

MASTICATORY EFFICIENCY, A LITERATURE REVIEW

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تحسين قدرة المريض على مضغ الأطعمة هي من أحد أهداف الترميم الصناعي بالإضافة للوصول إلى إسعاد المريض.
وقد استخدمت طرق مختلفة لتقييم هذه القدرة لكونها ذات قيمة كبيرة في الحصول على فعالية مضغ جيدة.

Improving the ability of patients to masticate food is one of the goals of performing prosthodontic restorations and is essential in achieving patient satisfaction. Different methods of assessing this function are discussed as are the factors considered important in achieving good masticatory efficiency.

Introduction

Mastication is one of the important functions of the stomatognathic system. It is required for the reduction of food and is claimed to assist swallowing and promote digestion. The influence of adequate or inadequate mastication on the digestion and general health of human beings has been investigated, but the results are not conclusive,

In a clinical study of human beings, Farrell¹ concluded that in healthy individuals, masticatory impairment or ingestion of non-chewed food does not decidedly affect digestion of modern diets. A similar observation has been made in an animal study.²

On the other hand, a few studies stressed the importance of mastication in the maintenance of good health. Kapur and Okubo³ found that ingestion of insufficiently masticated food was detrimental to the health of rats. In a study of a hospital population, Mumma and Quinton⁴ concluded that masticatory efficiency has some influence, though not statistically significant, on the occurrence of gastric distress. Greene et al⁵ have shown that patients with insufficient masticatory ability have a significantly higher incidence of gastrointestinal complaints than persons with sufficient masticatory ability. In a later study by Boccardo and Betancor,⁶ gastric secretion was found to be related to masticatory ability.

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Results from several studies regarding the relationship between masticatory efficiency and dietary intake are also contradictory. It has been suggested that difficulty in eating tough and hard food in patients, with decreased masticatory efficiency, may lead to omission of such food from the diet and result in an increased risk of dietary deficiency.⁷⁻⁹ However, some investigators found no relationship between masticatory efficiency and dietary intake.¹⁰⁻¹⁴

The importance of masticatory efficiency is still debatable. There is no valid support for the contention that good masticatory efficiency is essential for a satisfactory nutritional intake, or that reduced masticatory efficiency will lead to gastric distress. Until we have a complete knowledge of this topic, we have to assume, however, that the maintenance of a high degree of masticatory efficiency is a desirable goal.

Evaluation of Masticatory Efficiency

Since the beginning of this century, researchers have realized the need for a simple and reliable method of measuring masticatory efficiency. Such method can be useful in evaluating the success of dental restorative procedures.

Interest in studying masticatory function has been focused on assessing the efficiency or performance of mastication. This was accomplished by testing the subject's ability to grind, or pulverize food or a test material.

The breakdown of food in the masticatory act is complex and includes biomechanical, enzymatic, and bacteriological processes.¹⁵ However, most effort has been concentrated on studying the mechanical breakdown of food.

Various methods have been described in the literature for testing mechanical breakdown of food,^{16,28} which has been referred to by many terms, e.g. chewing efficiency, masticatory performance, masticatory efficiency, chewing ability, masticatory function, and masticatory effectiveness (Table 1).

A variety of test foods and materials have been proposed including peanuts, carrots, almonds, gelatin, chewing gum, soya bean, and silicon rubber.

The principles of performing the test varied according to the method. Some had the subject chew for a specific number of strokes, while others let the subject chew up to the

desire for swallowing (swallowing threshold). There was no basis for deciding the number of strokes, but it ranged between 10 and 50, with 20 as the most common number. In the majority of cases, the subject was asked to chew in the usual way with no restrictions except in a few situations, where one side of the mouth was selected.

It was found that the amount of food in the mouth will affect the size of the particles to be swallowed, "swallowing composition".²⁹⁻³¹ The increase in the bolus size resulted in a decrease in the chewing strokes per standard portion of food, leading to swallowing of coarser particles of food.²⁹ Swallowing composition was also correlated with the rate of food breakdown.³² This is interpreted as showing that subjects with poor masticatory efficiency do not compensate for this by chewing more strokes but tend to swallow larger particles than subjects with good masticatory efficiency.¹⁷

Author	Terms used	Test material	Mastication	Methods for determination of breakdown
Thompson (1937)	masticatory efficiency	raw Irish potato	10 strokes	fractional sieving
Dahlbery (1942)	masticatory efficiency	gelatin	until swallowing	fractional sieving + area of pieces
Manly and Braley (1950)	masticatory performance	peanuts	20 strokes	fractional sieving
Loos (1963)	masticatory function	hazelnuts	10,20 and 40 sec.	fractional sieving
Kapur (1964)	masticatory performance	carrot	40 strokes	fractional sieving
Kayser and Hoeven (1977)	masticatory performance	carrot	5,10 and strokes until swallowing	area of pieces
Helkimo et al (1978)	chewing efficiency	almonds	10,20 and 40 sec.	fractional sieving
Edlund and Lamm (1980)	masticatory efficiency	optosil	20 strokes	fractional sieving
Jiffry (1981)	swallowing composition	soya bean	until swallowing	fractional sieving
Gunne (1982)	masticatory efficiency	gelatin hardened by formalin	20 strokes until swallowing	area of pieces by dye concentration measurement
Heath (1982)	masticatory effectiveness	chewing gum	20 strokes	extraction of sugar
Wayler and Chauncey (1983)	masticatory performance	carrot	until swallowing	fractional sieving
Nakasima et al (1989)	masticatory ability	rubber capsule containing granules	15 strokes	joules of work performed

Methods of Analysis

Fractional Sieving

The majority of the tests developed so far depend on the fractional sieving of the chewed food or material in the analysis. The general principle is to pass the masticated material through a series of sieves of decreasing mesh size. Essentially, the more efficient the mastication, the greater the quantity of material that will pass through the finest sieve. The quantity of material collected is estimated by volume or by weight.

Manly and Braley¹⁸ concluded that using a 10 or 20 mesh U.S. standard screen in sieving peanuts is more sensitive than using finer screens, and that mastication is a selective process which tends to grind larger particles more than the fine particles. As yet, we do not know the optimal size of food particles to be swallowed, and consequently, there are no criteria for selection of the size of the mesh screen.

Area of Pieces

Dahlberg¹⁷ proposed this method of analysis using gelatin as a test material. As one of the functions of mastication is to enlarge the food particle area exposed to the digestive juices, measuring the area of pieces will be a reliable method for assessing masticatory efficiency. Kayser and Hoeven²¹ used a similar principle but with carrots as a test food.

Gunne²⁶ modified the previous method and he estimated masticatory efficiency by calculating the area of the chewed material (gelatin hardened by formalin) indirectly. He placed the chewed material in a water-soluble dye which, when diffused into the material, will result in a reduction in the concentration of the dye in the surrounding solution. This concentration is registered with the help of a photometer. A close correlation was found between the gelatin particle area and the reduction of the dye solution concentration.

Extraction of Sugar

Heath²⁵ proposed a method of estimating masticatory effectiveness using chewing gum. This material does not break up into particles during mastication, rather a principle of measuring the percentage loss of sugar on chewing was developed to determine a value for the masticatory

effectiveness. Although chewing gum is considered a soft material, it has been shown that it can be an effective method for both dentate individuals and denture wearers.^{25,33}

Another method, developed by Nakasima et al²⁸ is claimed to be simple, reliable, and rapid. It implies chewing on a rubber capsule under standardized conditions. This capsule contains a specific amount of pigment-coated granules which, when crushed, will leak out the pigment. The leaking of pigment inside the capsule is positively correlated to the energy used. The masticatory ability, defined as the joules of work performed, was calculated by measuring the concentration of dye in an aqueous solution of the capsule's contents.

Subjective Evaluation

This method of evaluation has attracted a lot of interest from researchers. Different types of questionnaires have been used in several studies often in combination with an objective masticatory efficiency test. The questions usually used include the perceived ease of chewing different foods and about the dietary intake. The self-evaluation of mastication includes the psychological effect on the subject and the resultant satisfaction or dissatisfaction. These data cannot be obtained with the objective methods.^{25,27,34,37}

Comparisons of Different Test Methods

The difficulty in chewing different types of food and materials, beside the difference in methods of analysis, makes it difficult to compare results from different test methods. However, Helkimo et al³⁸ found a close correlation among results obtained from comminution tests. Poyiadjis and Likeman³³ also found a significant correlation between masticatory performance results of two different tests but only in denture wearers.

Contrary to previous results, Krysinski et al³⁹ found neither direct comparisons nor exact conversions of results between three different methods. This observation has been substantiated by Gunne,⁴⁰ who compared a surface area determination method with a comminution method. He found that a value from one method corresponded with a large range of values in another method and vice versa. He concluded that each method measures one aspect of mastication.

When the subjective evaluation of masticatory

efficiency was compared with the objective test results, no positive correlation was found.^{25,56} Many people with poor masticatory efficiency, as judged from objective test methods, will still judge their masticatory function as good. It is concluded that self-assessment of chewing ability is, in general, too optimistic when compared with results of functional tests.⁴¹

Effect of Loss of Dentition

Manly and Braley¹⁸ tested the masticatory performance of more than one hundred dentitions, some complete, some with the third molar missing and some with two molars missing. The results revealed significant differences between the three groups. The mean masticatory performance score was lower with a reduction in the number of molars. However, they also found that the variation in performance among persons with the same number of teeth was very large. They concluded that counting the number of teeth is of little value in predicting how well any individual can masticate food.

Number of teeth was correlated with masticatory efficiency in subsequent investigations but the large variation in performance still dominated all studies.^{22,27,42}

Effect of Malocclusion

Variation from the normal or ideal intercuspation of teeth can reduce the chewing efficiency.⁴³ Changes in occlusion, as a result of wearing orthodontic appliances, have resulted in lower masticatory efficiency test scores.^{44,45} Patients with severe mandibular prognathism, or developmental deformities, showed a relatively low value in the masticatory efficiency test.^{46,47}

Omar et al⁴⁸ found a significant correlation between the masticatory efficiency scores and the occlusal status indices. In their study, the occlusal status indices included aspects of malocclusion.

Effect of Occlusal Contacts

Yurkstas and Manly⁴⁹ developed a method to quantify the extent of the grinding surface of natural teeth by using semiopaque wax. An impression of the occlusal surfaces of teeth is taken and the amount of light that passes through this wax will determine the food platform area.

They found a great variability in the food plat-

form area of similar teeth according to the type of intercuspation. However, they found a significant correlation between masticatory performance and occlusal contact area. Occlusal contact area was related to masticatory performance in a curvilinear manner and it was the major factor in accounting for variations in masticatory performance. This relationship has been demonstrated again in a later study by Luke and Lucas.⁴³

Later on, Helkimo et al²² proposed the number of occluding pairs of teeth as a relatively reliable measure of chewing efficiency, instead of the occlusal contact area, which is difficult to judge. Helkimo's finding was substantiated by other investigators although different methods of counting were used.^{42,48}

It can be concluded that the maintenance of occlusal contacts is essential for masticatory function.

Effect of Bite Force

Bite force measurement has been used frequently in the literature. The method usually used is to ask the patient to bite with different force levels (usually maximum) on a fork containing strain gauges. Bite force was found to be positively correlated to masticatory efficiency^{25,38,50} and it can vary according to the state of dentition.⁵¹

According to this method, it was found that denture wearers have substantially lower bite force than dentate subjects.^{25,51}

Glantz and Stafford⁵² pointed out that instruments, like the bite fork, have a major influence on the recorded bite force value. By the use of strain-gauged maxillary complete denture, they showed that the maximal bite force in denture wearers registered in the intercuspation position was much higher than that registered by the bite fork method.

Effect of Prosthetic Replacement

Loss of teeth, in general, can lead to a reduction in masticatory efficiency. The question was whether the restoration of missing teeth by prosthetic replacement can restore the masticatory function back to normal. This issue has been studied by many investigators. Most of the interest was focused on the evaluation of masticatory efficiency objectively in complete denture wearers. However, the function of dental arch restored by fixed or removable partial denture is considerably

improved.^{53,54} In another study,⁵⁵ it was found that chewing performance in subjects with cross-arch fixed partial dentures was almost as good as in subjects with complete healthy dentitions.

Masticatory Efficiency in Denture Wearers

According to many studies, masticatory efficiency is lower in denture wearers compared to dentate subjects.⁴¹ Masticatory efficiency in denture wearers is about one-fourth¹⁸ to one-sixth⁵⁶ relative to dentate subjects. Due to the reduced ability of dentures to pulverize food, Kapur and Soman⁵⁶ thought that the grinding of food is random in complete denture patients and, thus, the reduction takes place homogeneously in all particle sizes. This is contrary to the selective process of chewing in dentate subjects, where bigger particles (greater than 0.84 mm) are subdivided faster than smaller ones.¹⁸

Effect of Quality of Dentures and Residual Ridges

An enhanced denture quality would be expected to improve the masticatory efficiency in complete denture wearers. However, this has been refuted by some investigators. Optimizing the old denture, or the construction of a new one, gave no or only a slight improvement in masticatory efficiency after an adaptation period lasting up to six months.^{50,57} Even when the follow-up period was extended to 18 months in another study,³⁶ the same result was found. Nevertheless, in contrast to previous studies, a direct improvement in masticatory efficiency was found after the patients were provided with new dentures¹⁵ and after three months' adaptation.³³

Different denture base forms were tested for difference in masticatory performance.⁵⁸ No significant difference was noted. The investigators also showed that reduction of the extension of upper and lower denture bases in different areas failed to affect the chewing efficiency of patients, except when an overall reduction in extension of the periphery of the lower denture base had been made.

Heath²⁵ has shown that the height of residual mandibular bone is correlated to the masticatory effectiveness in house-bound pensioners. In another investigation,⁵⁸ the average masticatory performance ratio in subjects with good ridges was higher than in subjects with poor ridges, though the

difference was not statistically significant.

Patients who underwent surgical reconstruction of their deficient residual ridges had improved masticatory performance during the rehabilitation period with new dentures.³⁷ The subjective evaluation by the patients was also improved.

Effect of Cusp Form and Occlusal Contacts

Teeth with occlusal markings were found to be more effective in mastication than flat teeth.⁵⁹ This was also observed by Kapur and Soman,⁶⁰ who studied the influence of occlusal pattern on masticatory performance in complete denture wearers. An acrylic resin block was used for the posterior teeth and 15 different occlusal patterns were cut into these blocks. In general, it was found that posterior teeth with occlusal markings were more effective in pulverizing the test food (carrots and peanuts) than those with no markings.

Non-anatomical teeth were found less efficient in mastication than 20 degrees⁶¹ or 33 degrees¹⁶ denture posterior teeth.

In a series of investigations on the effect of denture factors on masticatory performance, Kapur and Soman⁶² studied the influence of the shape of the polished surface of complete dentures on chewing efficiency. They found no obvious differences in subjects' ability to chew with different denture forms. They also found that the position of the occlusal table in a complete denture can effect masticatory performance.⁶³ If the platform was over the crest of the lower alveolar ridge at the height of the lower canine and parallel to the flat portion of the ridge, then the most effective chewing situation existed to masticate peanuts and raw carrots. A significant reduction in chewing efficiency of subjects resulted when the food platforms were moved in dentures with teeth positioned buccal to the crest of ridges.

The reduction of the occlusal contact area of denture teeth will reduce the masticatory performance in denture wearers.⁶⁴ The loss in masticatory efficiency was directly, but not proportionally, related to the potential contact area.

Patients with Osseointegrated Implant Bridges

The treatment of edentulous patients by means of bridges on osseointegrated implant yields long-term success.⁶⁵ Lindquist and Carlsson⁶⁶ evaluated the masticatory function of 27 edentulous patients

with denture adaptation problems. They were first given optimal conventional complete dentures and then fixed prostheses on osseointegrated oral implants in the lower jaw. Functional evaluation was made with the old denture, after the insertion of the optimal denture, and 2 months and 3 years after insertion of the osseointegrated implant bridge.

No significant improvement of masticatory function was found after conventional denture treatment. However, after insertion of the fixed mandibular implant bridge, a marked improvement was noted in the patients' assessment of their chewing ability and in the results of chewing efficiency tests and bite force measurements, with a strain-gauged bite fork placed between the denture teeth. The test results were further improved after three years.

It was concluded that treatment of dissatisfied complete denture wearers, with osseointegrated implant bridges, will dramatically improve such oral functions as bite force and chewing efficiency as well as their oral well-being. This is in agreement with a previous study by Haraldson,⁶⁷ where a substantial functional rehabilitation was found in patients treated with this type of therapy.

References

- Farrell JHrh The effect of mastication on digestion of food. *Br Dent J* 1956, 100:149-55.
- Sognnaes RF. Studies on masticatory efficiency. *J Am Orthod Oral Surg* 1941; 27:383-8.
- Kapur KK, Okubo J. The effect of impaired mastication on the health of rats. *J Dent Res* 1970;49:61-8.
- Mumma RD, Quinton K. Effect of masticatory efficiency on the occurrence of gastric distress. *J Dent Res* 1970;49:69-74.
- Greene HI, Dreizen S, Spies TD. Clinical survey of the incidence of impaired masticatory function in patients of a nutrition clinic. *J Am Dent Assoc* 1949; 39:561-71.
- Boccardo JJ, Betancor E. Effect of acute masticatory insufficiency on gastric secretion. *J Dent Res* 1972;51:1500.
- Heath MR. Dietary selection by elderly persons, related to dental state. *Br Dent J* 1972; 132:145-8.
- Osterberg T, Steen B. Relationship between dental state and dietary intake in 70-year-old males and females in Goteborg, Sweden: A population study. *J Oral Rehabil* 1982;9:509-21.
- Chen MK, Lowenstein F. Masticatory handicap, socioeconomic status, and chronic conditions among adults. *J Am Dent Assoc* 1984;109:916-8.
- Neill DJ, Phillips HIB. The masticatory performance, dental state, and dietary intake of a group of elderly army pensioners. *Br Dent J* 1970;128:581-5.
- Hartsook EI. Food selection, dietary adequacy, and related dental problems of patients with dental prostheses. *J Prosthet Dent* 1974;32:32-40.
- Baxter JC. The nutritional intake of geriatric patients with varied dentitions. *J Prosthet Dent* 1984;51:164-8.
- Cunnc HSJ, Wall AK. The effect of new complete dentures on mastication and dietary intake. *Acta Odontol Scand* 1985;43:257-68.
- Sandstrom B, Lindquist LW. The effect of different prosthetic restorations on the dietary selection in edentulous patients. A longitudinal study of patients initially treated with optimal complete dentures and finally with tissue-integrated prostheses. *Acta Odontol Scand* 1987;45:423-8.
- Posselt U. *Physiology of occlusion and rehabilitation*. Oxford:Blackwell, 1964:63.
- Thompson MJ. Masticatory efficiency as related to cusp form in denture prosthesis. *J Am Dent Assoc*. 1937;24:207-19.
- Dahlberg B. The masticatory effect. *Acta Med Scand* 1942;Suppl 139.
- Manly RS, Braley LC. Masticatory performance and efficiency. *J Dent Res* 1950;29:448-562.
- Loos S. A simple test of masticatory function. *Int Dent J* 1563;13:615-6.
- Kapur KK, Soman SD, Yurkstas AA. Test food for measuring masticatory performance of denture wearers. *J Prosthet Dent* 1964;14:483-91.
- Kayser AF, Hoeven JS. Colorimetric determination of masticatory performance. *J Oral Rehabil* 1977;4:145-8.
- Helkimo E, Carlsson GE, Helkimo M. Chewing efficiency and state of dentition. *Acta Odontol Scand* 1978;36:33-41.
- Edlund J, Lamm CJ. Masticatory efficiency. *J Oral Rehabil* 1080;7:123-30.
- Jiffry MTM. Analysis of particles produced at the end of mastication in subjects with normal dentition. *J Oral Rehabil* 1981;8:113-9.
- Heath MR. The effect of maximum biting force and bone loss upon masticatory function and dietary selection of the elderly. *Int Dent J* 1982;32:345-56.
- Gunne HSJ. Masticatory efficiency. A new method for determination of the breakdown of masticated test material. *Acta Odontol Scand* 1983;41:271-6.
- Wayler AH, Chauncey HH. impact of complete dentures and impaired natural dentition on masticatory performance and food choice in healthy aging men. *J Prosthet Dent* 1983;49:427-33.
- Nakasima A, Higashi K, Ichinose M. A new, simple and accurate method for evaluating masticatory ability. *J Oral Rehabil* 1989;16:373-80.
- Yurkstas AA. The masticatory act. *J Prosthet Dent* 1965;15:248-60.
- Jiffry MTM. Variations in the particles produced at the end of mastication in subjects with different types of dentition. *J Oral Rehabil* 1983,10:357-62.
- Lucas PW, Luke DA. Is food particle size a criterion for the initiation of swallowing? *J Oral Rehabil* 1986;13:127-36.
- Yurkstas A. Compensation for inadequate mastication. *Br Dent J* 1951;91:261-2.

33. Poyiadjis YM, Likeman PR. Some clinical investigations of the masticatory performance of complete denture wearers, 1 Dent 1984; 12:334-41.
34. Bergman B, Carlsson G. Review of 54 complete denture wearers. Patient's opinions 1 year after treatment. Acta Odontol Scand 1972;30:399-414.
35. Agerberg G, Carlsson G. Chewing ability in relation to dental and general health. Analyses of data obtained from a questionnaire. Acta Odontol Scand 1981 ;39:147-53.
36. Gunne HSJ, Bergman B, Enbom L, Hogslrom J. Masticatory efficiency of complete denture patients. A clinical examination of potential changes at the transition from old to new dentures. Acta Odontol Scand 1982;40:289-97.
37. Renaud M, Mercier P, Vinet A. Mastication after surgical reconstruction of the mandibular residual ridge. J Oral Rehabil 1984;11:79-84.
38. Helkimo E, Heath MR, Jiffry MTM. Factors contributing to mastication: an investigation using 4 different test foods. 1 Oral Rehabil 1983; 10:431 (Abstract).
39. Krysinski Z, Ludwiczak T, Mucha J. Comparative investigations of selected methods of evaluating the masticatory ability. J Prosthet Dent 1981 ;46:568-74.
40. Gunne HSJ. Masticatory efficiency and dental state. A comparison between two methods. Acta Odontol Scand 1985;4:139-46.
41. Carlsson GE. Masticatory efficiency; The effect of age, the loss of teeth and prosthetic rehabilitation. Int Dent J 1984;34:93-7.
42. Oosrerhaven SP, Westert GP, Schaub RMH, Bilt A. Social and psychological implications of missing teeth for chewing ability. Comm Dent Oral Epidemiol 1988;16:79-82.
43. Luke DA, Lucas PW. Chewing efficiency in relation to occlusal and other variations in the natural human dentition. Br Dent J 1985;159:401-3.
44. Pancherz H, Anehus-Pancherz M. Masticatory function after activator treatment. An analysis of masticatory efficiency, occlusal contact conditions and EMG activity. Acta Odontol Scand 1978;36:309-1fc.
45. Pancherz H, Anehus-Pancherz M. The effect of continuous bite jumping with the Herbst appliance on the masticatory system: A functional analysis of treated class II malocclusion. Europ J Orthod 1982;4:37-44.
46. Astrand P. Chewing efficiency before and after surgical correction of developmental deformities of the jaws. Swed Dent J 1974;67:135-46.
47. Edlund J, Hansson T, Petersson A, Willmar K. Sagittal splitting of the mandibular ramus. Electromyography and radiologic follow-up study of temporomandibular joint function in 44 patients. Scand J Plast Reconstr Surg 1979;13:437-43.
48. Omar SM, McEwen JD, Ogston SA. A test for occlusal function. The value of a masticatory efficiency test in the assessment of occlusal function. Br J Orthod 1987;14:85-90.
49. Yurkstas AA, Manly RS. Measurement of occlusal contact area effective in mastication. Am J Orthod 1949;35:185-95.
50. Lindquist LW, Carlsson GE, Hedegard B. Changes in bite force and chewing efficiency after denture treatment in edentulous patients with denture adaptation difficulties. J Oral Rehabil 1986;13:21-9.
51. Helkimo E, Carlsson GE, Helkimo M. Bite force and state of dentition. Acta Odontol Scand 1977;35:297-303.
52. Glantz PO, Stafford GD. Bite forces and functional loading levels in maxillary complete denture. Dent Mater 1985;1:66-70.
53. Manly RS, Shiere FR. The effect of dental efficiency on mastication and food preference. Oral Surg 1950;3:674-85.
54. Yurkstas A, Fridley HH, Manly RS. A functional evaluation of fixed and removable bridgework. J Prosthet Dent 1951;1:570-7.
55. Laurell L, Lundgren D. Chewing ability in patients restored with cross-arch fixed partial dentures. J Prosthet Dent 1985;54:720-5.
56. Kapur KK, Soman SD. Masticatory performance and efficiency in denture wearers. J Prosthet Dent 1964;14:687-94.
57. Vinton P, Manly RS. Masticatory efficiency during the period of adjustment to dentures, J Prosthet Dent 1955;5:477-80.
58. Kapur KK, Soman S, Stone K. The effect of denture factors on masticatory performance. Part I. Influence of denture base extension. J Prosthet Dent 1965(a);15:54-64.
59. Yurkstas AA. The influence of geometric occlusal carvings on the masticatory effectiveness of complete dentures. J Prosthet Dent 1963;13:452-61.
60. Kapur KK, Soman S. The effect of denture factors on masticatory performance. Part IV. Influence of occlusal patterns. J Prosthet Dent 1965(d); 15:662-70.
61. Trapozzano VR. Testing of occlusal patterns on the same denture bases. J Prosthet Dent 1959;9:53-69.
62. Kapur KK, Soman S. The effect of denture factors on masticatory performance. Part II. Influence of the polished surface contour of the denture base, J Prosthet Dent 1965(b);15:231-40.
63. Kapur KK, Soman S. The effect of denture factors on masticatory performance. Part III. The location of the food platforms. J Prosthet Dent 1965(c); 15:451-63.
64. Lambrecht JR. The influence of occlusal contact area on chewing performance. J Prosthet Dent 1965;15:444-50.
65. Adell R, Lekholm U, Rockier B, Branemark PI. A 15-year study of osseointegrated implants in the treatment of edentulous jaw. Int J Oral Surg 1981 ;6:387-416.
66. Lindquist LW, Carlsson GE. Long-term effects on chewing with mandibular fixed prostheses on osseointegrated implants. Acta Odontol Scand 1985;43:39-45.
67. Haraldson T. Functional evaluation of bridges on osseointegrated implants in the edentulous jaw. Thesis. Faculty of Odontology, University of Goteborg, Sweden 1979.