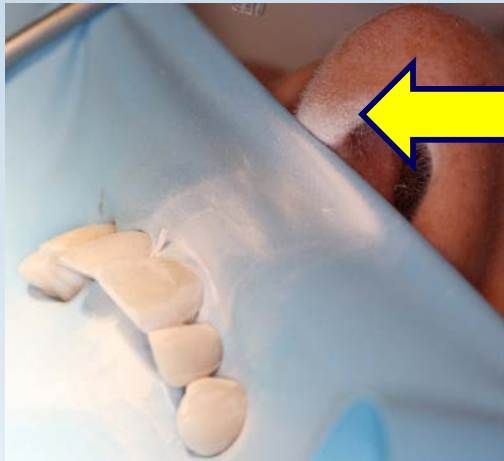


# Nanoparticles - Dental Materials

- Exposure scenarios
  - Dental practice office
    - Adjustment (grinding/polishing): e.g. of Composites
    - Gravimetric Analysis:
      - » respirable dust: 8-56 mg/m<sup>3</sup> immediately after grinding
    - Elektronmicroscopic Analysis:
      - » particles smaller than 1 µm and even 100 nm.
      - » multiple fillers in the resin matrix, but also of single nanofillers.

# Nanoparticles - Dental Materials

- Exposure scenarios
  - Dental practice office
    - Adjustment (grinding/polishing): e.g. of Composites
    - Clinical experiments



1 mio nanoparticles/cm<sup>3</sup>  
- short term

Particle size: nano

# Nanoparticles - Dental Materials

- Exposure scenarios
  - Dental practice office
    - Adjustment (grinding/polishing): ~~e.g. of Composites~~
    - Which do not contain nanoparticles
    - BUT: nanoparticles are produced during grinding
    - Independent from the presence of nanoparticles in the materials\*
    - **Cytotoxicity?** Toxic effect resin comp: 660 µg/mL (bronch. epith.cells)  
60 pg/cell (rat lung macrophages)\*\*

**We produce nanoparticles**

\* Bogdan et al., Journal of Occupational and Environmental Hygiene, 2014

\*\* Cokic et al., Dent Mater 2016; Landuyt et al., Part Fibre Toxicol 2016,

# Nanoparticles - Dental Materials

- Exposure scenarios
  - Patient
    - Wear



Type of restoration	Type of wear	Wear range CV = Coefficient of variation
Class I/II composite	Occlusal contact	72–172 $\mu\text{m}$ (CV 28–48) 80–93 $\mu\text{m}$ (CV?) 170 $\mu\text{m}$ (CV 41)
	Contact-free	20–101 $\mu\text{m}$ (CV 45–76) 25–101 $\mu\text{m}$ (CV 43)
	Occlusal, general Proximal contact	64–208 $\mu\text{m}$ (CV?) 114–243 $\mu\text{m}$ (CV 5–63)
Class V composite		20 $\mu\text{m}$ (CV 25)
Composite crowns	Occlusal, general	60–170 $\mu\text{m}$ (CV?)
Composite crowns (8 months)	Occlusal contact	238 $\mu\text{m}$ (CV 54)
Amalgam	Occlusal contact	120 $\mu\text{m}$ (CV?)
	Occlusal, general	28–101 $\mu\text{m}$ (CV 23)
Enamel	Occlusal contact	54–91 $\mu\text{m}$ (CV 65–75)
	Occlusal, general	41 $\mu\text{m}$ (CV?)
	Proximal	17 $\mu\text{m}$ (CV 24)

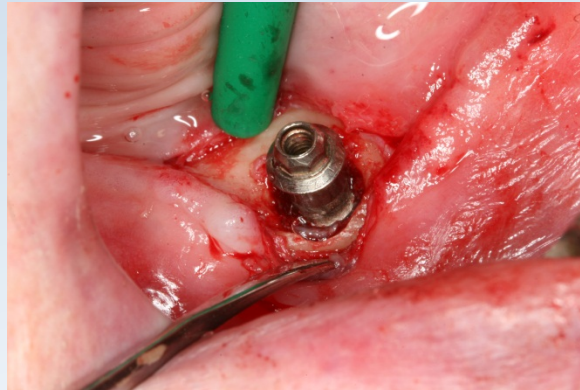
The in vivo measurements are based on different numbers of subjects, different subject selection

After two years



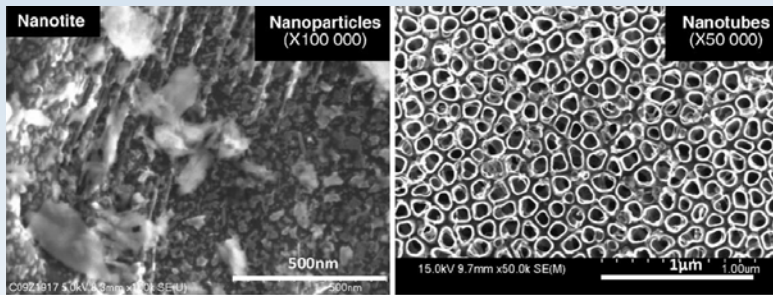
# Nanoparticles - Dental Materials

- Exposure scenarios
  - Patient
    - Implants, Ti nanoparticles, periimplantitis



# Nanoparticles - Dental Materials

- Exposure scenarios
  - Patient
    - Implants, Ti nanoparticles, periimplantitis
    - Implants?
    - Release of Ti from implants\*
    - Post mortem
    - Max: 37.7 mg/kg bone at 556 – 1587  $\mu\text{m}$  distance



# Nanoparticles - Dental Materials

- Exposure scenarios

- Environment

- Dust after grinding a resin composite
    - Procedure described, no further particle analysis
    - *Vibrio fischeri* bioluminescence and cytotoxicity on human A549 lung cells
    - Inhibition of *V. fischeri* bioluminescence at concentrations above 1.1 mg/mL
    - Cytotoxic effects (WST test) at concentrations of 0.1 mg/mL
    - Impact??

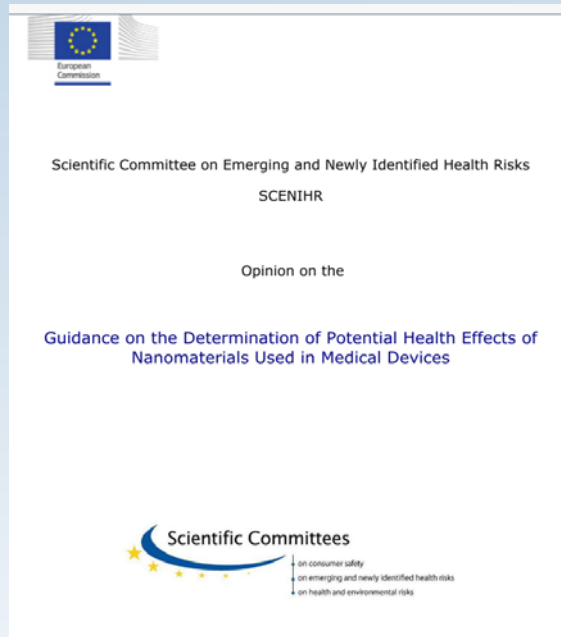
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# Nanoparticles - Dental Materials

- Exposure estimates
  - SCENIHR 2015

- Purely quantitative assessment
- Unset materials: free nanoparticles: high exposure
- Set materials (embedded): negligible



# Nanoparticles - Dental Materials

- Exposure estimates

- Inhalation – dental personnel

- Germany 2015:
    - 57 Mio fillings (data from insurances), 71,425 dentists
    - 3 fillings per day and dentist, 80% composites
    - Not all dentists place fillings (e.g. oral surgeons, orthodontists)
    - Estimated 3 – 6 fillings per day per dentist
    - For worst case calculation: **10 composites per dentist and day**



# Nanoparticles - Dental Materials

- Exposure estimates
  - Inhalation – dental personnel
    - For worst case calculation: **10 composites per dentist and day**
    - Based on data from van Landuyt (2012) et al.\*and from Bradna et al.(2017)\*\*



• K.L. Van Landuyt et al. Dent Mater 2012

\*\* Bradna et al. Monatsh Chem 2017

# Nanoparticles - Dental Materials

- Exposure estimates
  - Inhalation – dental personnel
    - 5 fillings front, 5 fillings posterior per day
    - 1 mm removal: 450 mg
    - 18 µg per dentist and day (WORST CASE)
  - German agency for occupational safety
    - Max acceptable: 110-190 µg/m<sup>3</sup>
    - 8 h working day, 10m<sup>3</sup> air uptake
    - 1100 – 1900 µg per day



No or negligible risk



# Nanoparticles - Dental Materials

- Exposure estimates
  - Inhalation – patient
    - 1-2 fillings per year (again data from Germany)
    - Worst case: 5 fillings per year
    - 1 mm removal: 450 mg
    - 9 – 25 ng per patient and day (WORST CASE)
  - Based on data from Terzano et al (2010)
    - Normal daily uptake is 400  $\mu\text{g}$



No or negligible risk

# Nanoparticles - Dental Materials

- Exposure estimates
  - Ingestion – patient
    - Max. 100  $\mu\text{m}$  annual loss (Heintze)
    - 20 restoration, 12 in molars, 8 in premolars
    - 3 ng per day
  - Based on data from Terzano et al (2010)
    - Normal daily uptake is 400  $\mu\text{g}$



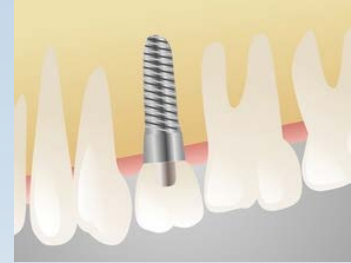
No or negligible risk

# Nanoparticles - Dental Materials

- Exposure estimates

- Implants – patient

- Max. post mortem: 37 mg Ti /kg bone\*
    - all Ti is nano-Ti, 1 kg bone is 1 L fluid
    - Concentration of nano-Ti: 37 µg/ml
    - Cytotox value in cell cultures
    - Human periodontal ligament cells\*\*
    - EC50: 2800 µg/ml



No or negligible risk

\* He, X et al. Dent Mater 32, 1042, 2016

\*\* He, X et al. Dent Mater 2015;31:734–44

Schmalz G. et al. Dental Mater 33, 1298, 2017

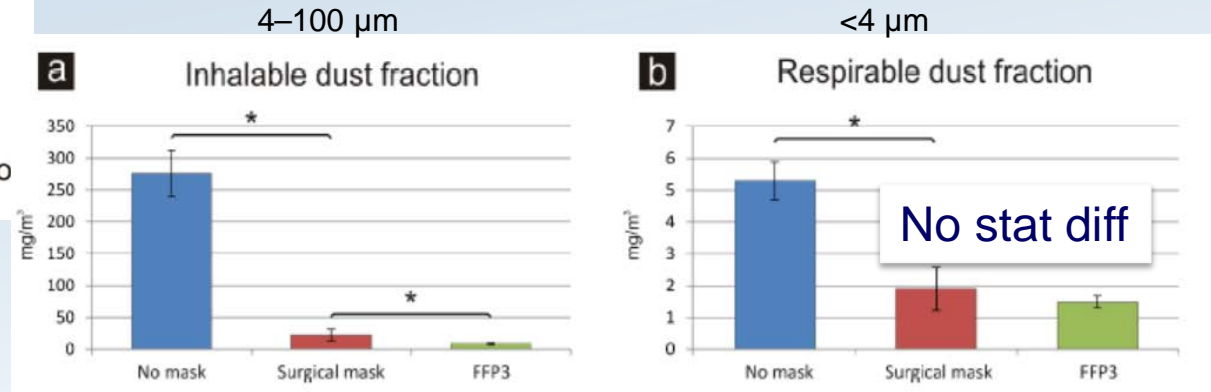
Schmalz G et al. Int Dent J. 2018

# Nanoparticles - Dental Materials

- Protective measures

- Face masks?

- FFP1 Surgical face mask (mainly protection against infection)
    - FFP3 mask (fine particle filter)



# Nanoparticles - Dental Materials

- Protective measures
  - Water spray
  - High volume suction
  - Data? Aerosols



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# Nanoparticle - Dental Materials

- Conclusions

- Large variety of dental materials
- Nanoparticle in and from dental materials (> 5000)
- Dental laboratory: occupational health safety regulations
- Exposure for dental personnel and patients negligible
- Vulnerable groups? Environment?
- Protective measure available
- However: Data basis is very limited  
Presently: better characterization of and standardized protocol to generate NPs (ISO, DIN) (O. Polydorou)

Thank you

F.X. Reichl

K. Van Landuyt

R. Hickel

S. Cokic

O. Polydorou





# Nanoparticles - Dental Materials

- Exposure estimates

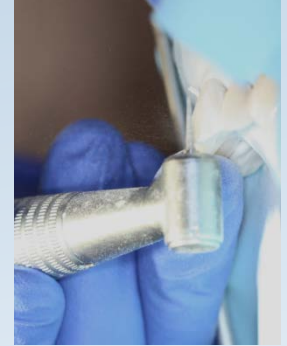
- Inhalation – dental personnel

- For worst case calculation: **10 composites per dentist and day**

- Based on data from van Landuyt (2012) et al.\*

- Based on data from Bradna et al.(2017)\*\*

- The nano-fraction of the dust is in mass%: 0.00016-0,0040 %



# Nanoparticles - Dental Materials

- Exposure estimates

- Inhalation – dental personnel

- For worst case calculation: **10 composites per dentist and day**
    - Based on data from van Landuyt (2012) et al.\*
    - The nano-fraction of the dust is in mass%: 0.0004-0.0013 %
    - Based on data from Bradna et al.(2017)\*\*
    - The nano-fraction of the dust is in mass%: 0.00016-0,0040 %

