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Original Article

Occlusal Pressure Pattern Analysis of Complete Dentures for Evaluation of Occlusal Adjustment

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The purpose of this study was to investigate occlusal pressure patterns of complete denture wearers to evaluate progress of occlusal adjustment of dentures. Thirty three edentulous subjects volunteered to participate in this study. A computer-based device was used to measure occlusal pressure sequence while tapping with their new dentures. The following variables obtained from each occlusal pressure pattern were assessed: Peak Time; Duration from the onset of pressure to the maximum pressure, Unloading Time; Duration from the maximum pressure to the end of pressure, Contacting Duration; Duration from the onset of pressure to the end of pressure, Tapping Cycle; Duration from the onset of pressure to the next onset, Peak Ratio; ratio of Peak Time to Unloading Time. Recordings were performed after the occlusal adjustment at each appointment and continued until denture adjustments were completed. Variables were analyzed using ANOVA and Bonferroni. A significant decrease was seen in Peak Ratio as the occlusal adjustments progressed ($p<0.05$). Its coefficient of variation was constantly the lowest among variables. The coefficient of variation of Peak Ratio was significantly lower than others at the completion of the adjustment ($p<0.05$). It was suggested that Peak Ratio was useful for evaluation of occlusal adjustment.

Key words: Complete denture, Occlusal pressure pattern, Occlusal adjustment

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Introduction

The absence of deflective occlusal contacts between opposing maxillary and mandibular teeth during jaw movement is related directly to a reasonable philosophy of complete denture occlusion, which means that by elimination of the presence of deflective occlusal contacts, equilibrium of denture occlusion is improved, resulting in stabilization of dentures[1]. To establish the philosophy of occlusion, the simultaneous contacts of occlusal surfaces on the maxillary and mandibular dentures without premature contacts while occluding is essential. Dental articulators, which simulate jaw movements, are used to perform occlusal adjustment of denture teeth. However, final assessment of denture occlusion should be performed in the oral cavity[2]. To examine occlusal contacts intraorally, bite registration materials such as articulating paper, wax, and silicone etc are often used[3-6]. The techniques using these materials are performed simply

and quickly, while it is difficult to determine the presence and the location of the premature occlusal contacts. The reason is that premature contacts would cause dentures to shift while occluding, leading to the pseudo-appropriate occlusal contacts in the false maximum intercuspation. This phenomenon is likely to occur when the residual ridges is unfavorably resorped. Accordingly, occlusal contact records obtained intraorally may not reflect the actual anatomic relationship. In this situation, the evaluation of the appropriateness of the occlusal contact has relied on the experiences and skills of the dental profession, which may be neither objective nor reliable for clinical decision making.

To determine the presence of the premature occlusal contacts objectively, it is necessary to evaluate the occlusal contact sequence. Several studies have been reported on occlusal contacts recorded by using a computer-based measuring device which is available to record the amount of occlusal pressure sequence[7-20]. One report shows that the equilibrium of occlusal contact of complete dentures can be evaluated by using a position of the center of gravity of occlusal loads[18]. This device is also featured with the unique function which displays numerical values of the occlusal contact pressure continuously during occlusal contact sequence. It is reported that these numerical values for complete denture wearers recorded while occluding allow the quantitative evaluation of the progress of the occlusal adjustment[19]. Recordings of occlusal pressure patterns sequence, which are independent of the occlusal scheme, have possibility to be used for the assessment of occlusal contact conditions of the complete dentures.

The purpose of the present study was to examine the potential of the occlusal pressure pattern of complete dentures for evaluation of occlusal adjustment immediately after the delivery of the newly fabricated complete denture.

Materials and Methods

Thirty three edentulous subjects (10 male and 23 female, with an average age of 71.8±6.0years) who visited the dental hospital of Tokyo Medical and Dental University to seek for new complete dentures volunteered to participate in this study. All the subjects were given information about the investigation and their consents were obtained. The inclusion criteria were as follows; 1) Residual ridges were not severely resorped. The mean score of their residual ridge conditions according to the Kapur's classification[21] was 13.2±1.9 (Table 1). This means that the condition of denture-bearing tissues of subjects was not severely poor. 2) There were no signs and symptoms with temporomandibular disorder. 3) The patients had worn dentures for more than 10 years. Their new dentures were fabricated in a conventional manner as followed; Definitive impressions were made using zinc oxide eugenol impression paste and impression compound with custom trays. Occlusal vertical dimension was recorded with occlusal rims, and then bite registration was made using a central bearing tracing device (Simplex®, Dentsply International Inc. USA). For anterior teeth, resin teeth (Real CROWN, SHOFU, Japan) were used, while hard resin teeth (ENDURA POSTERIO, SHOFU, Japan) were used for molar teeth. After the posterior teeth were arranged based on the theory of bilateral balanced occlusion, the dentures were polymerized with a heat curing resin, remounted on the articulator for occlusal re-adjustments. Then dentures were removed from articulator and polished. The subjects obtained denture adjustments on the day of the delivery and the next day, and then continued visits to the hospital on a weekly basis until subjects were free from any discomfort from the dentures. Denture adjustments were performed in a conventional manner; the adjustment of the tissue surface was performed using a pressure indicating paste (PRESSURE INDI-

Table 1. Age, gender and residual ridge conditions of the subjects.

Age(y)	Female(n)	Male(n)	Score of residual ridge condition according to Kapur's classification
71.8±6.0	23	10	13.2±1.9

(Mean±S.D.)

Table 2. Mean values and standard deviations of PT, UT, CD, TC and PR for all the denture adjustment appointments.

		Denture adjustment appointments					
		Delivery of the denture	2nd adjustment	3 rd adjustment	4th adjustment	5th adjustment	6th adjustment
Numbers of the subjects	n	33	33	33	33	15	4
PT	mean	0.169	0.148	0.153	0.148	0.132	0.110
	S.D.	0.067	0.057	0.058	0.053	0.040	0.051
UT	mean	0.122	0.117	0.128	0.134	0.127	0.103
	S.D.	0.036	0.041	0.047	0.050	0.036	0.028
CD	mean	0.291	0.265	0.282	0.282	0.259	0.213
	S.D.	0.100	0.094	0.101	0.100	0.074	0.078
TC	mean	0.514	0.447	0.485	0.501	0.421	0.371
	S.D.	0.244	0.175	0.199	0.224	0.116	0.172
PR	mean	1.373	1.277	1.202	1.112	1.041	1.043
	S.D.	0.261	0.241	0.221	0.200	0.141	0.233

CATOR PASTE, MIZZY, Netherlands) and a carbide bur (Carbide Bur#7, SHOFU, Japan). And then deflective occlusal contacts, which were detected with 40μm thickness of articulating paper (ARTICULATING PAPER, GC, Japan), were deleted with an abrasive bur (Carborundum Point HA#19, SHOFU, Japan). Occlusal contacts between the dentures in the centric occlusal position were checked using articulating paper. The deflective contacts detected in the centric occlusal position were then ground. This procedure was repeated until the posterior teeth of maxillary and mandibular dentures evenly contact each other in the centric occlusal position[22].

A computer-based occlusal pressure measuring device (I-SCAN system Ver5.0, Nitta, Japan) was used to record occlusal contact pressure sequence with a pressure sensing sheet (T-ScanII, Tekscan, USA) [23]. The spatial distribution of the measured pressure was displayed after being digitized with the software program at 127Hz sampling rate which was the maximum capable speed of this system, providing the occlusal pressure patterns. Subjects were seated upright in dental chairs, and then an operator inserted the recording handle with a sensor sheet. Subjects were instructed to tap the sheet in place between maxillary and mandibular dentures with maximum effort. The recording of occlusal pressure during this strong tapping task was continued for 15 seconds, and repeated three times with 5 minute intervals, and mean values were calculated. All the recordings were performed after the occlusal adjustments at each appointment. And the adjustments continued until the patient feel free of any discomfort with their dentures (Table2).

From the occlusal pressure pattern while tapping, the following variables were revealed for the analysis (Figure 1): Peak Time (PT); Duration from the onset of the initial pressure to the maximum pressure, Unloading Time (UT); Duration from the maximum pressure to the end of pressure, Contacting Duration (CD); Duration from the onset of initial pressure to the end, Tapping Cycle (TC); Duration from the onset of the initial pressure to the next onset, Peak Ratio (PR); The ratio of PT to UT, which is calculated by PT over UT. To prevent recording of tapping error, the mean values calculated with five successive waves with the most parallel peak values among the recorded waves for each tapping task were analyzed. All the variables were obtained at the appointment for the delivery of the denture, the second and the third appointment for the denture adjustments after the delivery, and the completion of the denture adjustments.

One-way ANOVA with repeated measurements was

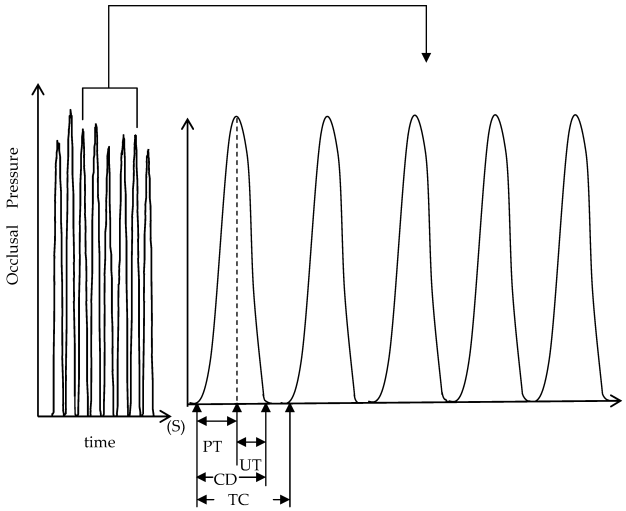

Figure 1. Occlusal pressure pattern while tapping

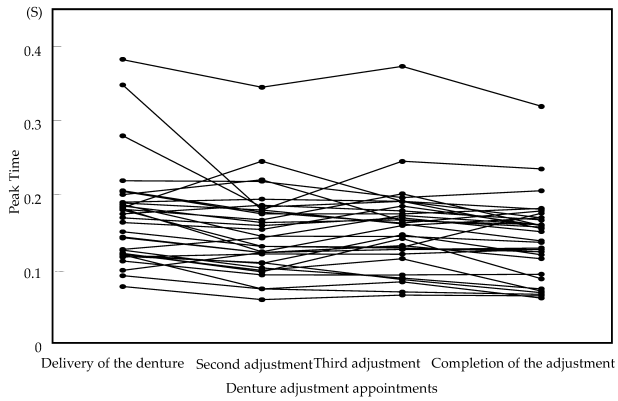

Figure 2. Peak Time for each appointment of the denture adjustment

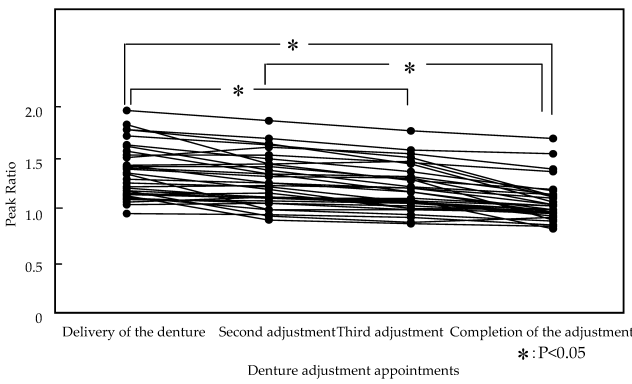

Figure 3. Peak Ratio for each appointment of the denture adjustment ANOVA showed a significant influence of the occlusal adjustments ($p < 0.05$). Multiple comparisons demonstrated the significant differences between the delivery of the dentures and the completion of the denture adjustment, the delivery of the dentures and the third adjustment, and the second adjustment and the completion of the adjustment ($p < 0.05$).

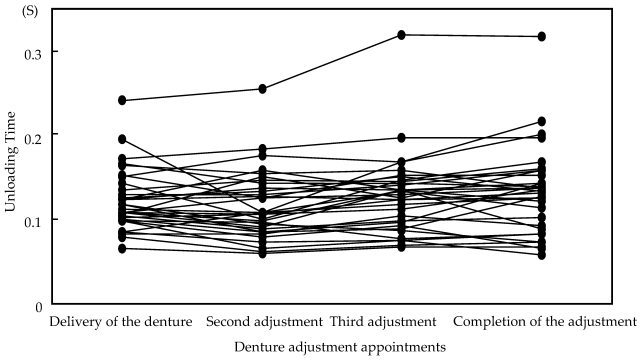

Figure 4. Unloading Time for each appointment of the denture adjustment

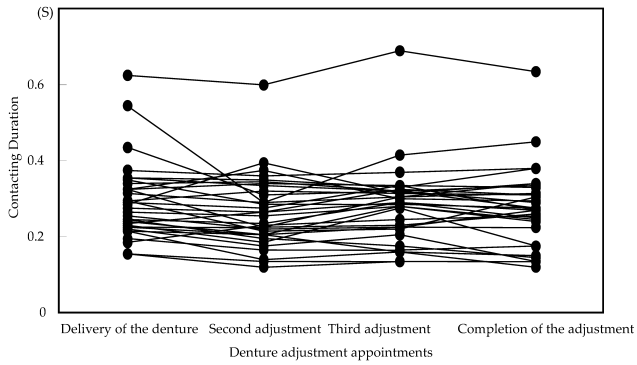

Figure 5. Contacting Duration for each appointment of the denture adjustment

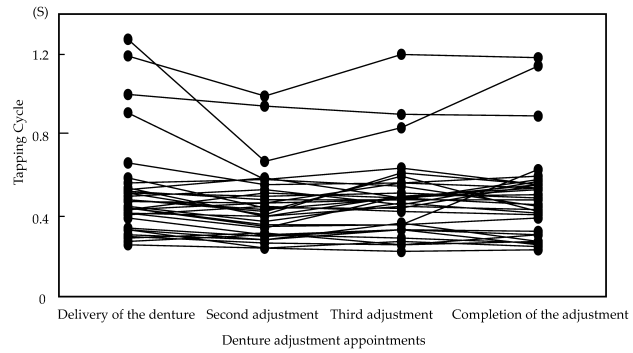

Figure 6. Tapping Cycle for each appointment of the denture adjustment

used to analyze the effect of the occlusal adjustments on the occlusal pressure patterns. Multiple comparisons were performed using the Bonferroni test between each adjustment appointment. The significance level was set at 0.05. The coefficient of variation for variables at each appointment was calculated, and the values specifically at the completion of adjustment were analyzed using ANOVA and the Bonferroni test.

Results

Table 2 shows the mean values and the standard deviations of all the data obtained during the period for denture adjustments. The denture adjustments were finished with 4 times of adjustment appointments for 14 subjects, 5 times for 15 subjects, and 6 times for 4 subjects.

PT, PR, UT, CD and TC at each adjustment appointment are shown in Figure 2-6. Among these variables, the significant decrease was observed only in PR ($p<0.05$). Multiple comparisons for PR demonstrated the significant differences between the delivery of the dentures and the completion of the adjustment, the delivery of the dentures and the third adjustment appointment, and the second adjustment appointment and the completion of the adjustment ($p<0.05$). UT showed no significant change (Figure 4). On the other hand, CD and TC showed more constant values along with the progress of the occlusal adjustments than other variables. There were no significant differences among the adjustment appointments (Figure 5,6).

The CV value of PR was constant at the lowest level among variables throughout the adjustment appointments (Figure 7). The CV value of PR at the completion of the adjustment was also significantly lower than others. ($p<0.05$, Figure 8).

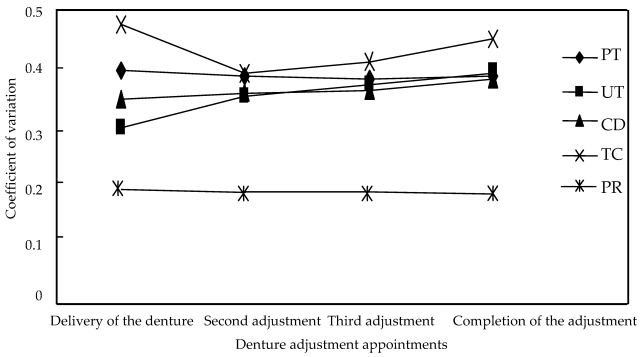

Figure 7. The mean values of CV values of the variables for each appointment of the denture adjustment

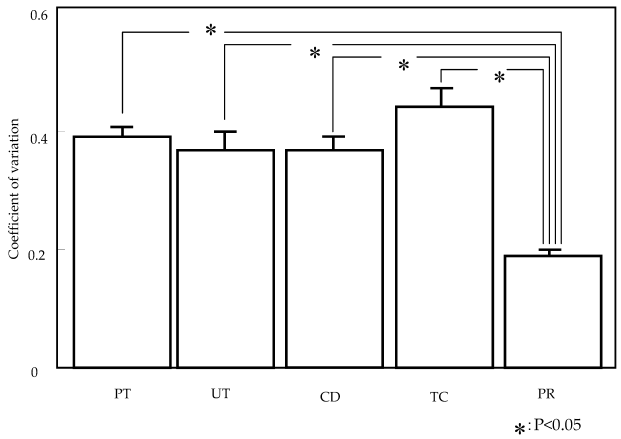

Figure 8. CV values for the variables at the completion of the adjustment
The CV value of PR was significantly lower than others ($p<0.05$).

Discussion

The presence of premature occlusal contacts produces time lag until the maximum intercuspation is established after occlusal surfaces of maxillary and mandibular dental arches contact while occluding. This time lag is reduced as the elimination of the premature contacts is progressed. The duration of time lag is not related to the occlusal scheme of the teeth but to the degree of error in any occlusal scheme. Accordingly, the variables related to this time lag obtained from occlusal contact recordings may be a potential common denominator for the evaluation of the occlusal contact condition regardless of the prosthesis type.

For complete denture, the detection of the premature contacts is difficult with conventional methods for occlusal adjustment because the presence of the premature contacts must cause denture shifts on residual ridges easily, leading to recording the faulty maximum intercuspation. Furthermore, the faulty intercuspation established at a mistaken mandibular position is also difficult to be recognized as an incorrect problematic occlusal condition with conventional methods for occlusal adjustment. One of the solutions for these problems may be the use of a method to detect the occlusal contacts in the time course. The time lag from the first premature contact to the maximum intercuspation at an appropriate mandibular position must be identified for the true evaluation of complete denture occlusal contacts.

To confirm whether premature contacts are eliminated properly, the occlusal contact sequence recording is one of the appropriate measures[18]. From the occlusal contact sequence recordings while tapping, a curve of time vs intensity was plotted and resulted in a bell shaped curve, which included the onset of pressure due to the first premature contact and the peak of the pressure. As the premature contacts are eliminated, the

duration between the two points in the time course is shortened. The short duration from the onset of occlusal pressure to the peak indicates the stable occlusal balance of dentures on the residual ridges, which should be achieved with the occlusal adjustment. Thus, the occlusal pressure pattern obtained while tapping is considered to provide the definitive parameters to express the condition of occlusal equilibrium.

For the present complete denture cases, in particular, a single tapping with the sensor sheet in place produced the initial pressure due to the premature contacts first, and then the pressure increased as the area of occlusal contacts increased. Once the peak was recorded, the occlusal contact pressure reduced gradually as the occlusion phase is progressed to the next phase. The bell shaped pressure patterns while tapping were clearly recorded, which enabled the exclusive selection of the peak.

Among the variables obtained from the occlusal pressure pattern, CD and TC were not influenced by the progress of the occlusal adjustment. It is reported that the duration for the mouth opening, the mouth closing and the occlusion as well as the tapping cycle was constant regardless of the quality of the denture fitness[24]. The present results of CD and TC, which were corresponding to the duration of the occluding phase and the tapping cycle, were coincident with the previous report. These results may be explained by the following physiological mechanism[25]. There exists a particular rhythm for each patient in mandibular movement specifically in the continuous reciprocating opening and closing motion. Moreover, this rhythm is maintained even when the periodic oscillations are blocked in the same manner as breathing or circulation. Namely, the basic rhythm is regulated by the pattern generator in the central nervous system. These considerations may provide the following supposition that when the soreness due to the misfit of the denture is eliminated by denture treatments, the rhythm of tapping, which is an inherent movement of individual patient, is likely to be kept constant. Consequently, this supposition may support the negative results obtained on CD and TC, which initiated more detailed observation of the occluding duration such as PT, UT, and PR for determining whether the deflective occlusal contacts were really corrected by the occlusal adjustments.

PT and UT, which represented the duration from the onset of the pressure to the peak and the following duration until the end of the pattern in a single tapping respectively, should have been considered as variables to evaluate the occlusal adjustment, however unexpectedly not. It may be caused by the large variation of the velocity due to the lack of the adaptation of patients to the new denture. On the contrary, the values of PR decreased significantly in accordance with the progress of the denture adjustments. PR values were 1.373 at the delivery, followed by 1.277 at the second adjustment appointment, 1.202 at the third adjustment appointment, and 1.072 at the completion of the denture adjustment, which showed gradual decreases with the convergence as the occlusal adjustment progressed. This behavior of PR is associated with the deformation of mucosa under the denture base and the reposition of mucosa, as well as the elimination of premature contacts. PT, the numerator in PT/UT, is likely to be reduced by eliminating the premature contacts in the course of the progress of the occlusal adjustments. The adaptation of the mucosa to the tissue surface of the denture must also influence the reduction positively. However, a certain amount of time will remain before the peak can be observed while tapping due to the presence of viscoelasticity in the mucosa under the denture. It is reported that the viscoelastic repositioning behavior of mucosa after releasing the applied load co-varies with its displacement occurred under loading[26]. In other words, when the deformation of the mucosa is large, time required for the repositioning of the mucosa is prolonged. This characteristic of the mucosa can devise the potential of the PR, because it is possible that the value of PR is constant with little variation among patients when the occlusal balance of the dentures is achieved properly.

When considering the indispensable requirement to evaluate the occlusal condition of the dentures, the small variance between the individuals is preferable. From this view point, CV values of PR showed the advantageous characteristic compared with other variables. CV values of PR, which were 0.190 at the delivery and 0.181 at the completion of the denture adjustments, were the smallest among other variables. The alveolar ridge conditions of the subjects, which were one of the factors that influences the variance of variables, were not initially estimated to be as poor as they were. According to Kapur's classification, residual ridges scored with 14 point or less are considered as poor even though they were not severely resorped. Thus, the alveolar ridge condition of the subjects did not affirm the advantageous conditions for wearing dentures. Therefore, it was doubtful that the denture stability was accepted for all the subjects, which might have produced the large variance and poor reproducibility within the subjects. However, in fact,

even with these subjects, the variance observed in PR was the smallest among the variables. This robustness of PR is considered to be essential as a clinical examination for complete denture wearers with various oral conditions.

The ability in the control of the mandibular movement must also largely influence the occlusal contacts while tapping. The mandibular movements for the subject were considered to be well controlled, contributing to an acceptable reproducibility. Additional information on the relation of PR to the degree of the ability in the control of the mandibular movement should be examined in further study. Considering PR as a criterion for diagnosis, the value of 1~1.1 may be suggested with in the present study setting. However, data accumulation would be needed to determine criteria which can be widely applied to denture patients with a variety of oral conditions.

Acknowledgments

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References

1) George AZ, Charles LB, Gunnar EC. Boucher's prosthodontic treatment for edentulous patients. Eleventh edition. St. Louis: Mosby; 1997. p. 263.
2) Miyake M, Sugawara Y, Tamura T, et al. Illustrated occlusal registration. (in Japanese). J Practice in Prothodontics Extra Issue 2001;80-91.
3) Gionhaku N, Yamaguti K, Yamamoto K, et al. Reappearance of occlusal adjustment supply: Part 1. basic studies. (in Japanese). J Jpn Prosthodont Soc 1989;25:592-599.
4) Millstein PL. An evaluation of occlusal indicator wax. J Prosthet Dent 1985;53:570-572.
5) Gazit E, Firtzug S, Liberman MA. Reproducibility of occlusal marking techniques. J Prosthet Dent 1986;55:505-509.
6) Shinoda H, Warita K, Kawawa T, et al. Accuracy of interocclusal recording materials for reproducibility of intercuspation on mounting stone casts. (in Japanese, English abstract). J Jpn Prosthodont Soc 1997;41:977-984.
7) Maness WL, Benjamin M, Podoloff R., et al. Electromyographic and computer analysis a new technology. Quintessence Int 1988;18:287-292.
8) Kerstein RB, Wright NR. Electromyographic and computer analyses of patients suffering from chronic myofacial pain-dysfunction syndrome: before and after treatment with immediate complete anterior guidance development. J Prosthet Dent 1991;66:677-686.
9) Kerstein RB. Disclusion time-reduction therapy with immediate complete anterior guidance development to treat chronic myofacial pain-dysfunction syndrome. Quintessennce Int 1992;23:735-747.
10) Mizui M, Nabeshima F, Tosa J, et al. Quantitative analysis of occlusal balance in intercuspal position using the T-Scan system. Int J Prosthodont 1994;7:62-71.
11) Kerstein RB. Disclusion time measurement studies: Stability of disclusion time-A 1-year follow-up. J Prosthet Dent 1994;72:164-168.
12) Kerstein RB. Disclusion time measurement studies: A comparison of disclusion time between chronic myofascial pain dysfunction patients and nonpatients a population analysis: A population analysis. J Prosthet Dent 1994;72:473-480.
13) Cartagena AG, Sequeros OG, Garcia VCG. Analysis of two methods for occlusal contact registration with T-Scan system. J Oral Rehabil 1996;24:426-432.
14) Sequeros OG, Garcia VCG, Cartagena AG. Study of occlusal contact variability within individuals in a position of maximum intercuspation using the T-SCAN system. J Oral Rehabil 1997;24:287-290.
15) Garcia VCG, Cartagena AG, Sequeros OG. Evaluation of occlusal contacts in maximum intercuspation using the T-Scan system. J Oral Rehabil 1997;24:899-903.
16) Kirveskari P. Assessment of occlusal stability by measuring contact time and centric side. J Oral Rehabil 1999;26:763-766.
17) Kerstein R.B, Grundset K. Obtaining measurable bilateral simultaneous occlusal contacts with computer-analyzed and guided occlusal adjustments. Quintessennce Int 2001;32:7-18.
18) Olivieri F, Kang K, Hirayama H, et al. New method for analyzing complete denture occlusion using the center of force concept a clinical report. J Prosthet Dent 1998;80:519-523.
19) Okuma K, Hirano S, Hayakawa I. A clinical application of the T-Scan II System- usefulness for evaluating occlusal contacts of complete denture wearers-. (in Japanese, English abstract). J Stomatol Soc Jpn 2002;69:277-284.
20) Hirano S, Okuma K, Hayakawa I. In vitro study on accuracy and repeatability of the T-Scan II System. (in Japanese, English abstract). J Stomatol Soc Jpn 2002;69:194-201.
21) Kapur KK. A clinical evaluation of denture adhesives.J Prosthet Dent 1967;18:550-558.
22) Hayakawa I. Principles and practices of complete dentures-creating the mental image of a denture-.Japan:Quintessence Publishing Co., Ltd, 2001:228-229.
23) I-SCAN users manual. (in Japanese). Japan: Nitta Corporation.
24) Araki T. A Study on occlusal adjustment and its estimation method of curative effect in complete denture wearers. (in Japanese). J Jpn Prosthodont Soc 2001;45:93-105.
25) Torii S, Kawamura H. Handbook of physiological sciences vol.13 physiology of biological rhythm. (in Japanese). Japan: Igaku-Shoin, 1987:12-23.
26) Hirano S. Study on analysis of viscoelastic property of palatal mucoperiosteum -about the creep recovery-. (in Japanese, English abstract). J Stomatol Soc Jpn 1992;59:75-92.