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Taste Perception in Relation to Dental Caries and BMI: A Narrative Review

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Abstract: *Taste perception is the sensory impression of food or other substances on the tongue and is one of the five traditional senses. It is the sensation produced when a substance in the mouth reacts chemically with taste receptor cells located on taste buds. Individual food preferences are important predictors of food intake and are highly influenced by taste perception and taste preference. Taste sensitivity varies widely among individuals due to the genetic polymorphisms and also the anatomical variations in the density of the fungiform papillae present on the tongue. Taste perception decreases with age.The caries experience was observed more among non-tasters compared to super and medium tasters due to overall increase in consumption of sugar rich foods by the non-tasters. Higher BMI was related to lower sensitivity to sweet taste due to the action of the hormone leptin. The higher liking for fat-and-sweet sensations has been associated with an increased risk of obesity So, preventive measures for the reduction in free sugars intake should be given importance. Hence, the purpose of this review is to discuss the significance of sense of taste, types of taste stimuli,development and aging, classification of tasters and taste perception in relation to dental caries and Body Mass Index.*

Keywords- *Body mass index, dental caries, obesity, propylthiouracil, sugars, tasters, taste perception*

I. BACKGROUND

The taste perception plays a very vital role in our life.[1]Taste and smell are unique to the individual and are perceived using chemical senses.[2] Sensory qualities of food namely the taste perception have priority in food selection, although food choices are based on a number of physiological, nutritional, environmental and socioeconomic factors.[3]A healthy diet is of importance for growth, development, and prevention of dietary-related diseases.[4]On the contrary there are various health conditions that are known to be related to dietary imbalance. These conditions include dental caries and obesity which are in turn known to affect general health. [5]

One of the dietary items known for its unfavorable effect is sugar when it is consumed above the recommended levels. Both the amount and frequency of sugar consumption may have an adverse effect on the teeth.[6]In addition, dietary habits such as frequent snacking have been related to overweight, due to the high content of fatand sugars. Obesity is increasing rapidly worldwide and is one of the most serious public health challenges in the 21st century.[7]The problem is steadily affecting many low and middle income countries, particularly in urban settings and its prevalence is increasing at an alarming rate.Sedentary life style and non-nutritive calorie consumption have triggered the obesity early in life.[8]As they age, obese subjects are found to have less sensitive taste perception unlike individuals with normal weight in whom taste is more pronounced with age.[9]

Many variables have been attributed for individual choice and prevalence of food like availability, economic, social, cultural and behavioural factors.The main driving force for food selection is its taste and sensory properties.[10]Right from the Vedic ages bitter taste has been used as an indicator of the poisonous substances or taken in smaller quantities as a medication.This bitter taste prevents such untoward incident leading to the classic refection response.[11] Thus most of us are very sensitive to this bitter taste perception, which is a safety mechanism for survival of an individual.[12]Humans have a very low threshold for this bitter taste. But sense of bitter taste is genetically controlled which is either present or absent in individual influencing their food choices.[13]

The purpose of this review is to discuss the importance of sense of taste, types of taste stimuli, development and agingof taste perception, classification of tasters and taste perception in relation to dental caries and Body Mass Index.

The sense of taste

The ingestion of food leads to a converging sensory perception which humans experience as a wide array of flavors, encoded by the sense of taste.[14]Taste perception commences when molecules from food (tastants) reach taste buds also known as then gustatory receptors. Humans usually have 5,000 to 10,000 taste buds which are mainly, but not exclusively embedded in the epithelium of the tongues surface.Some of the taste buds are also present on the palate, epiglottis, pharynx, and oesophagus.[15]In the oral cavity, about three quarters of the taste buds are found on the dorsal surface of the tongue in small raised structures called papillae. There are four different types of papillae are:[16]

- **The Vallate or Circumvallate papillae-** larger in size, 1-2 mm in diameter, 8-12 in number and situated immediately in front of the sulcus terminalis.These papillae are sensitive to bitter taste and involved in the gag reflex.
- **The Fungi form papillae**–numerous near the tip and margins of the tongue, and some are scattered over the dorsum have a mushroom-like appearance.They contain numerous taste buds on their surface that are able to discern sweetness, sourness, saltiness, bitterness and umami.
- **The Filiform papillae** - conical papillae covering the pre-sulcal area of the dorsum of tongue with a characteristic velvety appearance.They do not contain taste buds and are thus not involved in taste sensation.
- **The Foliate papillae** -four to five vertical folds on each side of the palatoglossal arch representing the vestiges of larger papillae.

Taste Bud Cells (TBCs)

According to functional and structural features, patterns of protein expression categorisedas follows**:**[7]

- **Type I cells** serve for the maintenance of the supporting structure of the taste buds;
- **Type II cells**are responsible for the perception of sweet, bitter, and umami taste via binding of tastants to G-protein coupled receptors (GPCR)
- **Type III cells** referred to as presynaptic, neuron-like cells, as they form ordinary, neuronal synapses with afferent nerve fibres at the basal side of a taste bud) release common neurotransmitters such as gamma aminobutyric acid (GABA) and serotonin (5-HT).

Types of taste stimuli

Taste is one of the chemosensory systems. Taste stimuli interact with taste receptor cells in the oral cavity. This information is processed by the brain, which generates taste perception. The various aspects of taste perception are: intensity, hedonics (pleasantness or unpleasantness) and quality.[17]Taste sensation can be categorized as sweetness, sourness, saltiness, bitterness, and umami. These basic tastes can either have a stimulatory effect and encourage intake (sweet, salty, and umami) or inhibit it (bitter and perhaps sour).[7,18]

- ***Sweet taste:*** Sweetness is evoked by sugars and a wide range of other chemicals (e.g. some sugar alcohols, glycosides, amino acids and proteins), which are often described as sweeteners. A heterodimer of the T1R2 and T1R3 proteins functions as the main sweet taste receptor.
- ***Salty taste***: Hedonic responses to salt taste depend on species, genotype, stimulus concentration and physiological state of individuals. At high concentrations, normally salt solutions are avoided, whereas lower concentrations are preferred relative to water.
- ***Sour taste***: Acids such as HCl or citric acid evoke sour taste. The polycystic kidney disease-1 and -2 like genes, Pkd1l3 and Pkd2l1, are the proposed candidates for sour taste receptors.
- ***Bitter taste***: Bitter-tasting stimuli naturally elicit reactions of disgust and rejection. This taste quality is likely to be evolved as a mechanism for avoiding toxic foods. The gene T2R is responsible for bitter taste perception.
- ***Umami taste***: The word 'umami' was invented about a century ago by a Japanese chemist, Dr.Kikunae Ikeda, to describe taste of glutamic acid and its salts, which evoke a taste sensation distinct from the four known taste qualities. 'Umami' is a combination of two Japanese words: 'umai' (delicious or savory) and 'mi' (taste). A heterodimer of T1R1 and T1R3 proteins functions as an umami taste receptor.

Development and aging of taste perception

Taste buds appears very early in the tongue of human foetus, at 7 to 8 weeks of gestation, but mature appearing taste buds are not observed until later in gestation .Development is not complete at birth and taste bud numbers continue to increase.[15]

Behavioral testing of human newborns reveals that the ability to discriminate between taste stimuli is present at birth, indicating that some attributes of taste preference behaviour are innate and do not require any experience for expression.[7] However, other studies have demonstrated that although these taste behaviours are present at birth they can be extensively modified by postnatal experience.[17]Studies reveal that taste perception fades with age leading to decreased taste sensitivity among the elderly due to the decrease in the density of the fungiform papillae on the tongue.[5]

Classification of tasters

Reports that humans vary in taste ability dates back to 1931 with the dual discovery of 'taste-blindness' for thiourea compounds which includes PROP and PTC, and the heritable basis for this trait.[12]Depending on the phenotypic pattern of PROP tasting, population can be categorized into three subsets[19] as

1. Supertasters,
2. Medium tasters
3. Nontasters

At the molecular level, the inheritance of this trait is dueto the presence of a major locus gene called TAS2R38 (TAS = TASTE, Family = 2, R = receptors, Member: 38), which is responsible for the taste of PTC and a number of other similar substances.[20]Since supertasters can perceive taste in a lower concentration of bitter or sweet substance than nontasters, food products with strong tastes may be perceived as too strong or unpleasant for supertasters. In contrast, nontasters might not be able to perceive the sweet or bitter taste in the same concentration as supertasters and hence, require a higher concentration to perceive taste in the food

products.[21]Nontasters may have a higher concentration and frequency of sugar intake compared to those who are medium tasters or supertasters and are, therefore, more susceptible to dental caries.[10]

Among Caucasians of Western European ancestry, the approximate population distribution of PROP taster groups (based on PROP bitterness intensity ratings) is: 30% non-tasters; 45% medium tasters; and 25% super-tasters (Bartoshuk et al., 1994; Tepper et al., 2009). However, the prevalence of non-tasters varies across the globe from a low of ~10% in East Asian populations to approaching 50% in some South Asian groups.[22]

Taste perception and dental caries

Genetic taste sensitivity and taste thresholds have been used to identify the caries risk at an early stage. The drug Propylthiouracil(PROP) is widely used to test the genetic sensitivity of the individuals in eliciting response to taste on a hedonic scale.[23]Sensitivity of PROP is known to be a reliable test in assessing the genetic sensitivity to bitter taste. Genetic sensitivity to bitter taste might be associated with the preference for or rejection of some foods by children.PROP is a medication used in the treatment of Grave's disease (hyperthyroidism).[5]

PROP tasters are more sensitive to many oral sensations, including bitter and sweet taste and the sensation of fats.[19]PROP tasters were more likely to dislike the taste of sweet solutions, whereas non-tasters were almost always those with a sweet preference. Tasters are more sensitive to sweetness, and they perceive lower concentrations of sugars to be sweeter and they also tend to dislike intensely sweet foods.[10,24]Overall dental caries status (mean DMFT/ dmft index value) was significantly larger for non-tasters compared to super-tasters.[10] This could be due to overall increase in consumption of sugar rich foods by non-tasters .There is a relationship between the phenotypic patterns of PTC tasting and tooth decay, especially among children in the school age.This trait could be used as a sign of early childhood caries (ECC) diagnosis.[21]

Parents modeling of food consumption can have a powerful effect on their child's consumption. A study by Johannsen et al, 2019 confirmed the influence of parents eating behavior of their children. In addition, using sugary snacks as reward have shown to increase the child's preference for that food. It is possible that a mother's taste preference may influence what the child is fed with, which in turn reflects the dental caries risk of the child.[25] Knowledge of an individual's taste threshold can be a useful screening tool and thus facilitates the identification of those who are at high risk for developing dental caries.[26]

Taste perception and Body Mass Index

Obesity is a state of excess adipose tissue mass .Obesity is often expressed in terms of body mass index. An individual's BMI is important in the determination of potential future health issues and has been widely used as a factor in the determination of various public health policies.[27]

Taste sensitivity and taste liking have been associated with weight status and BMI. Higher BMI is related to lower sensitivity to sweet taste .The higher liking for fat-and-sweet sensations has been associated with an increased risk of obesity. Studies have also reported the relationship between genetic sensitivity to bitter taste and BMI. There were more number of non-tasters in overweight category as compared to super-tasters and medium tasters.[28]Longitudinalstudies have shown that adolescent sweet taste perception is associated with BMI at both adolescence and early adulthood.This association is partly explained through their genetic overlap. The children consuming more sweets in the adolescence had high BMI in both adolescence as well in early adulthood leading to obesity.[29]

Certain kids programme of food promotions encouraged children to take high density caloric foods and hence made them obese. At least half of food advertisements during children's television programming were for energy-dense low nutrients foods such as candy, snacks, soda and fast food. [21]Eating while watching television also often leads to overeating . A few studies have noted that school eating patterns, school lunch choices begin to influence children's overall diet.[2]

Altered sense of taste in obesity

Obesity is linked to alterations in taste sensitivity accompanied by changes in food intake. In addition to genetic factors, nutrients such as long chain fatty acids (LCFAs) or caffeine have been related to the mRNA expression of taste receptor genes. Moreover, hormones, cytokines and their receptors have been found to be involved in mediating taste signaling in taste cells.[8]

Hormonal modulation of the sense of taste in obesity

Hormones can modulate the sense of taste. Leptin acts via binding to its obese receptor (Ob-R) in type II TBC and interferes with local KATP channels . The activation of KATP channel results in reduced sweet response signaling to the afferent nerve fibre in the taste cell and dampens sweet perception.[7]

The taste receptors have been found in the brain and play a fundamental role in regulating energy metabolism. Highest expression levels have been demonstrated for T1R3, T1R2, T2R11 Moreover, leptin but also glucose had an effect on gene expression level of sweet taste receptors in murine hypothalamic neuron derived cells. It indicates that taste receptors in the brain are involved in recognizing and sensing energy status and might be implicated in the control of energy homeostasis.[30]

Effect of Artificial Sweeteners Use on Sweet Taste Perception and weight loss efficacy

Taste influences eating behavior and the desire to eat certain products, which is related to the total energy provided to the body with food. Non-nutritive sweeteners (NNS) are hundred to thousand times sweeter than sucrose. Most NNS approved for use are derived synthetically. Due to their intense sweetening power, NNS used in small amounts can significantly reduce the energy value of products and simultaneously maintain their palatability.[31]

Due to physiological differences in the perception of sweet taste after consumption of NNS and their diverse effect on hunger and satiety centres, it has been assumed that the ingestion of foods containing NNS may not be an effective method to reduce energy intake for weight loss.[28]Moreover, it has been suggested that frequent exposure to NNS may even increase appetite for sweet foods. This fact seems to be an important goal in treating obesity because an inverse correlation between body mass index (BMI) and sweet taste sensitivity has been observed among overweight individuals. Obese individuals have lower sensitivity to all primary tastes than normal-weight individuals. [15]A lower sweetness detection threshold may lead to greater sugar and carbohydrate-rich foods consumption.[32]

Taste perception in association with dental caries and BMI

Inherited behavior and taste threshold play an important role in the frequency of carbohydrate intake.[12] Genetic sensitivity to taste is associated with the preference or rejection of some foods by children. In clinical practice, the bitter taste of PROP was found to be a consistent factor for assessing genetic taste sensitivity levels, which is influenced by TAS2R38 gene.[16]

According to the literature, in majority of the studies there were more number of non tasters in overweight category and a significant relationship was found between taste perception and nutritional status of the participants (BMI). Tastes perception of an individual can be assessed chair side by using PROP squares. It gives us an indication of how ability to perceive taste sensation plays a pioneering role in food choices.

II. Limitations

- Stimuli were designed to mimic the real world foods wherein sensitivity may vary with different types of sweeteners (e.g., Fructose, sucrose) and fat (erg, fatty acids).[5]
- The taste perception test for fats included solutions of different fatty acids instead of single type, which did not allow differentiating whether the participants made decisions depending on basic taste (fatty acid) or other textural properties of the solutions.[31].
- The preference for sweetness, total amount of sugar and frequency of intake were not recorded which can significantly affect the dental caries severity.[13]
- The variables such as racial, ethnicity, dental caries risk and protective factors(fluoridated drinking water, saliva flow rate) can significantly affect dental caries.[11]
- Self-reported BMI might produce measurement bias as the participants tend to slightly overestimate height and underestimate weight.[6]
- Not only factors related to taste perception could lead to weight gain, personality traits such as food neophobia which manifest itself as a limited variety of food in the diet, can result in higher BMI.[27]
- Studies have not recorded the directionality of association between taste perception and BMI.[21]
- The studies conducted in children below 5 years with low cognitive abilities could not assign the taste qualities correctly.[25]

Recommendations

- Studies should focus on factors affecting food preferences, energy intake in diet and behaviours in oral health to help design dietary plans and help control obesity.[5]
- Better tools and instruments are required to assess the taste perceptions more accurately and conveniently.[12]
- Longitudinal studies are needed to investigate whether the taste perception in children is influenced by changes in the oral microbiome after complete dental restorations.[5,8]
- Further research to explore the association between taste perception , dental caries and BMI with detailed geographic information about fluoride exposure and residence history is required.[21]
- Further studies are required to evaluate the association between hormonal factors and taste perception, dental caries and BMI.[9,16,23]
- Initiatives on restrictions of intake of free sugars such as taxation for sugar sweetened beverages or incentivising the purchase of healthy food and its association with oral health will be a boon for public health.[6]

The studies suggest that the type of taste perception , food preferences, the density of fungiform papillae and the genetic sensitivity for taste perception influence the development of dental caries and obesity. These studies also confirm the effect of sugary diet on the development of dental caries and obesity. Hence preventive measures for the reduction in intake of free sugars should be given importance.

III. Clinical significance

Dentists and other health care providers can assess for the chair side taste perception, as it will help to augment their knowledge while delivering treatment plan and preventive strategies, thus helping children in balancing the tipped scales of BMI issue due to food choices.The dental professionals have a significant role in diet counselling of the parents to provide low-sugar diet and healthy foods like vegetables, thus improving the general health of the children. It can provide the primary health care providers an insight into the genetic makeup of the child and thus plan treatment and preventive strategies leading to restore optimum health. This approach can minimize the morbidity associated with dental caries and obesity. In addition, oral hygiene measures and appropriate use of fluorides are effective intervention for caries prevention.

IV. Public Health Significance

Policy makers can work to introduce a range of measures involving both upstream and downstream approaches to reduce the excessive intake of added sugars. These approaches include fiscal pricing policies and regulation of marketing of products high in free sugars, restriction of advertising, introducing standards for school meals that include limits on free sugars andincentivizing the purchase of healthy food. Nutritional labelling of foods forms an important part of education for both health professionals and consumers. Maternal and child oral health programs and schools should incorporate combined nutrition and oral health interventions to promote the nutritional diet, oral hygiene and dental service.

V. CONCLUSION

Taste perception can be used as an important screening tool for the caries risk assessment and the nutritional status. Advanced tools for the accurate measurement of taste sensitivity leading to excessive sugar and fat consumption have to be developed. By promoting healthy dietary environment and restricting the consumption of foods with added sugars and fats the risk of dental caries and obesity among children and young adults can be reduced.

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