Correlation of masticatory muscle activity with masticatory ability in complete denture patients with canine guidance and balanced occlusion

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Abstract. Balanced occlusion is commonly used in complete denture occlusion scheme; however, canine guidance offers a simpler process and reduces alveolar ridge resorption. Correlative research of these two occlusion schemes is required. This study was done to analyze the correlation between masticatory muscle activity and masticatory ability of the subjects with canine guidance and balanced occlusion complete dentures. Ten denture wearers participated in this cross-over clinical trial, and five subjects were randomly selected to wear balanced occlusion followed by canine guidance complete dentures and vice versa. Electromyogram (EMG) activities of superficial masseter and anterior temporal muscles were measured and masticatory ability questionnaires were collected 30 days after the subjects wore each occlusal scheme. There were significant differences between the EMG activities of masticatory muscles in subjects who were given canine guidance and balanced occlusion complete dentures (p < 0.05). Subjects rated their masticatory ability as being significantly better when using canine guidance dentures (p = 0.046). There was a significant and strong correlation (p = 0.045; r = 0.642) between the EMG activity of anterior temporal muscles and masticatory ability when the subjects wore balanced occlusion dentures and between the EMG activity of superficial masseter muscles and masticatory ability (p = 0.043; r = 0.648) when wearing canine guidance dentures. Masticatory ability is better when using canine guidance dentures. There is a significant and strong correlation between masticatory muscle activity and masticatory ability.

1. Introduction
The need for prosthodontic treatment recently are high because of the increased number of population, life expectancies, and awareness of oral and dental health. Requests for teeth replacement with complete dentures continue to increase due to a lack of knowledge about the causes, treatments, and preventions for caries and periodontal disease. The main purpose of complete denture treatment is to restore masticatory function, facial aesthetic, and enhance patients' confidence, and the use of full dentures helps edentulous patients obtain adequate nutrition [1]. However, complete denture has some limitations since the masticatory efficiency of denture wearers is less than of dentate patients. For effective mastication, stability and occlusion in complete dentures must be considered. The choice of occlusion in tooth arrangements for complete dentures often confuses practitioners because of the specific considerations of each patient, such as aesthetic issues and alveolar ridge conditions [2]. Two occlusion schemes are available for complete dentures; both have balanced contact in centric occlusion, with the difference being in eccentric movement. The first scheme is balanced occlusion, which is used to balance...
teeth elements in lateral and protrusive movements. The second scheme is canine guidance, which separates posterior teeth during lateral movements for canine horizontal and vertical overlap [3].

Balanced occlusion stabilizes dentures and distributes force on residual ridges to protect the alveolar ridge from resorption. The advantage of balanced occlusion is less lateral force during functions and parafunctions. Based on study by Kydd, the use of anatomical, artificial teeth elements in balanced occlusion increases lateral force on residual ridges while chewing, although food bolus can separate teeth contacts, thus eliminating the function and advantages of balanced occlusion [2,3]. Based on electromyography study, complete dentures with canine guidance occlusion reduce elevator muscle activity. The prevention of residual ridges resorption by reducing the activity of masticatory muscles is still debated [3]. This study assumes that the proprioceptive ability of edentulous ridge mucosa guides neuromuscular function, especially after the loss of sensitive canines, which reduces muscle activity in lateral movements. Based on the research findings, the researchers suggest the use of gnathology systems similar to the natural teeth when treating edentulous patients [3].

Balanced occlusion in complete dentures requires a complicated procedure that includes mounting of a working model using a face-bow transfer method, recording condylar inclination, and determining centric relationships accurately that can be recorded several times [4]. Due to the complexity, most clinicians are not able to provide these data. In contrast, canine guidance complete dentures are simpler and only require the arrangement of canines and premolars so that posterior teeth are not in contact during lateral movements. The complicated process of making complete dentures does not affect patients’ satisfaction significantly [4]. The advantages of canine guidance complete denture are simpler in process, improved lower masticatory muscle activity, increased comfort when chewing food, and more stable [4,5].

2. Materials and Methods

This study included a clinical experiment with a cross-over clinical trial design. The subjects of this study were 14 patients in a teaching hospital, Faculty of Dentistry, Universitas Indonesia, who met the inclusion criteria, which were edentulous patients who needed complete denture treatment, normal alveolar ridge volume, no heart disease, no temporomandibular joint disorders, and no systemic diseases that affect the complete denture treatment procedures. The exclusion criteria were patients who were unwilling to participate in this study. The tools used were electromyogram (EMG) with a Nihon Kohden Neuropack 2 surface electrode, an planimeter to measure the surface area of the EMG-recorded results, and questionnaires to assess the ability of mastication in complete denture patients. Subjects were given information about the research and provided informed consent, personal data were recorded, and examinations of subjects’ oral conditions were performed. The initial EMG measurements were obtained from anterior temporalis muscles and superficial masseter muscles at maximum intercuspsation (i.e., the maximum isometric contraction for centric occlusion).

Figure 1. Installation of EMG electrode devices

Half of the subjects were randomly selected for canine guidance complete dentures, which were achieved by adding composite resin on the lingual surface of the maxillary canine so that during eccentric movements, molars were separated by 2 mm [6,7]. The other half were selected for balanced occlusion complete dentures. Both groups were instructed to use their partial dentures for 30 days, and
on the 30th day, the anterior temporalis and superficial masseter muscles were measured by EMG and the masticatory ability questionnaire was filled by the subjects. The EMG measurements were recorded using a planimeter. A cross over was performed for patients with balanced occlusion to canine guidance denture for a further 30 days and vice versa, after which measurements of anterior temporalis and superficial masseter muscles were taken using EMG and the questionnaire was completed by subjects.

3. Results and Discussion

3.1 Results
The subjects were edentulous patients requiring rehabilitation with complete dentures. The number of subjects who met the criteria was 10, but calculations indicated that a sample size of 14 subjects was required (i.e., seven subjects in each group). The number of samples gathered was less than the ideal sample calculation, but clinically, the results were significant. Thus, a calculation of research power was required by conversing the $Z_0$ value, which resulted in a research power of 80%. The subjects’ ages and genders can be seen in Table 1. The mean values of superficial masseter and anterior temporalis muscle activity in patients with balanced occlusion and canine guidance full dentures are in Table 2. All masticatory muscle EMG activity data have normal distributions based on a Shapiro-Wilks test and p-values > 0.05, which indicates significance. The questionnaire masticatory ability score had an abnormal distribution with a p-value < 0.05.

Table 1. Subject distribution based on age and gender

| Variables        | F | P |
|------------------|---|---|
| Age Category     |   |   |
| Age 51–70 yo     | 9 | 9 |
| Age 71 yo        | 1 | 9 |
| Gender Category  |   |   |
| Men              | 8 | 9 |
| Women            | 2 | 9 |

Table 2. Mean values of superficial masseter and anterior temporalis muscle activity in patients using balanced occlusion and canine guidance complete dentures based on emg surface areas.

| Variables                        | Standard | Mean |
|----------------------------------|----------|------|
| Balanced Occlusion Full Denture  |          |      |
| Superficial Masseter Muscles     |          |      |
| R                                | 457.96   | 301  |
| Left                             | 407.92   | 299  |
| Anterior Temporalis Muscles      |          |      |
| R                                | 308.04   | 286  |
| Left                             | 381.24   | 284  |
| Canine Guidance Full Denture     |          |      |
| Superficial Masseter Muscles     |          |      |
| R                                | 418.46   | 275  |
| Left                             | 419.66   | 280  |
| Anterior Temporalis Muscles      |          |      |
| R                                | 402.16   | 265  |
| Left                             | 344.03   | 249  |

Table 2 provides the mean values and standard deviations from the EMG data for masticatory muscle surface area. The average superficial masseter and anterior temporalis muscles in patients wearing balanced occlusion and canine guidance complete dentures were compared using a paired T-test, which
showed that all mean value EMG surface areas for right and left masticatory muscles were not significantly different ($p > 0.05$).

Table 3 shows that there are different mean values for the activity of left and right superficial masseter muscles in balanced occlusion and canine guidance complete denture patients, with significant $p$-values ($p < 0.05$) of 0.002 and 0.01, respectively.

**Table 3.** Mean value differences between superficial masseter muscle activity in patients using balanced occlusion and canine guidance complete dentures.

| Variables                | Mean (mm$^2$/s) | p-value |
|--------------------------|-----------------|---------|
| Right Superficial Masster Muscles |                 |         |
| Full Denture Patients   |                 |         |
| Balanced Occlusion       | 30175           |         |
| Canine Guidance          | 2755            | 0.002   |
| Left Superficial Masster Muscles |              |         |
| Full Denture Patients   |                 |         |
| Balanced Occlusion       | 29925           |         |
| Canine Guidance          | 2800            | 0.01    |

Table 4 shows that $p$-values were significant, at 0.031 and 0.013, which indicates that there is a significant difference in the mean values for anterior left and right temporalis muscles activity in patients using balanced occlusion and canine guidance full denture. A hypothetic test of paired category variables using a Wilcoxon test was performed to determine the differences in the average questionnaire score for masticatory ability in patients with balanced occlusion and canine guidance complete dentures. From each questionnaire, data were summarized and categorized based on cut-off values for the masticatory measurement tool questionnaires.

**Table 4.** Mean value differences between anterior temporalis muscle activity in patients using balanced occlusion and canine guidance full dentures.

| Variables                | Mean (mm$^2$/s) | p-value |
|--------------------------|-----------------|---------|
| Right Anterior Temporalis |                 |         |
| Full Denture Patients   |                 |         |
| Balanced Occlusion       | 2860            |         |
| Canine Guidance          | 2652            | 0.031   |
| Left Anterior Temporalis |                 |         |
| Muscles                  |                 |         |
| Full Denture Patients   |                 |         |
| Balanced Occlusion       | 28475           |         |
| Canine Guidance          | 24945           | 0.13    |
Table 5. The mean value scores of the questionnaires for masticatory ability in patients with balanced occlusion and canine guidance full dentures

| Variables                                      | %   | p-value |
|------------------------------------------------|-----|---------|
| Full Denture Patients with Balanced Occlusion  |     |         |
| Questionnaire Score                            |     |         |
| Good                                           | 30  |         |
| Bad                                            | 70  |         |
| Full Denture Patients with Canine Guidance     |     |         |
| Questionnaire Score                            |     |         |
| Good                                           | 70  |         |
| Bad                                            | 30  | 0.046   |

Table 5 shows that the p-value was significant at 0.046, which indicates that there were significant differences between the mean value questionnaire scores for masticatory ability in patients using balanced occlusion and canine guidance complete dentures. The next analysis was conducted to determine the relationship or correlation between superficial masseter and anterior temporalis muscles to masticatory ability based on the questionnaire score. First, a statistical test was conducted to compare the mean values of the left and right superficial masseter muscles and left and right anterior temporalis muscles to determine if the values were statistically different. The p-value was > 0.05 for every mean value comparison (Table 5). For this correlation test, the researcher chose the left side muscles for the questionnaire score for masticatory ability.

Table 6. Correlation between superficial masseter and anterior temporalis muscle activity and questionnaire scores for masticatory ability in patients using balanced occlusion and canine guidance complete dentures

| Variables                                      | Correlation | p-value |
|------------------------------------------------|-------------|---------|
| Complete Denture Patients Superficial Masseter Muscle | 0.545       | 0.031   |
| Questionnaire Score of Masticatory Ability      |             |         |
| Anterior Temporalis Muscles                     |             |         |
| Questionnaire Score of Masticatory Ability      | 0.642       | 0.045   |
| Complete Denture Patients Canine Guidance       |             |         |
| Superficial Masseter Muscles                    |             |         |
| Questionnaire Score of Masticatory Ability      | 0.648       | 0.043   |
| Anterior Temporalis Muscles                     |             |         |
| Questionnaire Score of Masticatory Ability      | -0.38       | 0.916   |

Table 6 shows that the correlation test for anterior temporalis muscles and the questionnaire score for masticatory ability in patients with balanced occlusion complete dentures had a p-value of 0.045, which indicates a significant correlation. The Spearman correlation value was 0.642, which shows that the correlation was positive and strong. Correlation tests for the superficial masseter muscles with the questionnaire score for masticatory ability in patients using canine guidance complete dentures had a p-value of 0.043, which indicates a significant correlation. The Spearman value was 0.648, which shows that the correlation was positive and strong.
3.2 Discussion
Ten subjects were asked to provide informed consent and undergo an EMG examination before answering a masticatory ability questionnaire. Research data were collected twice for each subject at intervals of 30 days. Dependent and independent variables were included, but co-founding variables were not because the data were collected for the same subjects using two sets of measurements and a single, blind cross-over method. The subjects did not know if their complete dentures were balanced occlusion or canine guidance because the researcher chose subjects randomly. The cross-over study design eliminated bias, such as differences mastication strength in each subject.

The data were taken by recording subject’s masticatory muscles while in full contraction in balanced occlusion and canine guidance complete dentures, using EMG. Surface EMG measures muscle activity noninvasively using surface electrodes placed on the skin overlying the muscle to determine the timing of the muscle contraction and to investigate the behavior of the muscle during functions of the stomatognathic system [8]. Both muscles included were the largest masticatory muscles that play an important role in maximum intercuspation for centric occlusion [9]. The EMG recordings were taken for superficial masseter and anterior temporalis muscles on both sides of the jaw in maximum isometric conditions to activate the maximum number of motor units that represent muscle activity, and then the recorded data were measured to determine surface area using a planimeter [9]. The subject data were taken using a questionnaire to evaluate masticatory ability when wearing balanced occlusion and canine guidance complete dentures.

The Shapiro-Wilks normality test was performed for all variables and was chosen because the number of subjects was less than 50. The results of the test showed a normal distribution for all variables (p > 0.05). To compare the mean values of the variables, a paired T-test was used because the variables were numerical and every subject was assigned to two conditions. Variables for masticatory were tested using a Wilcoxon test because the variables were categorized. To determine the correlation between masticatory muscle activity and masticatory ability, a Spearman test was chosen because both variable types were numerical and the test provides correlation strength between those two variables.

The data from EMG that was measured by the planimeter were numerical. For a hypothetical test of paired numeric variables, a paired T-test of the surface areas of EMG variables from right and left superficial masseter and anterior temporalis muscle activity was performed, with p-value of 0.002, 0.01, 0.031, and 0.013, respectively. The different mean values indicate statistical significance for every masticatory muscle examined. Based on these results, the EMG surface area for masticatory muscles in the subjects using canine guidance complete dentures was less than in subjects using balanced occlusion complete dentures. This was caused by muscle elongation or the ability of the sarcomere to elongate skeletal fiber and produce active muscle tension [10]. This result is consistent with Peroz, and it was determined that canine guidance full dentures decrease activity in elevator muscles, such as the superficial masseter and anterior temporalis muscles [3,11]. This reduction decreases resorption of residual ridges, which is an advantage for complete denture patients with this type of occlusion [12]. The results are contrary to Grubwieser’s study, which found no significant difference in the EMG measurements of masticatory muscles in subjects using balanced occlusion and canine guidance complete dentures [16]. This could be a result of differing sample sizes.

The data taken from the masticatory ability questionnaire were categorized by scale. A descriptive analysis revealed that 30% of balanced occlusion complete denture patients had good masticatory ability and 70% had poor masticatory ability, while 70% of canine guidance complete denture patients had good masticatory ability and 30% had bad masticatory ability. A correlation test of numeric variables showed a significant, positive, and strong correlation between EMG measurements of anterior temporalis muscles and masticatory ability questionnaire scores in balanced occlusion complete denture patients as well as for EMG measurements of superficial temporalis muscles and masticatory ability questionnaire scores for canine guidance complete denture patients. Not all variables had significant correlations; thus, it can be concluded that there is a correlation between EMG measurements of masticatory muscles and the masticatory ability questionnaire scores. This study was limited by a lack of initial EMG measurement data after subjects were randomly chosen to wear balanced occlusion or
canine guidance complete dentures. The initial data could have been used to compare the mean values of EMG measurement after the first 30 days. The variables in this study could be expanded to include mandibular movements using a kinesiograph to analyze the relationship between balanced occlusion and canine guidance full dentures and a range of mandibular movements.

4. Conclusion
There are differences in masticatory muscles (superficial masseter an anterior temporalis muscles) between balance occlusion and canine guidance complete dentures wearers. EMG measurements of masticatory muscle activity in canine guidance complete denture wearers were significantly lower compared to balanced occlusion complete denture wearers. Additionally, canine guidance complete dentures provide better masticatory ability than balance occlusion complete dentures.

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