

ORAL STEREOGNOSIS: A LITERATURE REVIEW

¹B.Sivapathasundharam, ^{2*}Protyusha Guha Biswas

¹Professor and Head, ²Assistant Professor

^{1,2}Department of Oral Pathology and Microbiology, Meenakshi Academy of Higher Education and Research Faculty of Dentistry Meenakshi Ammal Dental College and Hospital, Chennai, India.

E-mail of corresponding author: drprotyusha.oralpathology@madch.edu.in

ABSTRACT: *Stereognosis refers to the ability to identify and discriminate the form of an object solely based on the sensation of touch. Similarly, oral stereognosis is the capability of an individual to discern the form and shape of an object inside their oral cavity without any visual assistance. The oral stereognostic ability evaluates the oral functioning of an individual and also determines the response of patients towards various dental therapies. This is accomplished by the association of more than one group of mechanoreceptors that are located on several oral structures. Oral stereognostic testing greatly depends on the design of the experiment, since both the method and the material used for this kind of studies dramatically influences its result. The subject of oral stereognosis is closely linked with the overall oral health of an individual and their treatment per se, and needs wide exploration. This review is thus an attempt to comprehend the various aspects of oral stereognosis and provide clearer guidelines for further research in this field.*

Keywords: *Stereognosis, Oral stereognosis, Oral cavity, Mechanoreceptors, Oral stereognostic ability, Dentistry*

INTRODUCTION

Stereognosis, variously described as haptic perception or tactile gnosis, is the potential of an individual to recognise and discriminate the form of an object solely based on tactile sensation sans any visual or auditory cue.^[1] The word stereognosis comes from the Greek words “stereo” meaning solid and “gnosis” implying, knowledge. ^[2] Stereognosis helps in assessing the efficiency of the functioning of the central nervous system.^[3] Manual stereognosis involves interpretation of an object placed on an individual’s hand based on their ability to perceive and integrate various sensory modalities without any visual aids. The efficacy of one’s manual stereognostic ability depends on a sound peripheral sensory pathway, to receive discriminative touch and proprioceptive information along with functioning processing centres in the cortex of one’s parietal lobe.^[2]

Oral stereognosis, first described by Berry and Mahood in 1966, refers to the neurosensorial ability of the oral mucous membrane to interpret the form and shape of an object without any visual assistance.^[4] This inference of oral perception can be obtained by assessing one’s oral stereognostic ability (OSA) via stereognostic tests, a concept popularised by Grossman.^[4] Thus, stereognostic tests can be used to determine the oral functioning of an individual. This unique concept has garnered particular attention in several aspects of dentistry over the years. The ability to judge the form of an object by oral exploration, or in some cases, the failure of it, may thus help in providing useful insights into the nature of oral sensorimotor mechanisms and the effect of dental therapies on oral tissues.

MECHANISM OF ORAL STEREOGNOSIS

In the human body, the tissues of the oral cavity are one of the most intensely innervated. They contain a large number and variety of receptors on their surface namely mechanoreceptors, proprioceptors and nociceptors which meet inside the mouth to transduce various stimuli into electrochemical signals of the brain.^[5] Mechanoreceptors in the mouth detect tactile sensations which is the basis for oral stereognosis. They are specialised neurons involved in transmission of a multitude of signals regarding various sensory functions such as touch, pressure and proprioception to the brain via electrical signals.^[6] The oral tissues such as tongue, cheek, gingiva, periodontal ligament and the palate are richly innervated by these mechanoreceptors. Merkel's disks, Meissner's corpuscles, Ruffini endings and Pacinian corpuscles are the four primary kinds of tactile mechanoreceptors. The sensory nerves supplying to these mechanoreceptors provide substrate for any sensations in the oral mucosa.^[7]

Detection of a stimulus leads to activation of the sensory receptors, a feature called sensation. This produces a graded potential. If strong enough, this graded potential generates an action potential using an ion channel, which then travels to the central nervous system where there is active perception and processing of the sensory stimuli into a meaningful pattern.^[6]

The oral tactile information, which is key to OSA, is transported to the brain via the trigeminal nerve. The sensory nerve fibre from the periphery reaches the trigeminal ganglion in the middle cranial fossa via the three divisions of the trigeminal nerve: ophthalmic, maxillary and mandibular. From the ganglion, these nerves then pass centrally to reach the trigeminal nuclei located in the brainstem at the level of pons, finally ending at the thalamus and cortex (Figure 1).^[8] Naturally, the somatosensory cortex becomes the prime destination of all the oral afferent signals with regards to one's somatosensory awareness. It can be divided into primary and secondary somatosensory cortex. The primary somatosensory cortex is a strip extending mediolaterally behind the central sulcus of the brain comprising of Brodmann areas 1, 2, 3a and 3b, the activation of which is pivotal in the handling of tactile information.^[9] The secondary somatosensory cortex, on the other hand, is a region of the cortex in the parietal operculum above the lateral sulcus (Sylvian fissure) that responds to rare and complex somatosensory stimuli.^[10,11]

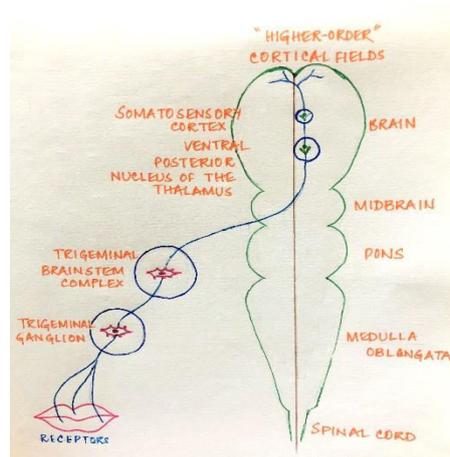


Fig 1: Pathway of oral tactile response

The sensory abilities vary greatly across the different oral structures depending on the concentration of sensory afferent nerve endings in each of these tissues. In tongue, the anterior part and the tip is more sensitive than the posterior part, similarly the middle portion shows greater sensitivity than the lateral parts.^[12,13] It is richly innervated by different mechanoreceptors at a superficial and deep level. The superficial mechanoreceptors are usually fast adapting and are known to have an exclusive role in exteroceptive tactile

recognition and haptic exploration of objects intraorally. Additionally, they are also crucial for “self-touch”, where the tongue is contacted with other tissues inside mouth, for sensory exploration. The deep mechanoreceptors, however, are mostly slow adapting and have more proprioceptive qualities than tactile.^[7,12] The middle portion of the palate has sparse presence of mechanoreceptors than its posterior part, especially near the anterior uvula.^[14] Furthermore, the periodontal ligament supporting the teeth, are attributed to their tactile function.^[15] Apart from the distribution of mechanoreceptors in other oral tissues including lips, buccal mucosa and gingiva, presence of these receptors can also be seen in the temporomandibular joint. However, these mechanoreceptors are primarily responsible for proprioceptive sensation of the lower jaw position and hardly contribute to the intraoral sensations.^[16] Studies have stated that in normal individuals, the two-point stimulation is highest in the tip of the tongue, followed by fingertip, lip, soft palate and alveolar ridge in that order.^[17]

ORAL STEREOGNOSTIC TESTS

Stereognosis is not merely the detection of tactile stimuli; it is a far more complex process and involves different other factors and components. Similar to manual stereognosis which finds application in neurology, hand therapy and neuropsychology; oral stereognosis can be beneficial in determining the oral functioning and assess the outcome of oral therapy.^[18,19] Oral stereognostic test involves tactile-kinaesthetic identification of an object's form, placed inside the subject's mouth, sans visual assistance. It is essentially a neurophysiological testing of the trigeminal system in humans which is extremely scarce owing to the difficulty in isolation of its peripheral branches. Psychophysical approaches have thus been developed as an alternative, which when performed in a standardised manner, yields the same result as that of the neuro physiological receptor function test.^[20] Berry and Mahood attempted to develop a standardised procedure for oral stereognostic test in terms of size, material, shape and number of test objects.^[4] Different approaches and modifications of the form and material of the test items have thereon been implemented over the years by various researchers with varied outcomes, without adhering to a standard methodology (Figure 2).^[21]

A range of 20 shapes has thus been formulated by the National Institute of Dental Research for a proper and uniform evaluation of OSA (Figure 3).^[22] However, despite the methodology, it is noteworthy that the nature of sensory psychophysical testing is subjective and it depends on several variables of the experimental set up.

SERIAL NO.	REFERENCE	TEST FORMS	MATERIALS
1.	Berry and Mahood		Acrylic resin
2.	Shelton et al.		Plastic
3.	Litvak et. al.		Metal alloy
4.	Van Aken et al.		Plastic
5.	Garrett et al.		Raw carrot
6.	Jacobs et al.		Acrylic resin

Fig 2: Form and material used for the test items in various studies

TEST FORMS DEVELOPED BY NATIONAL INSTITUTE OF DENTAL RESEARCH

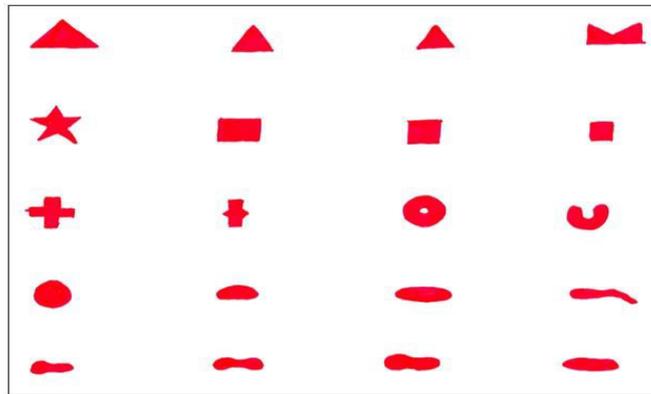


Fig 3: Range of shapes of the test objects developed by the National Institute of Dental Research

Test Environment

Stereognostic test conducted in a noisy environment may not be authentic, as background noises or sound from an instrument while placement of an object inside the mouth may act as a hint to the subject leading to change of interpretation.^[21] Therefore, it should be ensured that the psychophysical testing is conducted in a silent, comfortable room with steady illumination to eliminate any distracting noise.

Examiner

Oral stereognostic tests are no exception to the popular saying “too many cooks spoil the broth”. Multitude of investigators bring about a lack of standardisation, as inter examiner variability is crucial in oral stereognostic testing.^[23] Differences seem likely to occur during recording the identification time of the test pieces. Some examiners may be quicker in placing the material inside the subject’s mouth or in recording the identification time than others. In order to eliminate these problems and ensure accuracy of the test results, the observations should be done by a single examiner with complete focus both from the examiner as well as the subject. Furthermore, a standard set of instruction should be given to the subjects before starting the test in a simple clear language. The examiner should encourage the subjects to remain calm through the process and make it clear to them that there are no grades for it, in order to take any kind of pressure off them.

Test Pieces

Standardisation of test pieces is extremely important for recording the identification time as well as for maintaining the quality of responses from the subjects. Universally agreed forms of test pieces should be chosen with general characteristics including straight lines, curves (concave and convex), angles and simple measurements of length and width.^[4,24] In addition, two other important factors of each of the forms are intelligibility (ease of recognition) and confusability (level of confusion in terms of similarity of forms). An ideal test piece should have a moderate intelligibility and confusability value. While the level of difficulty may vary from one subject to another, it is advisable to use relatively simple form, as challenging forms may certainly increase the time required for identification of the objects and pose difficulty in verbalisation.^[25]

The test pieces should be formulated with an inert, non-toxic material. They should preferably be odourless, with no taste or at least, a pleasant one. Various materials have been used in oral stereognostic tests such as metals, acrylic resin, wax, plastic and raw carrot. ^{[4,21,26-}

^{30]}While raw carrot seems like a wise choice given its odourless and harmless nature, metal pieces have not been well tolerated by several subjects. ^[3]The pieces should have rounded edges to avoid any injury to the oral tissues. The patient should be carefully made to sit in a manner so as to avoid accidental aspiration.

The thickness of the test pieces should ideally be about 4 mm, and length of 10 mm. Flexible objects are unidentifiable. In case of using raw carrot as a test piece, stainless steel punches may be used for their uniform cutting. The pieces may be placed on the dorsum of the tongue using a tweezer or a toothpick may be inserted into the pieces for easy placement between the opposing teeth. ^[21,22]Placing the object between the opposing teeth facilitates greater oral perception of the pieces by manipulation between the teeth, tongue and palate. However, in cases of subjects with anterior open bite, cross bite or mouth breathers, it is rather feasible to place the piece directly inside the mouth.

Too many test pieces are to be avoided as it may tire the subjects, however they should be adequate to gauge the stereognostic ability of the study subject.

A sheet or a computer screen must be shown to the subjects illustrating the shapes of the test pieces in their normal and enlarged sizes in order to facilitate the recognition after the test. ^[3]

Scoring

Various scoring methods are using for recording the stereognostic ability of the study subjects.

THREE POINT SCALE

This method involves classifying the responses into three categories: correct, partially correct and incorrect. ^[32]Correct response is when the subject describes the test piece as accurately as the presented one; it can be called incorrect when the test piece is described completely different from the original one while a response may be considered partially correct when the subject describes an object having some resemblance to the presented one. The scoring for a correct, partially correct or incorrect response may be noted as 2, 1 and 0 respectively. ^[32]Alternatively, it can even be scored as 1, 2 and 3 for every correct, partially correct or a wrong response. ^[31]

AVERAGE IDENTIFICATION OF ERRORS

In this method, the responses are simply marked as correct or incorrect. Following this, the score is calculated by recording the average or percentage of all the correct and incorrect responses. ^[25,27,28,30,33]

AVERAGE IDENTIFICATION TIME

Here, the identification time for each test piece is recorded, irrespective of its accuracy. However, it is not just the identification time that is important in evaluating one's stereognostic ability, it is the entire identification process. ^[25, 33]

Patient

There are several factors regulating the test from the subject's purview. The psychological factors include the attitude of the subjects, their concentration as well as their anxiety levels. Every subject is different in their way of handling the test; some may be more enthusiastic in their participation than others while some may approach it with a preconceived notion about the process. The test pieces used may not be liked by some and may thus yield careless

responses. Some subjects may over process the stimulus while some may not exactly be suggestible with their responses unless absolutely sure about them.^[21] On the other hand, the physical factors such as the subject's age, gender, oral habits and dental status play vital roles in determining their stereognostic ability.^[21]

Age

Neurophysiological studies reveal that with increasing age, a decline in the conduction velocity of nerve impulses is evident.^[34] The oral sensory function shows deterioration after 80 years of age; the differentiative efficiency between a tactile and a vibratory stimulus declines on the upper lip while the two-point discriminative ability is known to reduce on the lips, cheek without any effect on the tongue or palate.^[35] Studies by several researchers have revealed that compared to the younger (21-26 years) individuals, elderly (60-70 years) individuals require 80% more identification time.^[25] Three times greater identification errors are seen in elders while younger subjects have a faster learning capacity. Not only sensory but even oral motor abilities show considerable decline with increasing age.^[25]

Gender

There does not seem to be a significant influence of gender on their stereognostic ability.^[36] However, females seem to distinguish subtle changes in their lips, cheek and chin positions better as compared to males.^[37]

Dental status

Dental status invariably affects oral stereognosis. Partial or complete loss of teeth leads to alteration in the oral function of an individual.^[28] Several cross-sectional studies have been conducted to establish the effect of dentition on OSA mostly using subjects with complete natural dentition as control.^[4,21,26-30] When comparing with complete denture subjects, far greater stereognostic ability was noted in subjects with natural dentition due to their ease of free oral exploration of the test piece.^[28] However, after 60 years of age, no significant difference between the two categories was noticed due to general loss of oral sensation with age.^[34]

Denture wearers show poorer response to oral stereognostic tests after removal of their dentures. Furthermore, dissatisfied patients with numerous complaints during denture insertion show higher levels of oral perception than the satisfied, happy patients. However, the relationship between patient satisfaction and their adaptation to complete dentures remain unclear.^[17,22] It is also interesting to note that the OSA in diabetic patients with complete denture is lower than non-diabetic denture wearers. This may be due to the altered sensation in diabetic patients owing to complications such as diabetic neuropathy and microcirculatory disturbances.^[38]

Studies done to compare the OSA of patients before and after their rehabilitation with implant supported fixed prosthesis show a significant decrease in identification time and error as compared to complete dentures.^[29]

A crucial role is played by the periodontal receptors and tongue in determining the stereognostic ability in dentate subjects. Therefore, a bilateral mandibular nerve block reduces their efficiency by about 20%.^[39]

Individuals with oral habits such as tongue thrusting leading to anterior open bite show a decreased level of OSA.^[40] Improper musculature balance owing to tongue thrust may affect the discriminatory capability of tongue, reflecting its impaired sensitivity and mobility. This, coupled with lack of contact between opposing anterior teeth in open bite leads to reduced oral sensory perception.^[40] Missing anterior teeth in otherwise natural dentition could also show reduced oral perception.^[28] Individuals with skeletal deformities such as prognathic or

retrognathic jaws; dental deformities such as cross bite, severe retrognathic teeth, proclined anterior teeth; or with conditions like tongue tie and mouth breathing, have disharmony between their tongue and perioral muscles and hence may show a deficiency in their OSA.

Although there is no direct relationship between one's stereognostic ability and their masticatory performance, individuals with better masticatory ability scored remarkably higher in tests that compared OSA among denture wearers.^[26]

The OSA is of greater importance in complete denture wearers rather than occlusal force. It even affects their intake of green and yellow vegetables.^[41] In edentulous patients, due to the absence of periodontal receptors of teeth and even the palate being covered by denture, it becomes the sole responsibility of the tongue to perceive food including yellow and green vegetables which lack cohesiveness and elasticity.^[42] This becomes challenging and thus, adult denture wearers tend to avoid the intake of vegetables, leading to a deficiency of essential nutrients and antioxidative vitamins among them.^[42]

ORAL VERSUS MANUAL STEREOGNOSIS

Although both manual as well as oral stereognosis is used for neurologic evaluation of the central nervous system and both activates the supramarginal gyrus, there is however no clear relationship between the two. Both shows a similar pattern of processing in the somatosensory system. Somatosensation occurs in the primary cortical areas while somato perception in more posterior parietal regions.^[43,44] However, there exist certain differences in the activation process between the two. Oral stereognosis activates the insula much more than manual stereognosis, probably causing a stronger affective (pleasant or unpleasant taste) response to objects inside the mouth. Furthermore, the lateral occipital cortex is seen to be activated more in manual than in oral stereognosis, implying that manual objects are represented both somatosensorily as well as visually in the brain unlike oral stereognosis.^[45] It can be attributed to the fact that while the objects that are handled by the hand is seen as well as felt by the fingers, oral cavity is not usually visible and is mainly manipulated intraorally.^[45] It could also be that, oral cavity is more enclosed that do not participate in a multisensory process of object identification or probably just involve a different neural mechanism.^[46] This may explain the reason why in manual stereognosis, the identification time and error caused are lesser as compared to oral stereognosis. The association between the identification time and errors is moderate in case of oral stereognosis and nil in manual stereognosis. Nevertheless, the measure of one's general stereognostic ability cannot be made based on their OSA.^[33]

APPLICATIONS OF ORAL STEREOGNOSIS

Oral stereognosis is a measure for the oral functioning of an individual. It also gauges the effectiveness of a therapy. Thus, determination of one's oral perception is crucial in the process of delivery of complete dentures/other restorations/orthodontics fixtures by the dentist and the patient's adaption to the same.^[21,26, 28, 29, 30] An oral stereognostic test performed on the patient before any restorative or rehabilitation procedure such as implants, prosthesis and complete dentures, helps season the dentist about the possible outcome of the treatment as well as the patient's attitude towards it. In cases where the clinician anticipates a poorer acceptance to a future oral rehabilitative therapy, he may attempt to better the patient performance by training them with transitional appliances to improve their oral perceptive and manipulative skills.^[22] In clinical scenarios where a dentist has to deliver a complete denture to a diabetic patient who may have denture adaptation problems from complications of the disease, information about their OSA will help to keep the expectations real. It may help the dentist in explaining the prognosis of the treatment to the patient as well as mentally prepare them about the possible limitations.^[38]

Apart from measuring oral dysfunctions, oral stereognostic test may be useful in determining impairments due to the presence of systemic or local pathology such as blindness, deafness, speech dysfunctions, cleft lip and palate, temporary sensory ablations.^[24]

Knowledge about kinaesthetic feedback and speech behaviour may help the speech pathologist in better comprehension of speech production and perception, in turn tailor the treatment for each patient.^[36, 47] The stereognostic ability of stutterers or individuals with articulation problems is poorer as compared to normal speakers and may thus require longer time during the tests.^[26,48] Patients with cerebral palsy and hemiplegia have lower stereognostic ability and are prone to make more errors than the normal subjects.^[21,24] Individuals with cleft lip and palate do not show any overall sensory impairment as it does not involve any sensory deficit in the oral area.^[39] Other pathological conditions such as burning mouth syndrome or perioral lesions do not seem to have any influence on OSA.^[49] Interestingly, although tongue is crucial in manipulation and perception of objects in oral stereognosis, surgical reduction of tongue in individuals with macroglossia do not affect one's OSA.^[50]

Conditions such as xerostomia make it difficult for an individual to talk, eat or swallow. The dryness of the mouth may reduce the efficacy of the tongue and other oral structures to manipulate food bolus inside the mouth or even a test piece in case of a stereognostic test. It may thus reduce one's OSA. Oral rehabilitative therapy and adaptation to it in such patients may be challenging and the clinician should counsel the patient prior to the treatment. Individuals with psychological problems, stress or cancerphobia may have an increased sense of oral perception making them highly unsatisfied patients. Dentists may obtain a reality check for themselves and the patient by performing a stereognostic test in such patients where there is no apparent cause for dissatisfaction after an oral therapy. Interestingly, patients with oral appliances or orthodontic braces, find it hard to adjust initially. However, they seem to adapt to it later and the oral tissues adjust accordingly. This again raises a serious question: does oral stereognosis indeed have such a significant effect on oral therapy?

CONCLUSION

Oral stereognosis, as aptly described by Wright is "the most elaborate function submersed by the parietal cortex which necessitates perfect reception of the impulses set up by the stimuli from the object. The sensations produced are synthesized in the cortex and compared with previous sensory memories."^[51] This sensory testing method is in fact an indicator of the functional sensibility which relies on perception and adds on to the integrated working of other activities of brain such as memorisation, discrimination and identification.^[3] Oral stereognostic testing is designed to reflect on the overall sensory ability rather than to detect the specific receptor groups involved in its mechanism.^[28] A good result in oral stereognostic test shows an individual's intact ability in receiving complete and precise information about the happenings in their oral cavity. It is often performed in conjugation with oral motor ability testing to correlate between the results of both.^[4]

The mechanism of oral stereognosis is rather complex, nevertheless, its understanding will open up unexplored areas of not only oral health but also the general health of an individual. The already established applications and the several more that are yet to be explored, make the study of oral stereognosis a very interesting read. Proper emphasis on a standard experimental design and methodology is of utmost importance while crafting future studies in order to evaluate a myriad of other fascinating directions of stereognosis in dentistry.

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REFERENCES

- [1]. Yekutieli, M. Jariwala M., Stretch P. Sensory deficit in the hands of children with cerebral palsy: a new look at assessment and prevalence. *Dev Med Child Neurol*, 1994; 36:61-24.
- [2]. Schermann T, Tadi P. Stereognosis. [Updated 2020 Mar 9]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2020 Jan.
- [3]. Shetty M, Prasad DK, Rani G, Shetty NS. Oral Stereognosis- A diagnostic tool. *JIAOMR* 2007;19: 400-4.
- [4]. Berry DC, Mahood M. Oral stereognosis and oral ability in relation to prosthetic treatment. *Br Dent J* 1996; 120:179–185.
- [5]. Moayed Y, Duenas-Bianchi LF, Lumpkin EA. Somatosensory innervation of the oral mucosa of adult and aging mice. *Sci Rep*. 2018; 8(1):9975.
- [6]. Haggard, P., and de Boer, L. Oral somatosensory awareness. *Neurosci. Biobehav. Rev.* 2014; 47:469–484.
- [7]. Capra NF. Mechanisms of oral sensation. *Dysphagia* 1995; 10:235–247.
- [8]. Walker H.K. Cranial nerve V: The trigeminal nerve. In: Walker H.K., Hall W.D., Hurst, J.W. (Eds.), *Clinical Methods: The History, Physical, and Laboratory Examinations*. 3rd ed. Butterworths, Boston; 1990.
- [9]. Purves D, Augustine GJ, Fitzpatrick D, et al. The Somatic Sensory Cortex. In: Purves D, Augustine GJ, Fitzpatrick D, et al (Eds.). *Neuroscience*. 2nd ed. Sunderland (MA): Sinauer Associates; 2001.
- [10]. Eickhoff S.B., Amunts K., Mohlberg H., Zilles K. The human parietal operculum. II. Stereotaxic maps and correlation with functional imaging results. *Cereb. Cortex*. 2006; 16 (2): 268–279.
- [11]. Fitzgerald P.J., Lane J.W., Thakur P.H., Hsiao S.S. Receptive field (RF) properties of the macaque second somatosensory cortex: RF size, shape, and somatotopic organization. *J. Neurosci.* 2006; 26 (24): 6485–6495.
- [12]. Trulsson M., Essick G.K. Low-threshold mechanoreceptive afferents in the human lingual nerve. *J. Neurophysiol.* 1997; 77 (2), 737–748.
- [13]. Trulsson M., Johansson R.S. Orofacial mechanoreceptors in humans: encoding characteristics and responses during natural orofacial behaviors. *Behav. Brain Res.* 2002;135 (1–2), 27–33.
- [14]. Morimoto. T, Takata. K. 6 - The sense of touch in the control of ingestion. In: D.A. Booth. (Eds.). In *Studies in the Neuroscience Series, Neurophysiology of Ingestion*. Pergamon; 1993: Volume 6. p 79-97.
- [15]. Türker K.S., Sowman P.F., Tuncer M., Tucker K.J., Brinkworth R.S.A. The role of periodontal mechanoreceptors in mastication. *Arch. Oral Biol.* 2002; 52 (4):361–364.
- [16]. Broekhuijsen M.L., van Willigen J.D. Factors influencing jaw position sense in man. *Arch. Oral Biol.* 1983; 28 (5): 387–391.
- [17]. Agrawal KK, Tripathi A, Chand P, Singh RD, Rao J, Singh BP. A study to evaluate the effect of oral stereognosis in acceptance of fixed prosthesis. *Indian J Dent Res* 2011; 22:611.
- [18]. Dannenbaum RM, Jones LA. The assessment and treatment of patients who have sensory loss following cortical lesions. *J Hand Ther* 1993; 6:130–138.
- [19]. Joseph R. The right cerebral hemisphere: emotion, music, visual–spatial skills, body-image, dreams, and awareness. *J Clin Psychol* 1988; 44:630–673.
- [20]. Vallbo ÅB, Johansson RS. Properties of cutaneous mechanoreceptors in the human hand related to touch sensation. *Hum Neurobiol* 1984; 3:3–14.

- [21]. Jacobs R, BouSerhal C, van Steenberghe D. Oral stereognosis: a review of the literature. *Clin Oral Investig*. 1998; 2(1):3-10.
- [22]. Meenakshi S, Gujjari AK, Thippeswamy HN, Raghunath N. Evaluation of oral stereognostic ability after rehabilitating patients with complete dentures: in vivo study. *J Indian Prosthodont Soc* 2014; 14: 363-368.
- [23]. Landt H, Ahlin L, Lindquist L. The experimenter effect on results with the oral form recognition tests and with tests measuring oral muscular ability. *J Oral Rehabil* 1975; 2:235–248.
- [24]. Moser H, La Gourgue J, Class L. Studies of oral stereognosis in normal, blind and deaf subjects. In: Bosma JF (ed) Second symposium on oral sensation and perception. Charles C Thomas Publisher, Springfield, Ill; 1967. pp 245–286.
- [25]. Landt H. Oral and manual recognition of forms. Part I. Test results based on the test pieces. *Swed Dent J* 1976; 69:15–23.
- [26]. Garrett NR, Kapur KK, Jochen DG. Oral stereognostic ability and masticatory performance in denture wearers. *Int J Prosthodont* 1994; 7:567–573.
- [27]. Landt H, Fransson B. Oral ability to recognise forms and oral muscular coordination ability in young and elderly adults. *J Oral Rehabil* 1975; 2:125–138.;
- [28]. Litvak H, Silverman SI, Garfinkel L. Oral stereognosis in dentulous and edentulous subjects. *J Prosthet Dent* 1971; 25:139–151.
- [29]. Lundqvist S. Speech and other oral functions. *Swed Dent J Suppl* 1993; 91:1–39.
- [30]. Müller F, Link I, Fuhr K, Utz K-H. Studies on adaptation to complete dentures. Part II: Oral stereognosis and tactile sensibility. *J Oral Rehabil* 1995; 22:759–767.
- [31]. Van Aken AAM, Waas M van, Kalk W, Rossum GMJM van. Differences in oral stereognosis between complete denture wearers. *Int J Prosthodont* 1991; 4:75–79.
- [32]. Siirilä H, Laine P. The relation of periodontal sensory appreciation to oral stereognosis and oral motor ability. *Suomi HammaslaakToim* 1967; 63:207–211.
- [33]. Landt H. Oral and manual recognition of forms. Part II. Test results based on the subjects. *Swed Dent J* 1976; 69:69–77.
- [34]. Masoro EJ. Physiology of aging. In: Holm-Pederson P, Löe H (eds) *Geriatric dentistry*. Munksgaard, Copenhagen; 1986. pp 34–55.
- [35]. Calhoun, KH, Gibson, B, Hartley, L, Minton, J, Hokanson, JA. Age-related changes in oral sensation. *Laryngoscope* 1992; 102: 109–16.
- [36]. Shelton R, Arndt W, Hetherington J. Testing oral stereognosis. In: Bosma JF (ed) Second symposium on oral sensation and perception. Charles C Thomas Publisher, Springfield, Ill. 1967; pp 221–243.
- [37]. Chen CC, Essick GK, Kelly MG, Nestor JM, Masse B. Gender-, side- and site-dependent variations in human perioral spatial resolution. *Arch Oral Biol* 1995; 40:539–548.
- [38]. Gnanasambandam K, Karthigeyan S, Ali SA, Govindharajan M, Raj K, Murugan R. Comparative study of evaluation of the oral stereognostic ability between diabetic and nondiabetic complete denture wearers with and without denture. *Dent Res J (Isfahan)* 2019; 16(2):122-126.
- [39]. Mason R. Studies on oral perception involving subjects with alterations in anatomy and physiology. In: Bosma JF (ed) Second symposium on oral sensation and perception. Charles C Thomas Publisher, Springfield, Ill; 1967: pp 295–301.
- [40]. Sridhar Premkumar, Srinivasan Avathvadi Venkatesan, Sivaram Rangachari, Altered oral sensory perception in tongue thrusters with an anterior open bite. *European Journal of Orthodontics*. 2011; 33(2): 139–142.
- [41]. Fukutake. M, et al., Relationship between oral stereognostic ability and dietary intake in older Japanese adults with complete dentures, *J Prosthodont Res* 2018.

- [42]. Kohyama K, Sasaki T, Hayakawa F. Characterization of food physical properties by the mastication parameters measured by electromyography of the jaw-closing muscles and mandibular kinematics in young adults. *BiosciBiotechnolBiochem* 2008; 72:1690–5.
- [43]. Hubel D.H., Wiesel T.N. Receptive fields and functional architecture of non-key striate cortex. *J. Physiol.* 1968; 195 (1): 215–243.
- [44]. Serre T., Oliva A., Poggio T. A feedforward architecture accounts for rapid categorization. *Proc. Natl. Acad. Sci. U.S.A.* 2007; 104 (15): 6424–6429.
- [45]. Fujii R., Takahashi T., Toyomura A., Miyamoto T., Ueno T., Yokoyama A. Comparison of cerebral activation involved in oral and manual stereognosis. *J. Clin. Neurosci.* 2011; 18 (11), 1520–1523.
- [46]. Lim J., Green B.G. Tactile interaction with taste localization: influence of gustatory quality and intensity. *Chem. Senses* 2008; 33 (2): 137–143.
- [47]. Bishop ME, Ringel RL, House AS. Orosensory perception, speech production, and deafness. *J Speech Hear Res* 1973; 16: 257–266.
- [48]. Speirs RL, Maktabi MA. Tongue skills and clearance of toffee in two age-groups and children with problems of speech articulation. *ASDC J Dent Child* 1990; 57:356–360.
- [49]. Grushka M, Sessle B, Howley T. Psychophysical assessment of tactile, pain and thermal sensory functions in burning mouth syndrome. *Pain* 1987; 28:169–184.
- [50]. Ingervall B, Schmoker R. Effect of surgical reduction of the tongue on oral stereognosis, oral motor ability, and the rest position of the tongue and mandible. *Am J Orthod Dentofacial Orthop* 1990; 97:58–65.
- [51]. Wright S.: *Applied Physiology*, Oxford University Press, London, 1963.