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Mastication, function, control mechanisms and consequences on nutrition

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Mastication
function, control mechanisms and consequences on nutrition

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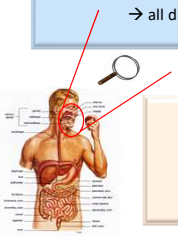
Mouth is the first compartment of food transformation
for the purpose of its assimilation
→ all digestive compartments are linked, each following the other, mouth being the first one



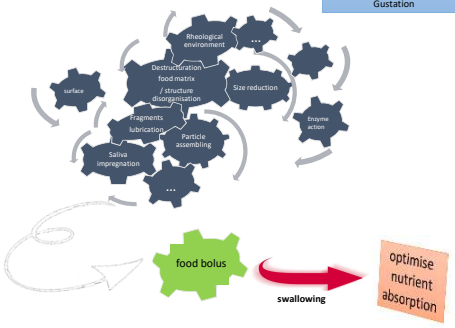
In the alimentary context,
the main activity of the mouth is mastication
mastication is operated
to **prepare a food bolus for swallowing**
without pain, discomfort or risk of aspiration

Mastication is the first step of digestion
and must be considered as such
- mechanical digestion
- chemical digestion

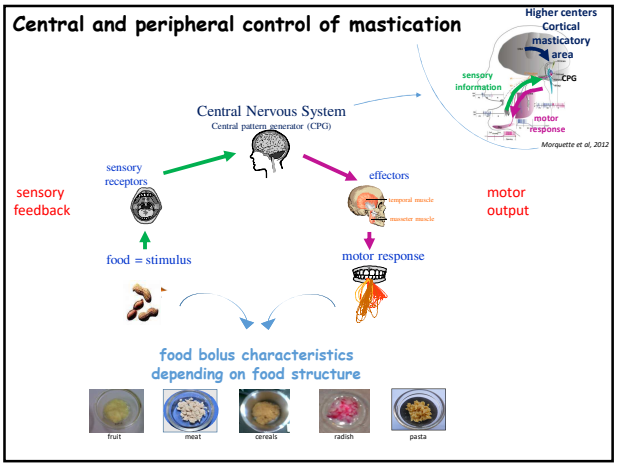
Mastication
major goal => food bolus

Associated functions
Salivation
Tongue activity
Swallowing
Gustation

1st contact of food with digestive tube



Central and peripheral control of mastication



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2 ways to study mastication

fonctioning → **dynamics of mastication**

Muscular contractions (electromyography)
Mandibular movements
amplitudes, velocities (kinematics)
Bite and mastication forces (sensor)
Tongue movements,
tongue-palate compression
… etc

result → **food bolus**

Food bolus collected after complete mastication
or at different moments of the masticatory sequence

Bolus characteristics - bolus formation
particle size distribution (granulometry)
rheological behaviour
(hardness, cohesiveness…)
biochemical characteristics
(saliva and enzyme activity…)
… etc

Combining knowledge on dynamics, masticatory parameters
and bolus characteristics
provide
→ a relevant understanding of the overall function
→ A chance to understand the subtle but critical role of mastication in nutrition

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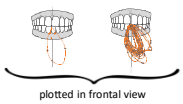
Functioning of mastication

Individual steadiness of mastication

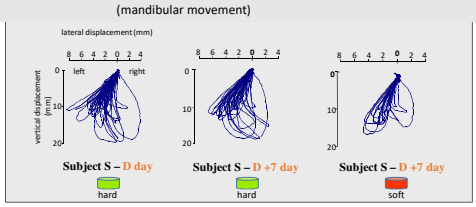


plotted in frontal view

Mandibular movement:
series of opening
and closing

Complete masticatory sequences for a subject S
chewing either the same food on separate occasions or another food only differing in hardness
(mandibular movement)

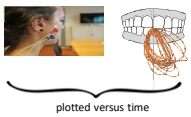
Reproducibility for a given subject



➡ **Mastication : reproducible/steady for a given subject (good oral health)**

Functioning of mastication

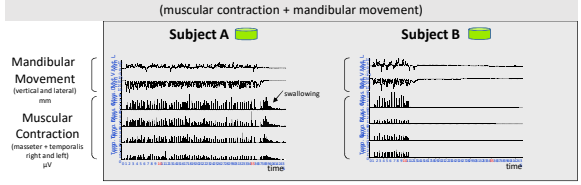
Between-subject variability



Mandibular movement
Muscular contraction

plotted versus time

Complete masticatory sequences for 2 subjects A and B chewing the same food
(muscular contraction + mandibular movement)

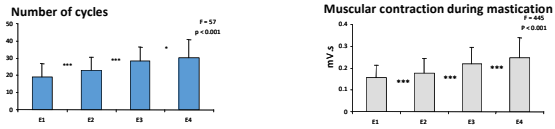


Mastication highly variable from a subject to another one even chewing the same food

Functioning of mastication

Adaptation of mastication to food properties

4 products of increasing hardness

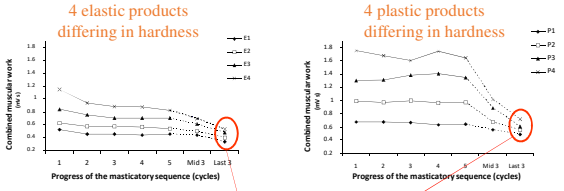


The adaptation of masticatory parameters depends either on food hardness or on rheological behaviour (elastic *vs* plastic… for example)

Peyron et al, 2002, Foster et al, 2006

Functioning of mastication

Adaptation of mastication to food bolus characteristics is effective during the whole sequence

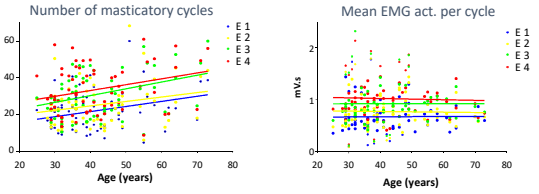


Whatever the initial food hardness, at the end of mastication the food bolus required the same quantity of muscle contraction

Functioning of mastication

Adaptation of mastication during "normal ageing"

4 elastic model foods only differing in hardness



Mastication duration increases with age

Masticatory muscle contraction is steady over the years

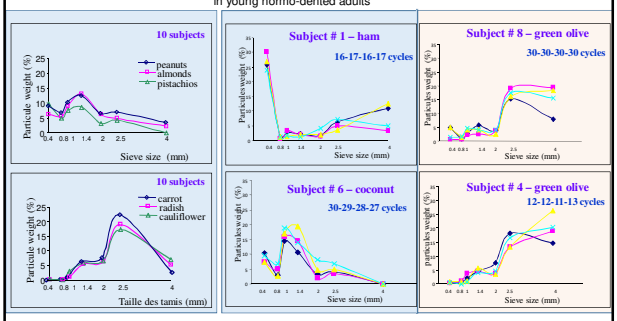
Adaptation of mastication to food properties is maintained over the years (correct dental state)

Peyron et al, 2004

Resulting food bolus

Food bolus granulometry is dependent on food structure
Reproducibility in food bolus granulometry

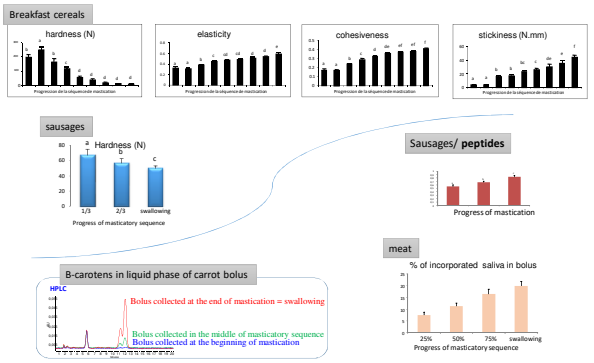
Particle size distribution in the food bolus collected just before swallowing in young normo-dented adults



within- and between-subject reproducibility in food bolus obtained with various masticatory strategies

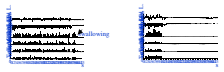
Resulting food bolus

Changes in food bolus properties over the whole masticatory sequence → interaction with saliva

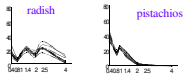


Peyron et al 2011, Hennequin et al, 2015, Peyron and Rémond, 2014

Great interindividual variability of mastication



Within- and between-subject steadiness in bolus granulometry



(10 subjects)

different mastication strategies

bolus with similar characteristics (granulometry and rheological behaviour)

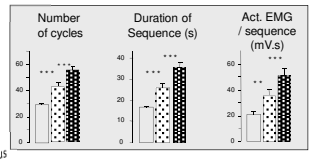
perception of these characteristics participates to swallowing initiation

in absence of oral deficiencies

Functioning in deficient mastication

What happens in case of oral deficiencies ?

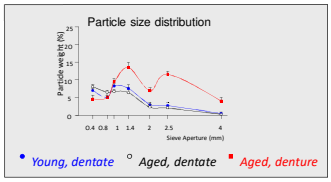
peanuts



young, dentates
aged, dentates
aged, edentulous + denture

Mastication ↗ with age
↗↗ with teeth loss

Resulting food bolus



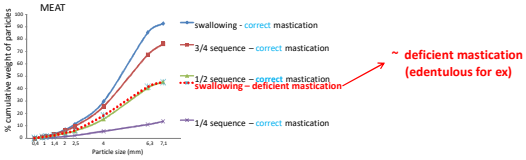
but denture wearers swallow a bolus insufficiently reduced

Longer masticatory sequence for denture wearers not sufficient to reduce the bolus

Mishellany-Dutour et al., 2008

Resulting food bolus

Particle size distribution in bolus of meat after correct or deficient mastication



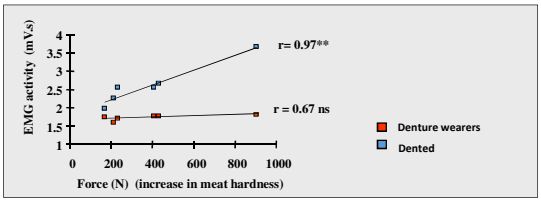
Meat bolus correctly masticated

Meat bolus insufficiently masticated

Functioning in deficient mastication

Deficient mastication – aged denture wearers

meat



Bad dental state → deficient mastication and bad adaptation to food hardness

Aged denture wearers are no longer able to adapt mastication to food

Veyrune and Mioche, 2000; Veyrune et al., 2007

Mastication and nutrition

Links between Food Intake-Nutrition and Oral Health

Daily food intake ↘ when Deterioration of dental state ↗

Energy
Proteins
fat
Polysaccharides
Calcium
Vitamin E

Subjects +21 teeth > Subjects 11-20 teeth > Subjects 1-10 teeth

Blood composition ↘ when Deterioration of dental state ↗

Vitamin C
Vitamin E
Beta-carotene
Folates

partially edented subjects 5-8 post teeth > partially edented subjects 1-4 post teeth > completely edented subjects denture > edented subjects Without post teeth

decrease in daily food intake
and decrease in nutrient absorption
are cumulative problems in case of deficient mastication due to bad dental state

Sahyoun et al, 2003
Morais et al, 2003
Hutton et al, 2002
N'Gom et Woda, 2002
Sheiham et al, 2001
Majon et al, 1999
Krall et al, 1998

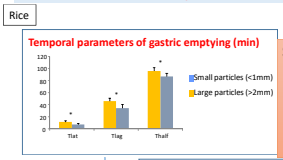
Mastication and nutrition

Mastication = 1st step of digestion due to …

Mechanical digestion in the mouth and further digestive consequences

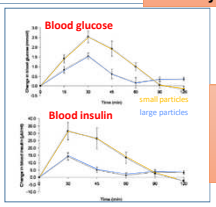
Ex : Effect of particle size on gastric emptying and on metabolism

Rice



Stomach activity is modified by particle size arriving from the mouth

→ large particles delay gastric emptying



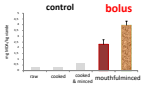
Bolus particle size also impacts metabolism

→ large particles limit
→ glycemia and insulinemia

Ranawana et al, 2011

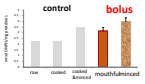
Mastication and nutrition

Mastication = 1st step of digestion due to …
Biochemical modification of food compounds/nutrients



- Beef --- mouthful
- Beef --- minced

lipid oxidation during mastication **in vitro without saliva**
more important when meat is minced before chewing



protein oxidation during mastication **in vitro without saliva**
more important when meat is minced before chewing

Important to consider the antioxidant status of saliva since it can protect food compounds from oxidation

→ Nutrient oxidation has important negative consequences on intestinal absorption

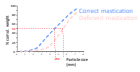
Santé-Lhoutellier & Peyron 2013

Mastication and nutrition

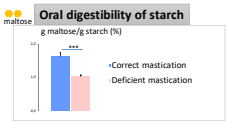
Mastication = 1st step of digestion
Impact of masticatory deficiency on oral and intestinal starch digestibility

→ simulation of edentulous people

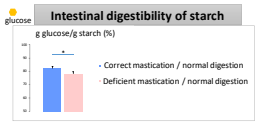
Particle size after mastication



Oral digestibility of starch



Intestinal digestibility of starch



⇨ after correct mastication, a part of the initial starch content has been hydrolyzed in maltose (dissolved in saliva)

⇨ after deficient mastication, starch hydrolysis is significantly lower
- **⇨ but normal digestion tends to balance oral deficiency to a certain limit**
- **⇨ a lack in absorption would be significant in case of combined deficient mastication AND digestion**

Mastication and nutrition

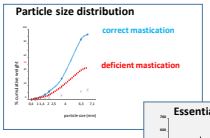
Mastication = 1st step of digestion
Impact of masticatory deficiency on amino-acids (AA) absorption

Amino acids plasma determination after correct or deficient mastication

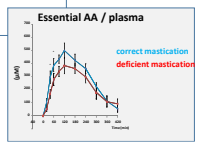
→ simulation of edentulous people

meat

Particle size distribution

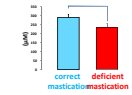


Essential AA / plasma



AUC

Postprandial plasmatic increase in essential AA



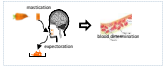
⇨ With deficient mastication, amino acids assimilation is slower and lower than with correct mastication
⇨ This is mainly due to greater particles in the swallowed food bolus limiting further digestion

Rémond and Peyron, 2013

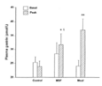
Mastication and nutrition

Mastication = 1st step of digestion due to …
Cephalic phase reflexes initiated in the mouth during food oral processing

SHAM FEEDING = Oral stimulations
but no swallowing,
no arrival of food bolus in the stomach
no digestion



Gastrin release



Robertson et al, 2001

Insulin release

Teff, 2000

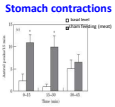
Gastric acidity

Martinez et al, 2002

Pancreatic polypeptide

Teff, 2000

Stomach contractions



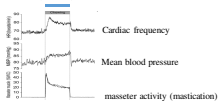
Katschinski et al, 2000

Cephalic phase reflexes aimed at preparing the digestive tract to the arrival of the food being chewed and analysed in the mouth

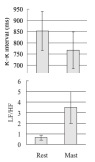
⇨ A myriad of CPRs exists
⇨ FOP gives an opportunity to the CNS to adapt the digestive tract and the metabolism to food content

Variations in cardiac frequency or energy expenditure during mastication

mastication chewing gum (5 min)



Hasegawa et al, 2007

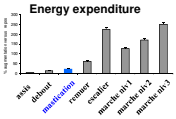


R-R decreases
→ Cardiac frequency increases

LF/HF ratio increases
Syst ortho∑ dominent
(analysis of cardiac variability)

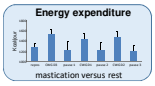
Shiba et al, 2002

Energy expenditure

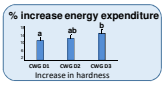


Lévine et al, 1999

Energy expenditure



% increase energy expenditure



Rousset & Peyron, 2012

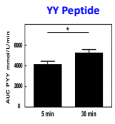
What mechanisms ? What consequences ? What role ?

- **→ energy expenditure during mastication, impact of texture / food hardness**
- **→ cephalic phase reflexes ? Autonomic nervous system ?**
- **→ in healthy human ? With pathology ?**

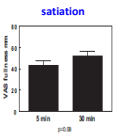
Mastication and nutrition

Mastication and satiety ?
⟶ comparison : meal ingested in 5 or 30 minutes

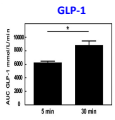
YY Peptide



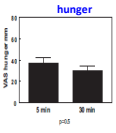
satiation

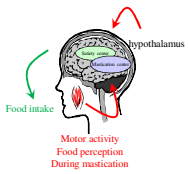


GLP-1



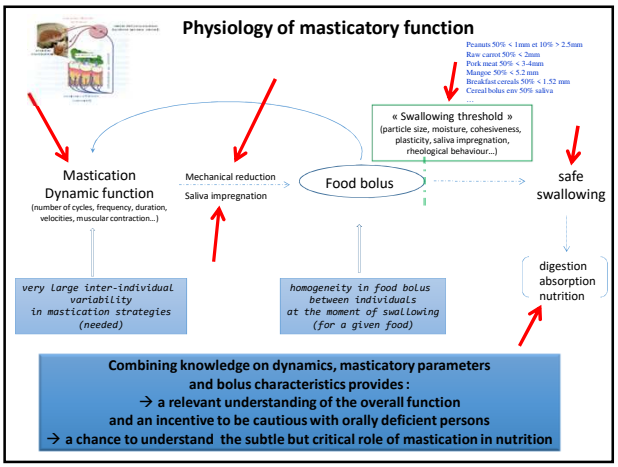
hunger

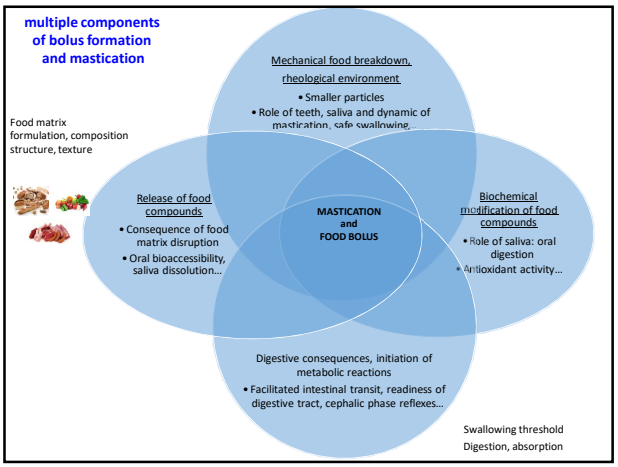


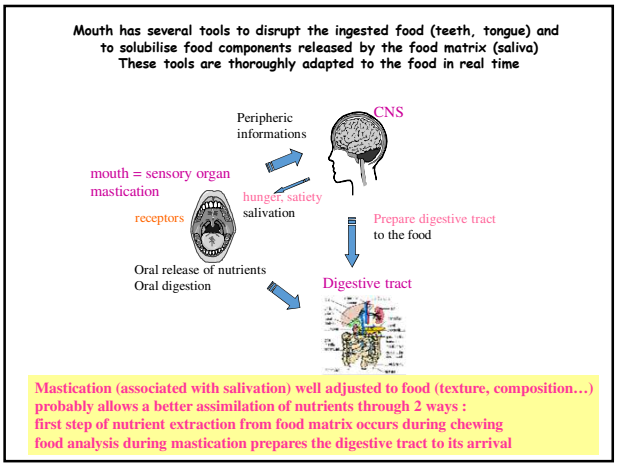


Peptides YY and GLP-1 = anorexygenic hormones

Kokkinos et al 2010


Physiology of masticatory function
Peanuts 50% < 1mm et 10% > 2.5mm
Raw carrot 50% < 2mm
Pork meat 50% < 3-4mm
Mangoe 50% < 5.2 mm
Breakfast cereals 50% < 1.52 mm
Cereal bolus env 50% saliva
...
« Swallowing threshold »
(particle size, moisture, cohesiveness, plasticity, saliva impregnation, rheological behaviour...)
Mastication
Dynamic function
(number of cycles, frequency, duration, velocities, muscular contraction...)
Mechanical reduction
Saliva impregnation
Food bolus
safe swallowing
digestion
absorption
nutrition
very large inter-individual variability in mastication strategies (needed)
homogeneity in food bolus between individuals at the moment of swallowing (for a given food)
Combining knowledge on dynamics, masticatory parameters and bolus characteristics provides :
→ a relevant understanding of the overall function
and an incentive to be cautious with orally deficient persons
→ a chance to understand the subtle but critical role of mastication in nutrition


multiple components of bolus formation and mastication
Mechanical food breakdown, rheological environment
• Smaller particles
• Role of teeth, saliva and dynamic of mastication, safe swallowing
Food matrix formulation, composition structure, texture
Release of food compounds
• Consequence of food matrix disruption
• Oral bioaccessibility, saliva dissolution...
MASTICATION and FOOD BOLUS
Biochemical modification of food compounds
• Role of saliva: oral digestion
• Antioxidant activity...
Digestive consequences, initiation of metabolic reactions
• Facilitated intestinal transit, readiness of digestive tract, cephalic phase reflexes...
Swallowing threshold
Digestion, absorption


Mouth has several tools to disrupt the ingested food (teeth, tongue) and to solubilise food components released by the food matrix (saliva)
These tools are thoroughly adapted to the food in real time
Peripheric informations
CNS
mouth = sensory organ mastication
hunger, satiety
salivation
receptors
Prepare digestive tract to the food
Oral release of nutrients
Oral digestion
Digestive tract
Mastication (associated with salivation) well adjusted to food (texture, composition…) probably allows a better assimilation of nutrients through 2 ways :
first step of nutrient extraction from food matrix occurs during chewing
food analysis during mastication prepares the digestive tract to its arrival

Thank you for your attention !
1st International Congress, Teeth, Posture and Diet, Cetraro, Italy, October, 2016