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# Computerised occlusal analysis of mini-dental implant-retained mandibular overdentures: A 1-year prospective clinical study

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## Abstract

Occlusal analysis is a substantial tool for the functional improvement evaluation after using implant-retained overdenture comparing to complete denture without dental implant retaining. To evaluate occlusal pattern, chewing force distribution in mini-dental implant-retained mandibular overdentures by computerised occlusal analysis system and to compare patient satisfaction after 1-year function. Thirty-one patients wearing complete dentures were included in the study. Prior to mini-dental implant-retained treatment, all patients were assessed for occlusion and force distribution using computerised occlusal analysis system (T-Scan®), and then, all patients received two mini-dental implant-retained mandibular overdentures. Mini-dental implants were immediately loaded using low vertical profile attachments (Equator®). T-Scan® was used to evaluate chewing force and force distribution at 1 day, 3 months, 6 months and 12 months. The patient satisfactions before implant placement and after 1 year were evaluated using questionnaires which included satisfaction of denture quality, psychosocial behaviour and chewing efficiency modified from the validated questionnaires. Clinical evaluation of two mini-dental implant-retained mandibular overdentures showed 100% success rate after 1 year. T-Scan® demonstrated that maximum occlusal contact force increased continuously. The force distribution; the tooth contact number increased over the period. At 1-year follow-up, overall patient satisfaction was significantly greater than before receiving mini-dental implant treatment ($P < .001$). Using computerised occlusal analysis, mini-dental implants improve complete denture function significantly in terms of maximum occlusal contact force, tooth contact number without the impairment of force distribution. The oral function of the patients has been enhanced.

KEYWORDS

computerised occlusal analysis, force distribution, mini-dental implant-retained overdenture, overdenture, T-Scan

**Abbreviations:** ASA, American Society of Anesthesiologists; ICOI, International Congress of Oral Implantologists; MOF, maximum occlusal contact force; TCTR, Thai Clinical Trial Registry; VAS, visual analogue scale.

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## 1 | BACKGROUND

According to the glossary of oral and maxillofacial implants, mini-dental implant has been defined as "implant fabricated of the same biocompatible materials as other implant but of smaller dimensions (<3 mm)."[1,2] Two mini-dental implants have been used successfully to retain complete dentures, especially in the mandible.[1,2] In various studies, patients using dental implant-retained overdentures have reported better chewing function and significantly higher overall satisfaction than when using conventional complete dentures.[3-6]

In a recent systematic review, it was demonstrated that mini-implant-supported overdentures provide better patient satisfaction than do standard-diameter-implant overdentures.[7]

Conventional implant-retained overdentures often require two steps, primary stability of implant placement and denture connection attachment.[1,2,6,8] Compared to conventional implant, mini-dental implant is better for elderly people with ridge resorption, chronic diseases, fear of surgery and their lower cost.[1,2]

Although a mandibular implant-retained overdenture is not as good a treatment choice as a fixed implant-supported prosthesis, it provides complete denture wearers significant chewing and quality-of-life improvement.[8-10]

Various attachment types, such as magnetic, ball, Locator® and Equator® attachments, have been used in un-splinted implant-retained overdentures.[11] The Equator® attachment is a recently introduced mini-implant attachment which has smaller size than other attachment systems, and has been proved to have fewer prosthetic complications than has the ball attachment. Moreover, the surgical procedure for mini-dental implants is less invasive than that for conventional implant placement, which requires full-thickness flap surgery. In mini-dental implant procedures, a tissue punch is most often performed because there is sufficient bone width for implant placement.[2] Flapless surgery is shown to provide less discomfort, less swelling, less post-operative pain and reduced healing time than full-thickness flap surgery.[12-16]

According to Aunmeungtong and colleagues, the cumulative survival rates of two immediate mini-dental implant-retained mandibular overdentures and of four immediate mini-dental implant-retained mandibular overdentures were 100% in 1-year study. There were no significant differences in clinical result, marginal bone loss and patient satisfaction between two mini-dental implant-retained mandibular overdentures and four mini-dental implant-retained mandibular overdentures.[2]

During osseointegration period, the force distribution of implant-retained overdenture using immediate protocol plays an important role for the success of the treatment. Overloading from occlusal force around dental implants should be avoided. Thus, occlusal analysis becomes an important step for the implant treatment success. Occlusal evaluation should be provided after immediate load to avoid overloading complications that may occur.[17-21] Well-distributed occlusal force and occlusal contact area should be achieved in order to increase the masticatory performance of complete denture wearers.[22-24] The most common way to evaluate occlusion is using articulating paper. However, it is subjective and might be misleading.[25-29] Computerised occlusal analysis system was introduced recently to objectively evaluate occlusal force distribution. It was found that occlusal indicator is reliable to assist in occlusal adjustment.[30,31] T-Scan® (Tekscan, Inc) is a digital occlusal analysis system for recording and measuring tooth contact, force distribution and timing in real-time using pressure-sensitive bite transducer.[32-34] The occlusal force distribution, occlusal interference and relative force of each interference can be determined from the occlusal recorded.[32,33] The T-Scan® records occlusal parameters, such as the centre of force, demonstrating the symmetry of the occlusal force, first contact, the area of early contact between maxillary and mandibular teeth, maximum occlusal contact force (MOF) and maximum intercuspation (the occlusal position of the mandible in which the cusps of the teeth of one arch fully interpose themselves with the cusps of the teeth of the opposing arch). Maximum intercuspation is an important jaw position that defines both the anterior-posterior and lateral relationships of the mandible and maxilla, as well as the superior-inferior relationship known as the vertical dimension of occlusion.[34] Occlusal analysis is also a substantial tool for the functional improvement evaluation after using implant-retained overdentures in terms of bite force and occlusal distribution comparing to complete denture without dental implant.[22-24,33]

From above, mini-dental implant is easy to place and can immediately be loaded by retaining the lower complete denture. The use of mini-dental implant for 1-day treatment in rural area is possible. The pilot project using mini-dental implant in dental mobile units has been planned and performed in rural area in Chiang Mai Province, Thailand.

The aims of the study were prospectively evaluating the occlusal pattern, chewing force distribution in mini-dental implant-retained mandibular overdentures by computerised occlusal analysis system and comparing patient satisfaction after 1-year function of immediately loaded two mini-dental implants.

## 2 | METHODS

The study was designed as a prospective clinical study. This study was approved by the Human Experimentation Committee of the Faculty of Dentistry, Chiang Mai University number 1/2017. It has been registered for Thai Clinical Trial Registry (TCTR) number 20170216002.

Thirty-one patients participating in this study were recruited from four rural districts hospitals of Chiang Mai province, Thailand. The inclusion criteria were as follows: patients who had complete dentures which were in good bilateral force balanced conditions[22-24] and had been used for at least 1 year. The participating patients had no contraindications for minor oral surgery and no severe systemic disease according to American Society of Anesthesiologists (ASA) classification class 1 to class 2. The patients were not heavy smokers (<10 cigarettes per day). The patients had good attitude to dental implant treatment and could return for the follow-up study schedule. The implant areas (lower left and right canine regions) had sufficient bone height (more than 14 mm.) and width (more than 6 mm.).

For the sample size calculation, the software G*Power (Dusseldorf University) was used to confirm the sample size of this study. The calculated of minimum sample size are 26 patients, with alpha error probability of 0.05, 1-beta error probability of 0.8, matched pair. One examiner who is an expert in T-Scan® computer analysis has been assigned for the result evaluation (intra-examiner reliability with 0.991 intra-class correlation coefficient). Pre-operatively, the patients were evaluated for the occlusal pattern, chewing force distribution and maximum occlusal contact force using T-Scan® computerised occlusal analysis system (T-Scan 8, Software version 8.0.1, Tekscan, Inc) (Figure 1). The patient satisfactions were also evaluated using questionnaires which included satisfaction of denture quality, psychosocial behaviour and chewing efficiency modified from the validated questionnaires[35] (Table 1) using a 10-cm visual analogue scale (VAS) as a cross mark on a scale from 0 to 100 mm for measurement.

The participating patients were examined radiographically using cone-beam computer tomography together with the radiologic markers in lower complete denture at lower canine regions for implant position marking. Two mini-implants with diameter of 3 mm and length of 12 mm (PW Plus Co., Ltd) were placed under local anaesthesia (4% articaine with 1:100 000 epinephrine) using flapless technique at the positions which have been previously marked at the lower denture. After mini-implants were placed, the dentures were connected immediately with the mini-dental implants through a low vertical profile attachment system (Equator®, Rhein83) with 0.6 kg retentive force and self-cure pink acrylic resin (Tokuyama® Rebase II, Tokuyama Dental Corporation) (Figure 2). Post-operative radiograph (orthopantomogram) was taken to confirm the implant positions. The patients were provided with analgesic (Paracetamol 500 mg four times/d) and antibiotic (Amoxicillin 500 mg four times/d) for 3 days. Following a 6-month period of use, the Equator® retentive caps were changed to the higher retention forces (1.2 kg).

The occlusal patterns of the patients, which are chewing force distribution and maximum occlusal contact force, were analysed by using T-Scan®. The occlusal analyses were repeated at 1 day, 3 months, 6 months and 12 months after mini-implant placement. The patients' satisfaction was measured again at 12-month function.

The results of the study were evaluated by one examiner. The data obtained from T-Scan® were MOF and force distribution (Figure 3). The force distribution was measured and analysed in three evaluations. The first evaluation was the bilateral force difference (per cent difference between left chewing area and right chewing area from canine to second molar area). The second was tooth contact number (amount of tooth contact from canine to second molar area). The third was degree of force distribution (the occlusal contact arch was separated into two segments each side, with the canine premolars one segment, and the molars the second, thus a total of four segments) which was analysed the force distribution. The occlusal force data were statistically analysed by using SPSS 22.0 software (SPSS Inc); descriptive statistics (mean and standard deviation); Greenhouse–Geisser test (one-way repeated measure ANOVA) was used to analyse normal distribution data; and the Bonferroni correction test was used to analyse multiple treatment period comparison.

The 12-month patient satisfactions were also evaluated using the same pre-operative questionnaire, using a 10-cm VAS for measurement. The patient satisfaction was statistically analysed using descriptive statistics (mean and standard deviation); Kolmogorov–Smirnov test was used to analyse for normal distribution data; and paired *t* test was used to compare results regarding patients' satisfaction before treatment and after 12 months.

## 3 | RESULTS

In this 1-year study of mini-dental implant-retained mandibular overdentures, thirty-one subjects (21 males and 10 females) were enrolled. The mean age of participant was 65.84 ± 7.66 years. The demographic data are shown in Table 2.

### 3.1 | Success of mini-dental implant after 1 year

The success rate of dental implants was 100% according to the criteria established at the Consensus Conference of the International Congress of Oral Implantologists (ICOI) in Pisa in 2007.[36]

### 3.2 | Computerised occlusal analysis

MOF data were normally distributed. The MOF at before implant placement, 1-day function, 3-month function, 6-month function and 1-year function increased continuously. There was a significant difference between the MOF before implant placement (84.14% ± 5.79) and after 1 year of function (89.77% ± 4.56), ($P < .05$). There was


**FIGURE 1** T-Scan® computerised occlusal analysis system. A, T-Scan® device and T-Scan® software. B, Using T-Scan® device in patients. C, Occlusal pattern analysis, maximum occlusal contact force (MOF) and force distribution

**TABLE 1** Questionnaires and results of patients' satisfaction between before and after 1-y function of mini-dental implant-retained mandibular overdentures

| Questionnaires for patient satisfaction | VAS before treatment | VAS after treatment |
|---|---|---|
| 1. How do you find your prosthesis in general? | 57.78 ± 21.18 | 94.63 ± 12.00 |
| 2. How well does your prosthesis remain in place? | 60.19 ± 21.95 | 93.33 ± 13.01 |
| 3. How well can you eat with your prosthesis? | 60.56 ± 22.29 | 96.11 ± 8.36 |
| 4. How well can you talk with your prosthesis? | 65.19 ± 21.01 | 94.30 ± 11.50 |
| 5. How do you find the appearance of your prosthesis? | 62.96 ± 21.98 | 95.04 ± 10.83 |
| 6. Describe the extent of comfort with your upper denture? | 68.26 ± 25.39 | 93.70 ± 9.67 |
| 7. Describe the extent of comfort with your lower denture? | 56.48 ± 20.56 | 96.96 ± 7.73 |
| 8. How would you rate the fit of your upper denture? | 64.22 ± 24.58 | 87.41 ± 17.01 |
| 9. How would you rate the fit of your lower denture? | 60.00 ± 22.70 | 95.22 ± 11.31 |
| 10. Do you have improvement speaking with your prosthesis? | 62.96 ± 23.83 | 98.37 ± 5.35 |
| 11. How often does your prosthesis affect your socializing? | 64.67 ± 23.51 | 92.85 ± 13.20 |
| 12. Are there more activities you can do, using your prosthesis with confidence? | 68.89 ± 25.01 | 95.41 ± 11.84 |
| 13. Indicate if your prosthesis improves your work? | 70.00 ± 26.17 | 97.04 ± 7.24 |
| 14. Can you bite off soft foods easily? | 59.85 ± 21.43 | 82.22 ± 18.26 |
| 15. Can you bite off hard foods easily? | 47.22 ± 27.47 | 77.41 ± 21.05 |
| 16. Can you chew soft foods easily? | 62.59 ± 22.29 | 92.59 ± 14.83 |
| 17. Can you chew hard foods easily? | 50.93 ± 30.45 | 88.52 ± 17.69 |
| 18. How satisfied are you with the healing since your implant surgery? | | 97.78 ± 5.60 |
| 19. Do you think your implant-supported prosthesis is actually part of you? | | 97.59 ± 5.78 |
| 20. To what extent has yours implant-supported prosthesis implant-supported prosthesis improved your social and work relationship with other people? | | 97.22 ± 6.52 |

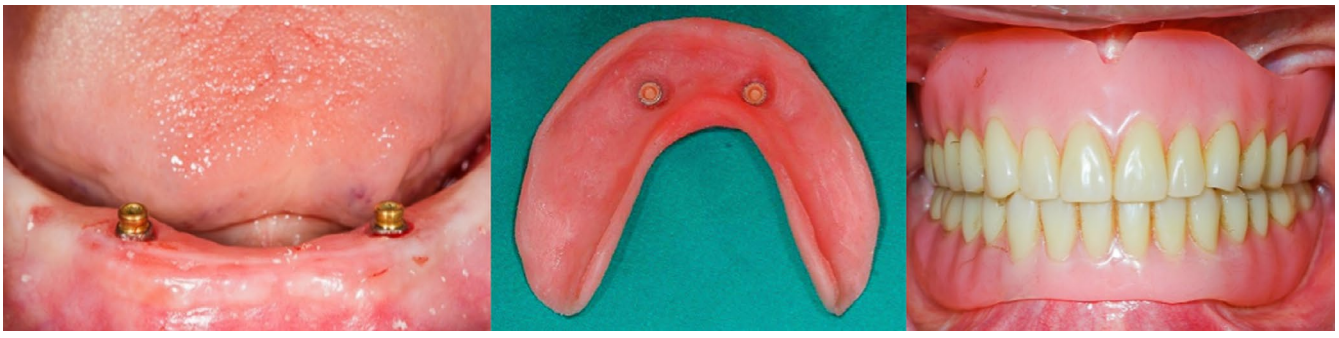

**FIGURE 2** Mini-dental implant-retained mandibular overdenture

a significant difference found between maximum occlusal contact force after 1 day of function (85.27% ± 5.92) and 1 year of function (89.77% ± 4.56), ($P < .05$) (Table 3).

Force distribution was analysed by using three separate evaluations. In the first evaluation, the bilateral force difference data were normally distributed. There were no significant differences regarding the bilateral forces data obtained before implant placement, at 1 day of function, following 3 months, 6 months and 1 year of function. (Figure 4).

In the second evaluation, the tooth contact number data were normally distributed. There was a significant difference between the tooth contact number before implant placement (6.63 ± 1.95) and after 1 year of function (7.73 ± 1.66), ($P < .05$). There was no significant difference found between tooth contact number after 3 months of function (7.22 ± 2.13) and 6 months of function (6.58 ± 2.18) (Figure 5).

In the third evaluation, the degree of force distribution data was normally distributed. There was no significant difference between the degree of force distribution at the observation time (Figure 6).

## 3.3 | Patients' satisfaction

According to the questionnaires, the results are shown in Table 1. All patients' satisfaction indices were significantly improved ($P < .001$) after using mini-dental implant-retained overdentures. The quality-of-life scores after 1-year function are about 97.2%.

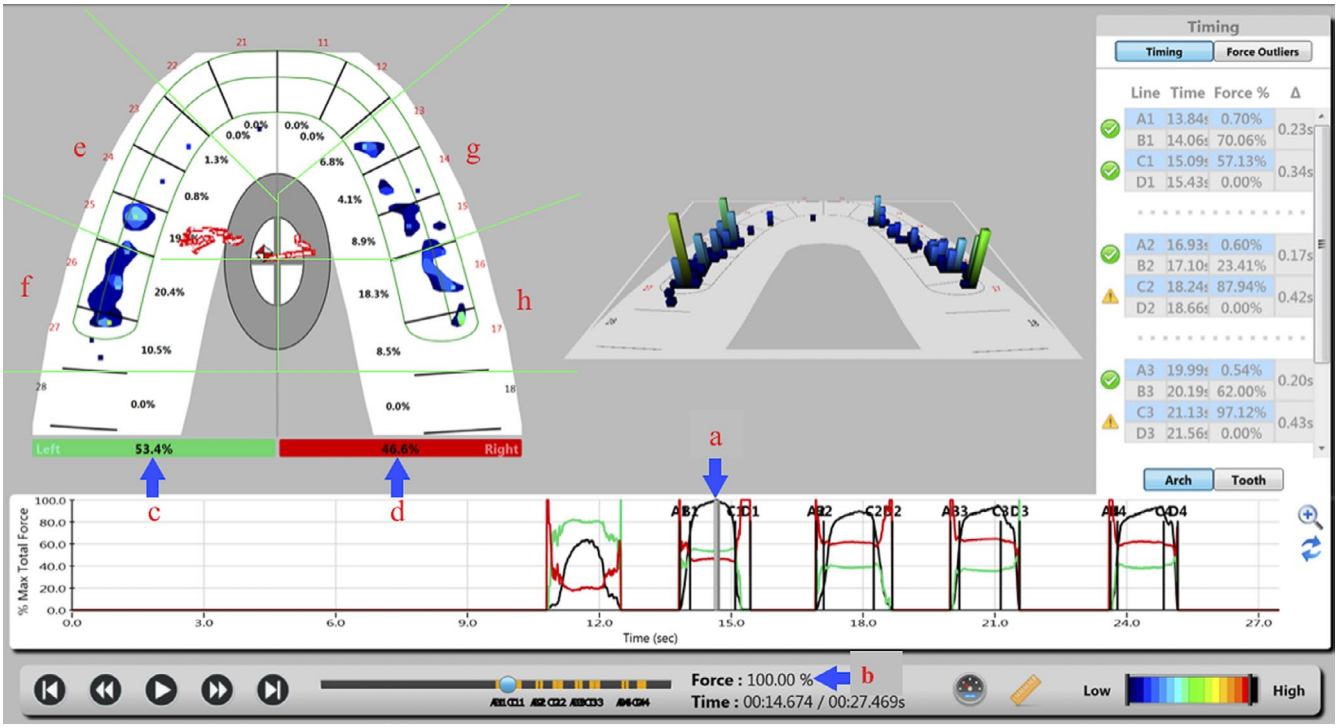


**FIGURE 3** Occlusal force evaluation by T-Scan®. A, The maximum occlusal contact time. B, The amount of maximum occlusal contact force. C and D,, Force distribution, bilateral force difference. E-H, Force distribution, tooth contact number and degree of force distribution

**TABLE 2** Demographic data of participants

| | Gender | | |
|---|---|---|---|
| Age | Male | Female | Total |
| < 60 | 3 | 3 | 6 |
| 60-69 | 11 | 4 | 15 |
| 70-79 | 5 | 3 | 8 |
| >80 | 2 | 0 | 2 |
| Total | 21 | 10 | 31 |

## 4 | DISCUSSION

The success of mini-dental implant-retained overdentures has been well documented. The success rate is about 91.17%-100%.[2,12,16,19,37,38] From our study, the success rate of the treatment is 100%. The factors that may have influenced the success of the treatment are the denture status, the denture design, the adequate tissue support and the parafunctional habits.[39] The results of this study show that using mini-dental implant-retained overdentures provided within the setting of a mobile dental treatment unit is possible and that good results are achievable. However, regular maintenance of implant-borne prostheses and long-term care of the attachment part together with the physiologic change in the alveolar bone are still required, and they play an important role for the long-term success.

Occlusal analysis becomes an important step for the success of implant treatment. The proper occlusion in complete denture is the crucial factor to improve the success of the treatment. Using computerised occlusal analysis assists the dentist to detect occlusal force and occlusal distribution and allow the dentist to adjust the occlusion accurately.[30-34] It is also used together with conventional articulating paper.[26]

Several studies showed that using two or four dental implants retained overdenture improve the function of the denture.[1,2,40,41] From our study, we are comparing the occlusal analysis before and after using mini-dental implants to retain the lower complete dentures.

Evaluating MOF of a complete denture is one important indicator for measuring the complete denture function. The results of our study show that we can measure the MOF of the complete denture. Before using the mini-dental implant-retained overdenture, the initial maximum occlusal contact force was about 84%. It has been estimated that the MOF in a complete denture is about 102.2N to 142.9N. Using mini-dental implants to support the complete denture increases MOF significantly up to 90% at 1 year of function ($P < .05$, Figure 7).

Principle of the occlusion in complete denture is distribution of the chewing force to bilateral balanced occlusion. With this occlusal design, patients can use the complete denture effectively. Force distribution represents the bilateral balanced occlusion. From our study, the use of mini-dental implant does not impair the balancing occlusion which has been designed from the beginning of complete denture fabrication (Figures 4 and 6).

However, when compared the tooth contact number, we found that use of mini-dental implant-retained overdentures can improve

**TABLE 3** The changes in occlusal force measurements over time

| Time | Before implantation | 1-d function | 3-mo function | 6-mo function | 12-mo function | Significant *P* value |
|---|---|---|---|---|---|---|
| Per cent of maximum occlusal contact force | 84.14 ± 5.79 | 85.27 ± 5.92 | 88.22 ± 7.11 | 87.62 ± 5.63 | 89.77 ± 4.56 | Before implantation and 12-mo function; *P* = .004<br>1-d function and 12-mo function; *P* = .013 |
| Per cent of bilateral force difference | 22.29 ± 21.52 | 23.35 ± 19.50 | 18.93 ± 13.36 | 22.48 ± 13.35 | 17.25 ± 12.36 | |
| Tooth contact number | 6.63 ± 1.95 | 5.84 ± 2.30 | 7.22 ± 2.13 | 6.58 ± 2.18 | 7.73 ± 1.66 | Before implantation and 12-mo function; *P* = .022<br>1-d function and 3-mo function; *P* = .001<br>1-d function and 12-mo function; *P* < .001<br>6-mo function and 12-mo function; *P* = .009 |
| Degree of force distribution | 3.39 ± 0.75 | 2.92 ± 0.99 | 3.58 ± 0.70 | 3.32 ± 0.85 | 3.62 ± 0.65 | 1-d function and 3-mo function; *P* = .001<br>1-d function and 12-mo function; *P* = .003 |

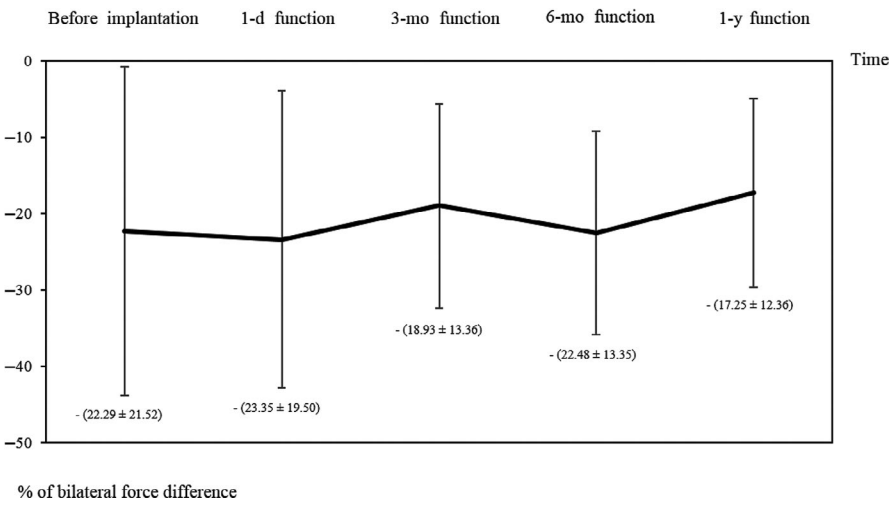


**FIGURE 4** Force distribution, bilateral force difference in 1-y function of mini-dental implant-retained mandibular overdentures

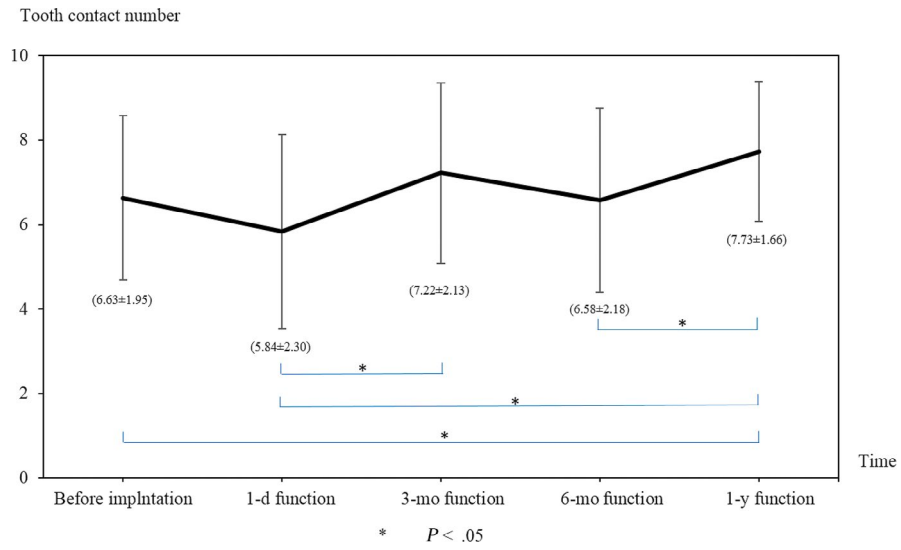


**FIGURE 5** Force distribution, tooth contact number in 1-y function of mini-dental implant-retained mandibular overdentures

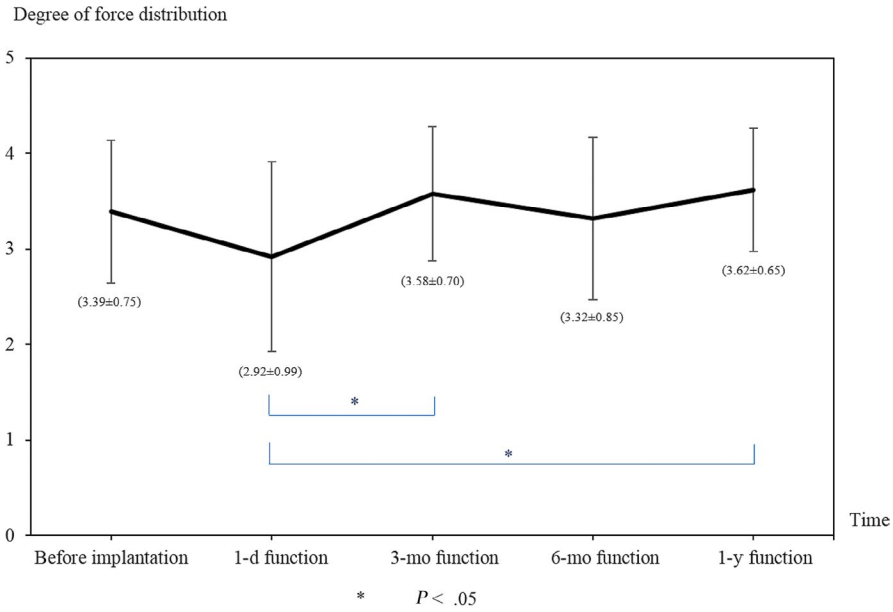


**FIGURE 6** Force distribution, degree of force distribution in 1-y function of mini-dental implant-retained mandibular overdentures

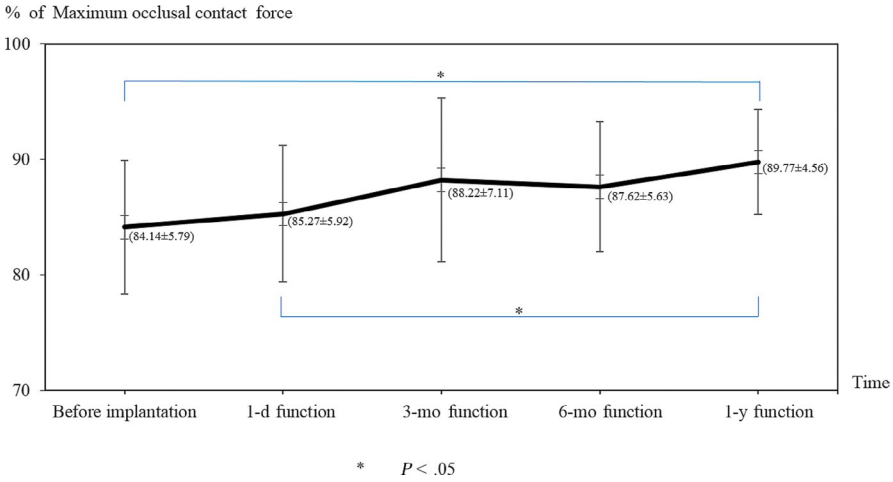


**FIGURE 7** Maximum occlusal contact force in 1-y function of mini-dental implant-retained mandibular overdentures

tooth contact number significantly ($P < .05$, Figure 5), thus improving the chewing function of the complete denture.

At the 6-month function, the MOF, the bilateral force difference, the tooth contact number and the degree of force distribution values were found slightly decreased due to the deterioration of the Equator® retentive caps. After changing the retentive caps, all the values were found increased at the 12-month follow-up.

Overall patients' satisfactions and quality of life from this study were significantly increased after 1-year function when compared to before mini-dental implant placement ($P < .001$). As with previous studies, comparing complete dentures and mini-dental implant-retained overdentures, overall patients' satisfaction was significantly increased with mini-dental implant-retained overdentures.[43-45]

Focusing on potential drawbacks using two mini-dental implants for retention of a complete denture, according to osseointegration, disintegration of the mini-dental implants could happen due to excessive occlusal forces such as using the anterior part of the denture only, or due to atrophy of the edentulous ridge after long-term use of a complete denture without relining the denture base.

The limitations of the study are the parameters obtained from the T-Scan. It can be interpreted in proportion from the diagrams of the software. For example, the maximum occlusal contact force can be shown only in per cent when compared to the other areas of the patients' occlusion, but it cannot show the numerical value of the force in Newton. Further studies using software for more detailed occlusal force analysis is required to confirm the results of the present study.

## 5 | CONCLUSION

Within the limitations of the study, by using computerised occlusal analysis, mini-dental implant can improve complete denture function significantly in terms of maximum occlusal contact force and tooth

contact number without the impairment of force distribution. The oral function of the patients has been enhanced.

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## CONFLICT OF INTEREST

None declared.

## AUTHORS' CONTRIBUTIONS

Pathawee Khongkhunthian contributed to the concept and design of the study, Phongkamon Kabbua contributed to data collection, data analysis/interpretation, statistics, and drafting of the article. Pathawee Khongkhunthian and Weerapan Aunmeungtong contributed to the critical revision and approval of the article.

## ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study protocol was approved by the Human Experimentation Committee of the Faculty of Dentistry, Chiang Mai University number 1/2017. It has been registered for Thai Clinical Trial Registry (TCTR) number 20170216002. Written consent was obtained from all participants.

## CONSENT FOR PUBLICATION

The written consent to publish was obtained from all participants.

## DATA AVAILABILITY STATEMENT

The data sets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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