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A novel colourimetric technique to assess chewing function using two-coloured specimens: Validation and application

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ABSTRACT

Objectives: Chewing efficiency may be evaluated using cohesive specimen, especially in elderly or dysphagic patients. The aim of this study was to evaluate three two-coloured chewing gums for a colour-mixing ability test and to validate a new purpose built software (ViewGum©).

Methods: Dentate participants (dentate-group) and edentulous patients with mandibular two-implant overdentures (IOD-group) were recruited. First, the dentate-group chewed three different types of two-coloured gum (gum1–gum3) for 5, 10, 20, 30 and 50 chewing cycles. Subsequently the number of chewing cycles with the highest intra- and inter-rater agreement was determined visually by applying a scale (SA) and opto-electronically (ViewGum©, Bland–Altman analysis). The ViewGum© software determines semi-automatically the variance of hue (VOH); inadequate mixing presents with larger VOH than complete mixing. Secondly, the dentate-group and the IOD-group were compared.

Results: The dentate-group comprised 20 participants (10 female, 30.3 ± 6.7 years); the IOD-group 15 participants (10 female, 74.6 ± 8.3 years). Intra-rater and inter-rater agreement (SA) was very high at 20 chewing cycles (95.00–98.75%). Gums 1–3 showed different colour-mixing characteristics as a function of chewing cycles, gum1 showed a logarithmic association; gum2 and gum3 demonstrated more linear behaviours. However, the number of chewing cycles could be predicted in all specimens from VOH (all $p < 0.0001$, mixed linear regression models). Both analyses proved discriminative to the dental state.

Conclusion: ViewGum© proved to be a reliable and discriminative tool to opto-electronically assess chewing efficiency, given an elastic specimen is chewed for 20 cycles and could be recommended for the evaluation of chewing efficiency in a clinical and research setting.

Clinical Significance: Chewing is a complex function of the oro-facial structures and the central nervous system. The application of the proposed assessments of the chewing function in geriatrics or special care dentistry could help visualising oro-functional or dental comorbidities in dysphagic patients or those suffering from protein-energy malnutrition.

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1. Introduction

Mastication is a complex function of the oro-facial system and the central nervous system. It involves numerous structures like teeth, palate, tongue and cheeks as well as neural pathways and reflexes to guide the mandibular force and movement through muscle control.[1] The goals of mastication comprise fragmenting food stuffs to increase the surface area and mix the aliment with saliva in order to form a bolus that is safe to swallow.[2] Besides these functional aspects, the mastication plays an important psychosocial role especially late in life when enjoying meals becomes one of the principal pleasures.[3]

The chewing process might be compromised by several factors. Most commonly, the lack of teeth or saliva as well as reduced muscular forces is associated with an impaired chewing function.[4] This oral impairment might have considerable influence on the individual's well being. Furthermore, food choice and nutritional intake are closely related to the chewing efficiency.[5] Tooth loss contributes essentially to the impairment of chewing function, hence edentulous persons suffer from a well-documented significant oral handicap which cannot fully be compensated by dental interventions.[6]

In the context of geriatric and special care medicine and dentistry it seems to be imperative to have methods at hand which allow for easy, simple and quick evaluation of the chewing function. Impaired chewing and bolus formation might have a significant impact in this fragile population, because of poor motor control, reduced sensitivity and a high prevalence of dysphagia. Consequently, elderly persons are at risk for chewing related protein-energy malnutrition.[5] For the evaluation of the masticatory process one has to distinguish between chewing ability and chewing efficiency/performance. Chewing ability refers to the subjective perception,[7] yet very old persons tend to overestimate their performance.[8] Objectively assessed, the term ''masticatory efficiency'' is defined as the ''effort required achieving a standard degree of comminution''.[9] An approach firstly described by Gaudenz in 1902, the chewing efficiency relates to the particle size of a test food which is evaluated after a defined chewing sequence.[10] Nowadays test foods like silicon cubes or peanuts are used. The resulting fragments are analysed by sieving or opto-electronical methods to evaluate the particle size distribution *D*50.[11] Fragmenting tests are still regarded as the gold standard when it comes to assessing the masticatory efficiency; however they present some inherent inconveniences. The sieving method requires specialised equipment, which makes it expensive and cumbersome. Further, the comminuted specimen needs to be collected *in toto* after chewing, which can be challenging if the particles are very small and the mobility and sensitivity of the oral structures are reduced. Small particles may furthermore constitute an aspiration risk in dysphagic patients. Hence comminution tests are little suited for a clinical setting like a geriatric ward and alternative methods using cohesive specimen such as coloured chewing gums or wax have been proposed.[12–14] Here, a two-coloured sample is masticated for a given number of chewing cycles and the resulting bolus is evaluated either visually on a reference scale or opto-electronically. These techniques evaluate both the colour-mixing ability and the capacity to form a bolus. It was demonstrated that colour-mixing tests correlate significantly with the sieving method, especially in patients with impaired masticatory function,[15] yet the ideal specimen has not yet been identified.

The aim of this study was to evaluate three two-coloured chewing gums for a colour-mixing ability test and to validate a new purpose built software (ViewGum©). The following hypotheses H0 were tested:

i. The new opto-electronic colourimetric method cannot detect different degrees of colour mixture in three two-coloured chewing gums.
ii. A simple visual test cannot discriminate dental states.
iii. The new opto-electronic colourimetric method is not able to discriminate different oro-dental conditions and serves to evaluate chewing efficiency.
iv. The parameters gender, age and maximum voluntary bite force are no additional predictors of chewing efficiency when measured with two-coloured chewing gums.
v. A simple mathematical correlation does not exist between the chewing efficiency obtained with different types of specimen.

2. Material and methods

2.1. *Inclusion and exclusion criteria*

Participants were recruited to form two groups, a dentate-group representing ''ideal chewers'' as well as an edentulous-group (IOD-group) with a presumed impaired chewing function.[16] The inclusion criteria for the dentate-group comprised an age between 18 and 40 years, having at least 26 teeth, a maximum DMFT (decayed missing filled teeth) score of 4 and an Angle Class I occlusion. They all perceived their chewing ability as normal. The IOD-group had no age limit; here the participants had to have clinically acceptable conventional upper dentures and two-implant overdentures in the mandible. Exclusion criteria were the presence of oro-facial pain, signs of severe TMD dysfunction or neuromuscular disorders.

2.2. *Specimens*

As a control, the ''Hubba-Bubba Tape Gum'' (gum1, The Wrigley Company Ltd., England) was selected, because it is well documented and widely used since its introduction in 2007.[13] Unfortunately the company discontinued the production and now produces the gum without artificial colourings; hence it became unsuitable for colourimetric evaluation. For the current study, residual strips of the original gum were cut from pink and azure colours in the dimensions of 30 mm × 18 mm × 3 mm and prepared according to the original protocol.[13]

The second type of specimen was developed and produced specifically for assessing masticatory performance for research purposes (gum2, Lotte™, Tokyo).[17] It was developed for the *8020 Promotion Foundation (Japan)* to be similar to gum1.[13] It is composed of two individually packed gum beads, which are manually stuck together (18.8 mm × 14.2 mm × 3.9 mm).