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Comparison of oral stereognosis in relation to age and the use of complete dentures - An in vivo study

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Abstract

Statement of problem: Oral sensory ability has been found to be associated with masticatory performance; therefore, decline of the oral sensory ability may be a significant factor linked to masticatory disorder in the elderly.

Aim: The aim of this study was to examine the age-related difference in oral sensory function by testing oral stereognostic ability (OSA) and to determine the effect of wearing complete dentures on OSA.

Materials and method: Volunteer dentate (20 persons) and edentulous (30 persons) elderly patients were randomly selected from among patients of the Govt. Dental College and Hospital. Each edentulous subject was wearing maxillary and mandibular complete denture. As controls, 30 volunteer students from the graduate school of dentistry, all having 28 teeth, also participated in this study. Study group was divided into four groups: Group A (Old dentate), Group B (Old edentulous with denture), Group C (Old edentulous without denture) and Group D (Young dentate). The OSA tests were conducted using test pieces with 12 different shaped forms. The score of the responses and the length of time needed for identification were analysed as the OSA score and response time, respectively. ANOVA and paired t-tests were used to examine significant differences. P-values <0.05 were considered to be statistically significant.

Results: The OSA score in younger dentate subjects was significantly higher than in older dentate subjects and complete denture wearers. However, no significant difference was found in the OSA score between older dentate subjects and complete denture wearers. The Oral stereognostic ability (OSA) score is inversely proportional to Oral stereognostic ability (OSA) time in Group A, Group B & Group D. Group C is nonsignificant ($p>0.05$). Mean value of Oral stereognostic ability score in large objects is significantly greater than mean value in smaller objects in all groups. Old dentate has significantly highest mean value for large circle shape while young dentate has significant highest mean value for large square shape. Old edentulous with denture group has significantly highest mean value for large square, those without denture has significantly highest mean for large circle. All groups show

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significantly lowest mean value for small semicircle shape. Test pieces without corner have significantly higher mean value of oral stereognostic ability score than test pieces with corner in all four groups.
Conclusion: i) Oral stereognostic ability decreases with age; however, oral sensory function was not significantly different between fully dentate persons and complete denture wearers in the elderly. ii) An age-related difference in oral sensory function, as measured by OSA tests, was found. Covering the palatal mucosa with a denture, i.e wearing complete dentures does not reduce oral stereognostic ability. Within the limitation of the present study and from the results, it can be concluded that 1. The oral stereognosis test presented, is a reliable test for measuring patient's oral stereognostic ability. 2. Oral stereognosis can be used as an aid in predicting patients performance with the complete denture. 3. A negative correlation exists between oral stereognosis ability and satisfaction of patient with the complete denture.

Key words: oral stereognosis, dentures, in vivo, age, OSA, old edentulous.

Introduction

Stereognosis is the ability of perceiving and understanding the form and nature of objects by the sense of touch [1]. The subject is required to identify familiar objects by hand manipulation with the eyes closed. Stereognosis tests are used to evaluate the integrity of sensory feedback. The neurologic evaluation of central nervous system integrity frequently employs stereognostic tests.
In general, deterioration of most sensory abilities, such as visual, hearing, tactile and chemosensory, appear to occur almost inevitably with age in humans. Humans reach an optimum sensory capacity in their twenties, maintain this peak for several years and then it declines, with the rate of decline having a wide individual variation [2]. Oral sensory ability has been found to be associated with masticatory performance [3, 4, 5]; therefore, decline of the oral sensory ability may be a significant factor linked to masticatory disorder in the elderly.
Various methods to measure oral sensitivity have been used, including oral form recognition, interdental size and weight discrimination tests, intra-oral size judgments of small holes, two-point discrimination and thermal discrimination test [5, 6]. Oral stereognostic ability (OSA) has been employed in many studies in order to evaluate oral perception. An individual who scores well in a test of the OSA has received sufficient sensory information with which to identify shapes explored in the mouth [7].
Stereognostic testing is not designed to assess specific groups of sensory receptors, but overall sensory ability and oral motor ability [1, 8]. Some studies have suggested decline of the OSA with age [9, 10, 11], but the results are not necessarily consistent [6]. Oral sterognostic ability in denture wearers has also been reported to be poorer [7] or no different [12] when compared to dentate persons.
When investigating the influence of age, comparing younger and older subjects with natural dentition is important. However, previous studies have not compared oral sensory ability among younger dentate, older dentate and older edentulous persons simultaneously using the same method.
This is a study of oral stereognosis in dentulous and edentulous subjects, the purpose being to investigate the relationship of oral perception to diagnostic and therapeutic procedures in dental treatment. The investigation compares levels of oral discriminatory skills to age, to the presence or absence of teeth, to speech articulation, and to patient evaluation of their prostheses.

Materials and Method

Volunteer dentate (20 persons) and edentulous (30 persons) elderly patients were randomly selected from among patients of the Govt. Dental College and Hospital. They were independently living and cognitively competent. We did not do a specific test or examination

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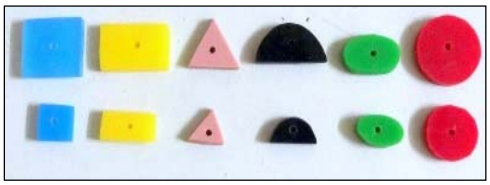
for assessing cognitive function of the subjects. Instead we judged their cognitive function from the response during medical interview.

Dentate subjects had a complete dentition of 28 teeth except for the third molars. Each edentulous subject was wearing maxillary and mandibular complete denture. As controls, 30 volunteer students from the graduate school of dentistry, all having 28 teeth, also participated in this study.

Study group was divided into four groups: Group A (Old dentate), Group B (Old edentulous with denture), Group C (Old edentulous without denture) and Group D (Young dentate). All patients visited the clinic for a recall appointment, were examined and found to be free from oral symptoms and pathologies. The protocol of this study was approved by the Ethical Committee of Gujarat University. All subjects gave written informed consent for their participation. For each edentulous subject, the date of the insertion of their complete dentures was determined and recorded based upon their clinical record. From this information, the length of time that each patient has been successfully wearing their dentures was determined. Due to the poor reliability of a patient's memory, assessing the length of denture wearing experience, including the previous dentures, and how many sets of dentures individuals had worn at the time of the interview was not reliable or valid.

Oral stereognostic ability test

The OSA tests were conducted following the method of Garrett *et al*. [12] and Hirano *et al*. [4] The test pieces comprised 12 shaped forms, which included circles, ellipses, semicircles, squares, rectangles and triangles of both large (12 · 12 · 3 mm) and small (8 · 8 · 2 mm) types [4]. The test pieces were made of acrylic to which dental floss was attached. The dental floss protruded from the subject's mouth to prevent aspiration of the test pieces [7]. We did the preliminary experiment comparing the OSA score and response time with and without dental floss in the same ten subjects. There is no significant difference between the two conditions in the OSA score and response time.



Photograph 1: Test pieces used in this study

The test was carried out in a quiet environment where the subject was seated comfortably in an upright position. The test pieces were kept out of the subjects' sight during the test. Subjects were told they should use their tongue and palate to identify the shape. They were instructed to respond as quickly as possible and to avoid biting on the test pieces. Pictures of all 12 test pieces were shown to the subject and the corresponding picture was pointed out for each shape. To prevent a learning effect, no practice trials were held. Each of the 12 pieces was presented twice. The 24 presentations were made in random order. Participants were not informed of the correct answers at any point during testing.

The six shape forms were grouped into three pairs of similar forms: circles and ellipses, squares and rectangles, triangles and semicircles [4]. The duration time for recognition was noted and the answers were recorded using a three-point scale. The discriminatory ability of test subjects has been reported to be a better predictor of OSA than a two-point scale (4, 8, 12). A correct identification was scored as two points; an incorrect identification within the same group of forms was scored as one point; and an incorrect identification of a dissimilar form was scored as zero. For example, when a circle form was presented, the correct answer of 'circle' was scored as two points; that of an 'ellipse' was scored as one point; and the other four answers (square, rectangle, triangle and semicircle) were scored as zero. If all answers were corrected, a full 48 points were scored. The score of the responses and the length of time

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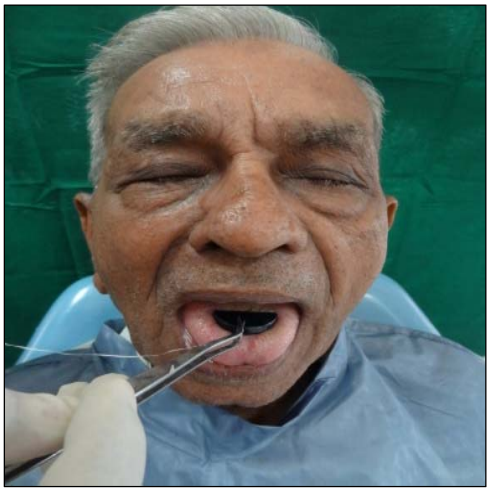
needed for identification were analysed as the OSA score and response time, respectively.



Photograph 2: Placing the test form in patient's mouth

Photograph 3: manipulation of test form

Photograph 4: identification of the test form by the patient

The OSA tests were conducted with test pieces of 12 shaped forms. The duration time for recognition was noted and the answers were recorded using a three-point scale. ANOVA and paired t-tests were used to examine significant differences. P-values <0.05 were considered to be statistically significant.

Results

Table 1: Oral Stereognostic Ability score (Mean and S.D.) in different groups

		N	Mean	Std. Deviation	Std. Error	Anova P Value
Test 1	Group A	240	1.283	.711	.046	<0.0001
	Group B	360	1.342	.694	.037	
	Group C	360	1.092	.700	.037	
	Group D	360	1.550	.609	.032	
	Total	1320	1.320	.697	.019	
Test 2	Group A	240	1.421	.674	.043	<0.0001
	Group B	360	1.481	.650	.034	
	Group C	360	1.306	.689	.036	
	Group D	360	1.622	.603	.032	
	Total	1320	1.461	.663	.018	

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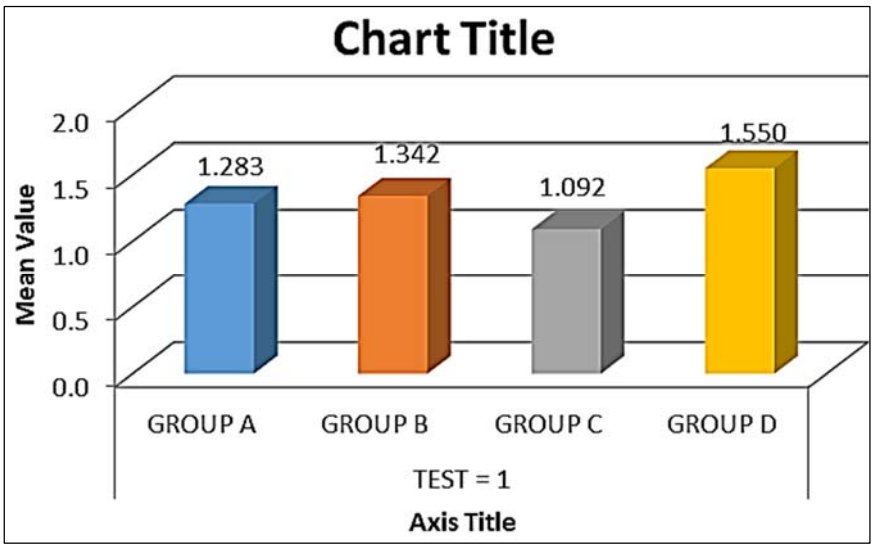

Fig 1: Oral stereognostic ability score (mean and s.d.) in different groups. (Test 1)

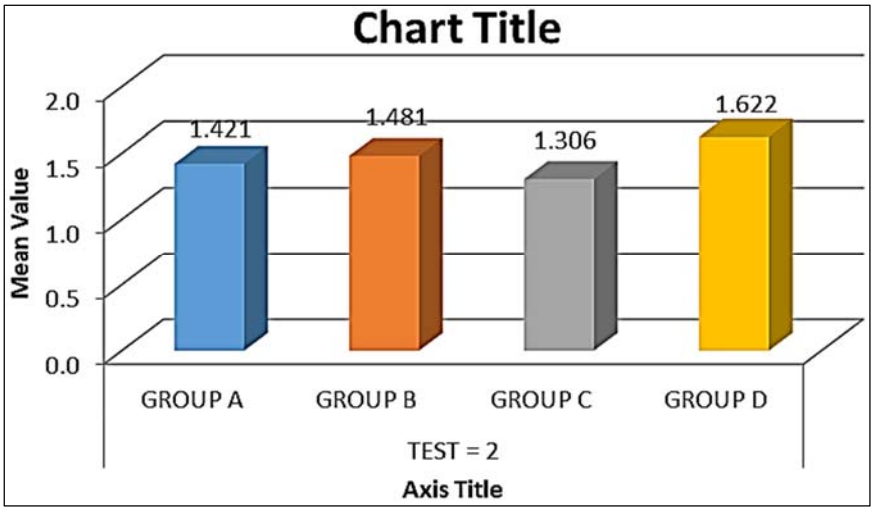

Fig 2: Oral stereognostic ability score (mean and s.d.) in different groups. (Test 2)

Table 2: TUKEY-HSD procedure to identify the significant group for oral stereognostic ability (OSA)

	Group	Group	Mean Difference	Std. Error	p value
Test 1	Group A	Group B	-0.058	0.056	0.729
	Group A	Group C	0.192	0.056	0.004
	Group A	Group D	-0.267	0.056	<0.0001
	Group B	Group C	0.25	0.05	<0.0001
	Group B	Group D	-0.208	0.05	<0.0001
	Group C	Group D	-0.458	0.05	<0.0001
Test 2	Group A	Group B	-0.06	0.054	0.691
	Group A	Group C	0.115	0.054	0.015
	Group A	Group D	-0.201	0.054	0.001
	Group B	Group C	0.175	0.049	0.002
	Group B	Group D	-0.142	0.049	0.019
	Group C	Group D	-0.317	0.049	<0.0001

The OSA score in younger dentate subjects was significantly higher than in older dentate subjects and complete denture wearers. However, no significant difference was found in the OSA score between older dentate subjects and complete denture wearers.

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Table 3: Co-relation between Oral Stereognostic Ability score and Oral Stereognostic time in various group

		N	Correlation	p value
Group A, Test = 1	Time & Score	240	-.247	<0.0001
Group A, Test = 2	Time & Score	240	-.242	<0.0001
Group B, Test = 1	Time & Score	359	-.259	<0.0001
Group B, Test = 2	Time & Score	360	-.262	<0.0001
Group C, Test = 1	Time & Score	360	-.015	.772
Group C, Test = 2	Time & Score	360	-.027	.613
Group D, Test = 1	Time & Score	360	-.252	<0.0001
Group D, Test = 2	Time & Score	360	-.145	.006

The Oral stereognostic ability (OSA) score is inversely proportional to Oral stereognostic ability (OSA) time in Group A, Group B & Group D. Group C is nonsignificant (p>0.05).

Small vs. large objects
Independent Sample T-Test

Table 4: Oral Stereognostic Ability score (Mean and S.D.) for large and small objects

		N	Mean	Std. Deviation	Std. Error Mean	Mean Difference	p Value
Group A	Small	120	1.158	0.635	0.058	-0.25	0.006
	Large	120	1.408	0.761	0.07		
Group B	Small	180	1.211	0.685	0.051	-0.261	<0.0001
	Large	180	1.472	0.68	0.051		
Test 1							
Group C	Small	180	0.978	0.66	0.049	-0.228	0.002
	Large	180	1.206	0.722	0.054		
Group D	Small	180	1.406	0.649	0.048	-0.289	<0.0001
	Large	180	1.694	0.53	0.039		
Group A	Small	120	1.292	0.703	0.064	-0.258	0.003
	Large	120	1.55	0.62	0.057		
Group B	Small	180	1.339	0.662	0.049	-0.283	<0.0001
	Large	180	1.622	0.609	0.045		
Test 2							
Group C	Small	180	1.183	0.689	0.051	-0.244	0.001
	Large	180	1.428	0.669	0.05		
Group D	Small	180	1.539	0.655	0.049	-0.167	0.009
	Large	180	1.706	0.536	0.04		

Mean value of Oral stereognostic ability score in large objects is significantly greater than mean value in smaller objects in all groups.

Table 5: Oral Stereognostic Ability score (Mean and S.D.) for each shape in older dentate group

	N	Mean	Std. Deviation	Std. Error	Anova P Value
Square-Large	40	1.73	0.506	0.08	
Square-Small	40	1.53	0.554	0.088	
Rectangle-Large	40	1.6	0.591	0.093	
Rectangle-Small	40	1.43	0.501	0.079	
Triangle-Large	40	1.43	0.636	0.101	
Triangle-Small	40	1.05	0.677	0.107	<0.0001
Semicircle-Large	40	0.9	0.81	0.128	
Semicircle-Small	40	0.65	0.7	0.111	
Circle-Large	40	1.83	0.385	0.061	

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Circle-Small	40	1.38	0.54	0.085	
Ellipse-Large	40	1.4	0.778	0.123	
Ellipse-Small	40	1.33	0.656	0.104	
Total	480	1.35	0.695	0.032	

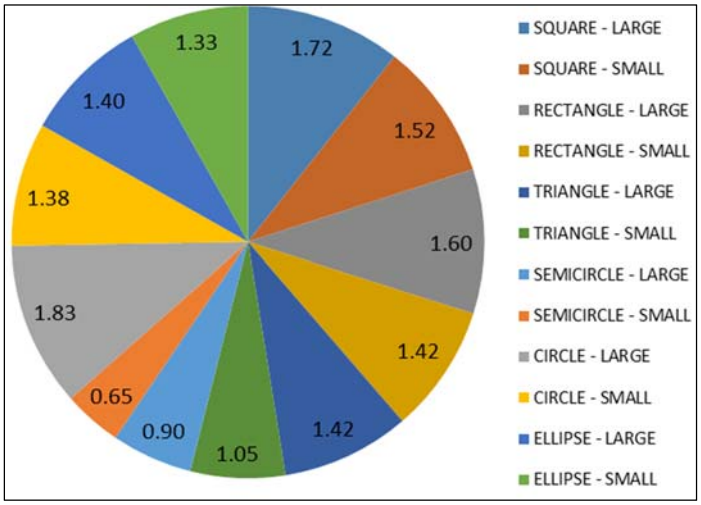

Fig 3: Pie chart showing Oral Stereognostic Ability score (mean and s.d.) for each shape in older dentate group

Table 6: Oral Stereognostic Ability score (Mean and S.D.) for each shape in old edentulous with denture group

	N	Mean	Std. Deviation	Std. Error	Anova P Value
Square-Large	60	1.78	0.49	0.063	
Square-Small	60	1.65	0.515	0.066	
Rectangle-Large	60	1.67	0.51	0.066	
Rectangle-Small	60	1.45	0.565	0.073	
Triangle-Large	60	1.62	0.585	0.076	
Triangle-Small	60	1.1	0.706	0.091	<0.0001
Semicircle-Large	60	0.92	0.766	0.099	
Semicircle-Small	60	0.78	0.666	0.086	
Circle-Large	60	1.73	0.516	0.067	
Circle-Small	60	1.42	0.619	0.08	
Ellipse-Large	60	1.57	0.593	0.077	
Ellipse-Small	60	1.25	0.628	0.081	
Total	720	1.41	0.676	0.025	

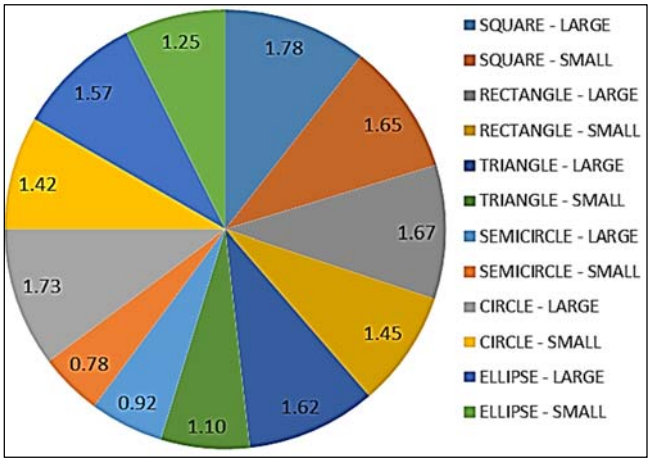

Fig 4: Pie chart showing Oral Stereognostic Ability score (mean and s.d.) for each shape in old edentulous with denture group

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Table 7: Oral Stereognostic Ability score (Mean and S.D.) for each shape in old edentulous without denture group

	N	Mean	Std. Deviation	Std. Error	Anova P Value
Square-Large	60	1.6	0.643	0.083	
Square-Small	60	1.23	0.647	0.084	
Rectangle-Large	60	1.45	0.594	0.077	
Rectangle-Small	60	1.32	0.537	0.069	
Triangle-Large	60	1.27	0.66	0.085	
Triangle-Small	60	1.07	0.686	0.089	
Semicircle-Large	60	0.78	0.666	0.086	<0.0001
Semicircle-Small	60	0.62	0.783	0.101	
Circle-Large	60	1.68	0.567	0.073	
Circle-Small	60	1.12	0.555	0.072	
Ellipse-Large	60	1.12	0.691	0.089	
Ellipse-Small	60	1.13	0.65	0.084	
Total	720	1.2	0.702	0.026	

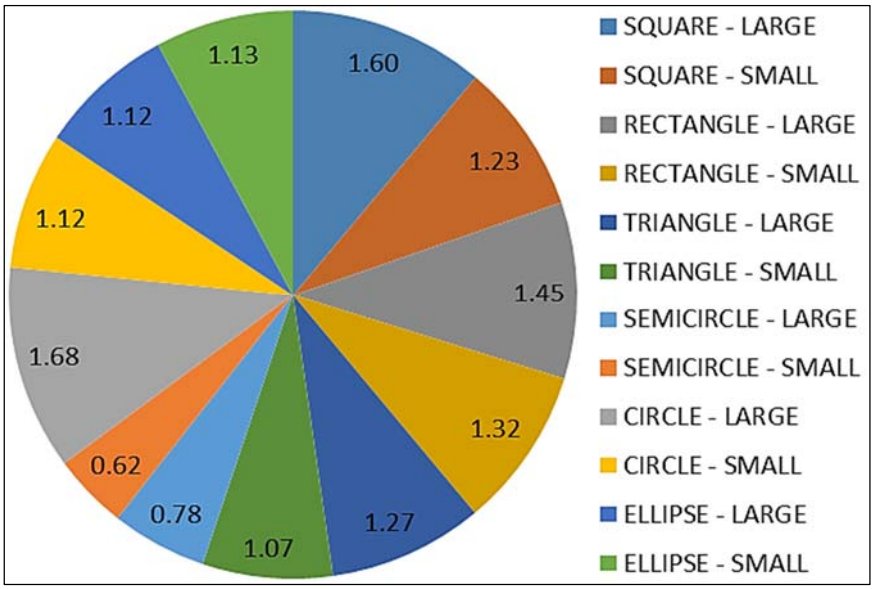

Fig 5: Pie chart showing Oral Stereognostic Ability score (mean and s.d.) for each shape in old edentulous without denture group

Table 8: Oral Stereognostic Ability score (Mean and S.D.) for each shape in young dentate group

	N	Mean	Std. Deviation	Std. Error	Anova P Value
Square-Large	60	1.95	0.22	0.028	
Square-Small	60	1.78	0.49	0.063	
Rectangle-Large	60	1.73	0.446	0.058	
Rectangle-Small	60	1.57	0.5	0.065	
Triangle-Large	60	1.73	0.446	0.058	
Triangle-Small	60	1.33	0.655	0.085	<0.0001
Semicircle-Large	60	1.38	0.691	0.089	
Semicircle-Small	60	0.95	0.79	0.102	
Circle-Large	60	1.8	0.48	0.062	
Circle-Small	60	1.68	0.504	0.065	
Ellipse-Large	60	1.6	0.616	0.08	
Ellipse-Small	60	1.52	0.596	0.077	
Total	720	1.59	0.607	0.023	

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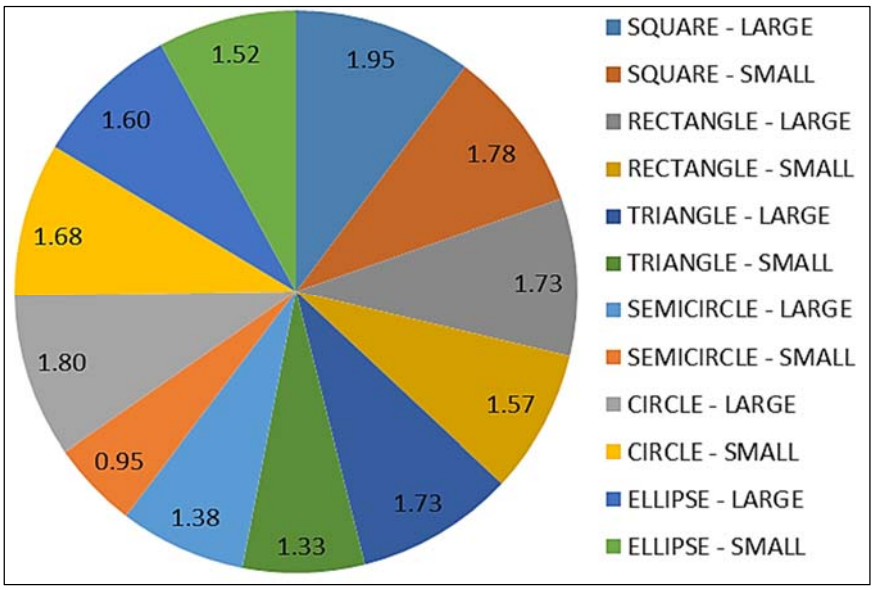

Fig 6: Pie chart showing Oral Stereognostic Ability score (mean and s.d.) for each shape in young dentate group

Old dentate has significantly highest mean value for large circle shape while young dentate has significant highest mean value for large square shape. Old edentulous with denture group has significantly highest mean value for large square, those without denture has significantly highest mean for large circle. All groups show significantly lowest mean value for small semicircle shape.

Within Group Corner (T-Test)

Table 9: Oral Stereognostic Ability score (Mean and S.D.) for test pieces with and without corner in old dentate group

	Corner	N	Mean	Std. Deviation	Std. Error Mean	Mean Difference	p value
Group A	With	320	1.288	0.716	0.040	-0.194	0.004
	Without	160	1.481	0.634	0.050	-0.194	
Group B	With	480	1.371	0.702	0.032	-0.121	0.024
	Without	240	1.492	0.614	0.040	-0.121	
Group C	With	480	1.371	0.702	0.032	-0.121	0.024
	Without	240	1.492	0.614	0.040	-0.121	
Group D	With	480	1.554	0.627	0.029	-0.096	0.046
	Without	240	1.650	0.559	0.036	-0.096	

Test pieces without corner have significantly higher mean value of oral stereognostic ability score than test pieces with corner in all four groups.

Discussion

The ability of the patient to use the dentures for mastication or speech, considerations of esthetics, psychologic factors, and the attitude of the patient all inference his ability to adjust to, accept and even manipulate the dentures. From the above results we can conclude that oral stereognostic ability score was higher in younger dentate group than in older dentate subjects and complete denture wearers (Fig. 1, 2). However, no significant difference was found in the OSA score between older dentate subjects and complete denture wearers compared to older age group. This is in favour of study done by K. Ikebe *et al.* [13] in 2007 and in agreement with Grasso & Catalanatto [14] (1979) and Landt & Fransson [15] (1975). They concluded that an inverse relation was found between stereognostic ability and age: the younger subjects recognized a larger number of objects.

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In this study, older dentate subjects needed about twice the time as younger ones to identify test pieces. Identification ability of older subjects was lesser than that for younger ones. Among complete denture wearers, the response time was significantly extended with individual's age. These results suggest that ageing has a negative influence on oral sensory information. These findings are not surprising because detection thresholds become higher [16] and the conduction velocity of the nerve impulse in sensory and motor fibres decreases with age [17]. In addition, sensory inputs are synthesized in the cortex and compared with previous sensory memories in order to permit identification of shapes. Memory and cognition also decline with age in healthy people [17].

It was observed that oral stereognostic score for young age group was found to be significantly higher than older age group. McDonald and Aungst [18] in their studies showed that the ability to identify form in the mouth improved with age, remained stable in young adults, and deteriorated in old age. Muller *et al*. [10] in their study reported that the tactile sensibility was found to be impaired with age and diminished capability of adaptation. Oral stereognosis involves cortical function, memory and vision factors that are impaired in elderly. Our result was similar to the study done by Paulo Henrique Orlato Rossetti *et al*. [19] that Stereognostic ability diminishes with age (number of correct responses and longer times for recognition).

Table-3 showing that oral stereognostic ability (OSA) score is inversely proportional to oral stereognostic ability (OSA) time. This is in favour of study done by K. Ikebe *et al*. [13] in 2007. They conluded that the individuals with high oral stereognostic scores required less time for the shape identification.

OSA of older dentate subjects should be better than that of complete denture wearers, simply because their palates are not covered. After the loss of natural teeth and the insertion of a maxillary denture, patients frequently complain of a reduced perception in the oral cavity. However, among the older subjects, a significant difference was not noted between dentate individuals and complete denture wearers. This is thought to be a result of the habituation process. This results also provides some confirmation that sensation on palate is not so important as tongue for oral stereognosis ability [6]. We also expected that complete denture wearers would have better or at least similar OSA when they removed their dentures.

This situation frequently occurs after the loss of natural teeth and the insertion of a maxillary denture, and illustrates well a patient's complaint regarding reduced perception in the oral cavity. Unexpectedly, when the complete dentures were removed, significant reduction of the OSA score and delay in the response time were observed. This is thought to be a result of the sudden change in the oral environment. The maxillary complete denture may act mainly as a rigid support against which the tongue can manipulate the object to be identified. Thus the presence of functionally adequate dentures, and consequent exclusion of the palatal mucosa from sensorial mechanisms, does not appear to cause a decrease in the patients OSA [15].

Table 4 showing that large test pieces showed a higher OSA score than small pieces.this result is similar to the study done by Van Aken *et al*. [16] and Mantecchini G *et al*. [20].

Table 5-8, figure 3-6, showing that Old dentate group has significantly highest mean value for large circle shape while young dentate has significant highest mean value for large square shape. Old edentulous with denture group has significantly highest mean value for large square those without denture has significantly highest mean for large circle. All groups show significantly lowest mean value for small semicircle shape. This is different from the result obtained in the study done by K. Ikebe *et al*. [13] in 2007. They concluded that younger dentate had highest mean value for large circle shape and the older dentate had the highest mean value for large triangle.

The selected shapes in this study provided sufficient difficulty, as is evident from a wide range of discrimination among the younger dentate, older dentate and older complete denture-wearing groups [12]. The pattern of response in shape identification seemed remarkably similar for all groups studied. As reported previously [8, 21], large test pieces showed higher a OSA score than small pieces.

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Table 9 showing that test pieces without corner have significantly higher mean value of oral stereognostic ability score than test pieces with corner in all four groups. In this study test pieces with corners were recognized less correctly than those without corners, which is not in accordance with the study done by Van waas *et al*. [21]. According to their study, test pieces with corners were recognized more correctly than those without corners.

These results suggest that ageing has a negative influence on oral sensory information. These findings are not surprising because detection thresholds become higher (Gescheider GA) [22] and the conduction velocity of the nerve impulse in sensory and motor fibres decreases with age. In addition, sensory inputs are synthesized in the cortex and compared with previous sensory memories in order to permit identification of shapes. Memory and cognition also decline with age in healthy people (Masoro EJ) [23].

However, among the older subjects, a significant difference was not noted between dentate individuals and complete denture wearers. This is thought to be a result of the habituation process. This results also provides some confirmation that sensation on palate is not so important as tongue for oral stereognosis ability (Masoro EJ) [23].

The tongue may compensate for the loss of the role of the palate in oral sensation in complete denture wearers. It might suggest that the role of the tongue in stereognosis is far more important than the input of the palatal receptors in this regard and that dentures made to the appropriate occlusal vertical dimension and proper arch forms confine the tongue within a normal space, allowing it to more easily recognize shapes.

The present study shows that overall OSA scores were significantly better in subjects with normal dentition as they had good and complete set of natural teeth supported by periodontal ligaments which provided effective proprioception for form identification. Other areas involved in oral perception like anterior lingual surfaces and sensory innervation of oral mucosa, pharynx and larynx were similar in both groups. These findings support the earlier studies which emphasize the role of sensory innervations other than periodontium [24].

OSA scores improved in both the groups as the test was repeated and almost all subjects showed better results. This is probably due to experience following subsequent experiments. The OSA scores also varied for different shapes of test pieces.

It is well documented that a patient with a high level of oral perception can be intolerant to errors in denture construction which would be unnoticed by a less orally aware subject. However, if technically correct prostheses were assured and all other parameters were maintained, then this high level of sensory appreciation will prove beneficial as it would help the subject to properly identify what is in the mouth and then adapt to it in a more acceptable way. It is therefore, recommended that for successful denture wearing other factors in addition to oral perception and oral performance are also of prime importance [6, 21, 25].

Conclusion

The results of this study lead to the following conclusions:

i) Oral stereognostic ability decreases with age; however, oral sensory function was not significantly different between fully dentate persons and complete denture wearers in the elderly.
ii) An age-related difference in oral sensory function, as measured by OSA tests, was found. Covering the palatal mucosa with a denture, i.e. wearing complete dentures does not reduce oral stereognostic ability;

Within the limitation of the present study and from the results, it can be concluded that

1. The oral stereognosis test presented, is a reliable test for measuring patient's oral stereognostic ability.
2. Oral stereognosis can be used as an aid in predicting patients' performance with the complete denture.
3. A negative correlation exists between oral stereognosis ability and satisfaction of patient with the complete denture.

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The phenomenon of oral stereognosis is very complex. In future, studies can standardize the test forms with respect to the surface detail, shape, the order of presenting the test forms, and the time duration for identification to prove the accuracy of the perceptive skills.
The oral sensory ability in case of compromised tongue and palate in comparison with the general adaptation to complete dentures can be studied. The perception skill of patients with different palatal forms and tongue size can form a future study. Since Oral stereognosis is a learning ability too, training skills and activities can be given to the patient to increase the motor ability followed by stereognosis test to ascertain an accurate correlation.

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