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Influence of Fixed Prosthodontic Treatment on Occlusal Contacts in Centric Occlusion: A Preliminary Study

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

Aim: Adequate occlusal contacts are believed to be necessary for dentition function. This study aims to evaluate the impact of prosthodontic treatment on intercuspal occlusal contacts in relation to contact number and contact area.
Methodology: The pre-treatment and post-treatment models of 13 patients who underwent fixed prosthodontic treatment on several teeth were retrieved. All the models were scanned by a Micro-CT scanner and 3D virtual images were established. To evaluate the occlusion, the models were virtually articulated. Two occlusion variables were evaluated: (1) contact number and (2) contact area. In addition, the impact of the inter-arch location (maxillary vs. mandibular arches) and intra-arch location (anterior vs. posterior teeth) was assessed.

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Results: The prosthodontic treatment had significantly increased the contact number and contact area. The effect of the inter-arch location was insignificant. However, the intra-arch location had significantly affected the contact number and area, where the posterior teeth had a significantly greater contact number and area. The posterior teeth were more influenced by the prosthodontic treatment than the anterior teeth, while the anterior teeth were minimally influenced.
Conclusion: The prosthodontic treatment improved the quality of occlusal contacts by increasing the contact number and area. The effect of the prosthodontic treatment was more prominent in the posterior region, while, anteriorly, the occlusal variables were minimally affected.

Keywords: Contact number; contact area; articulation; micro-CT.

1. INTRODUCTION

Adequate contacts in maximal intercuspation is one of the main factors responsible for maintaining correct alignment of the teeth and stabilization of the mandible [1]. Further, since maximal tooth contacts occur in this position, the quality of intercuspation will influence chewing efficiency [2-4]. Two variables dictate the quality of maximal intercuspation: (1) contact number and (2) contact area. It has been speculated that more functional stability and chewing efficiency will occur with increasing the contact number and contact area [3,5]. Therefore, these variables have been used frequently as a measure of the adequacy of dental occlusion. In the literature, the contact number [6-9] and area [3,4,10] were heavily investigated and quantified. Most of the studies had evaluated the contact number and area of intact dentition in young individuals. However, occlusion features are dynamic and subject to change with aging and dental treatment. Restoration, tooth wear and fracture will inevitably affect the tooth morphology and subsequently the contact number and area will change in the intercuspal position [11]. As one of the objectives of prosthodontic treatment is to improve oral function, it is imperative to observe the changes of occlusal contacts and areas following the treatment [12,13]. To date, there has been minimal research that quantifies the impact of prosthodontic treatment on occlusal contacts.

The aim of this preliminary study is to compare the quality of intercuspal occlusal contacts before and after fixed prosthodontic treatment in terms of contact number and contact area. Further, the effect of the intra-arch (anterior vs. posterior teeth) and inter-arch variables (maxillary vs mandibular arches) is evaluated. The null hypotheses are the contact number and area will increase following the prosthodontic treatment, and there is no influence of the inter-arch and intra-arch variables on intercuspal occlusal contacts quality.

2. MATERIALS AND METHODS

Thirteen patients participated in the study. Seven of the participants were males and six of them were females. The age range was between 42 and 67 years. The main inclusion criterion was the presence of stable occlusion [14]. Detailed inclusion criteria were presented in (Table 1). All have received fixed prosthodontic treatment on several teeth in the form of porcelain-fused-to metal prostheses (crowns or fixed partial dentures) in at least one arch. The treatments were provided at the Oral Health Centre of Western Australia by one prosthodontics specialist. A human research ethics approval was obtained from the Human Research Ethics Committee of the University of Western Australia (RA/44/1/5079).

2.1 Pre-treatment and Post-treatment Models

Irreversible hydrocolloid impressions (Alginate, GC America, IL, USA) were taken for each patient before (pre-treatment) and after the completion of the prosthodontic treatment (post-treatment). The centric relation position was used to record the occlusal relationship prior to prostheses fabrication. Therefore, following prostheses insertion, there was a coincidence between centric relation and maximal intercuspation positions [14]. The post-treatment impressions were taken at the review visits (one to four weeks post-treatment) and after providing all the necessary occlusal adjustments. The impressions were poured by dental stone (Buff Stone, Adelaide Moulding & Casting Supplies, South Australia, Australia). The lateral occlusion scheme followed the biologic occlusion principles (canine-guided occlusion or group function occlusion) [1,14].

As the occlusion of all the models was reproducible in maximal intercuspation, all the models were hand-relatable and mounted on dental articulator (Whip Mix, Louiseville, KY,

USA). To facilitate the subsequent digital evaluation, silicone material putty (Dental Speedex Putty, Coltene/Whaledent AG, Altstatten, Switzerland) was applied on the buccal aspects on the posterior teeth of the articulated models. The models and the silicone registration indices were scanned by a Micro-CT scanner (SkyScan, Bruker microCT, Kontich, Belgium). Virtual 3D Stereolithography (STL) images (Fig. 1) were constructed from the Digital Imaging and Communication Medicine (DICOM) images with the aid of a DICOM viewing program (CTvox, Bruker microCT, Kontich, Belgium).

2.2 Virtual Occlusion

All the virtual models were remeshed with a density of 0.1 mm to facilitate the computational speed and allow a uniform comparison between the pre- and post-treatment models. With the aid of the virtual silicone indices, the models were articulated through the process of image registration (Fig. 2). A 3D rendering software package (Geomagic Studio, Raindrop Geomagic Inc., Research Triangle Park, NC, USA) was used for the registration process [7]. As discussed by several authors, the registration process involved two sequential steps: (1) point-to-point registration and (2) global registration [15,16]. The point-to-point registration is based on manually selecting points of common surfaces on the virtual model and silicone index. The global registration aims to approximate the best alignment of the virtual model against the virtual silicone index according to the Iterative Closest Point Algorithm. The same process was repeated for the other silicone index and the opposing arch. Eventually, the silicone indices were deleted digitally, and the two models were digitally articulated (Fig. 2D).

2.3 Analysis

The models were imported to mesh measurement software (Meshlab Software, Visual Computing Lab, University of Pisa, Italy) to analyse the occlusal contacts. As mentioned by previous researchers who digitally evaluated the occlusion, a threshold was set to allow visualizing the contacting surfaces [7,10]. 200 µm was selected to determine the critical surfaces of occlusion [10]. To allow the visualization of the occlusal relationship, the opposing surfaces were colour-coded according to the inter-occlusal distance, where the red colour indicates a 0 µm distance and the yellow colour indicates a distance of 200 µm or less (Fig. 3). Therefore, the number of occlusal contacts was represented by the number of yellow to red spots on the contacting surfaces (Fig. 4A). The contact area was determined by quantifying the area with yellow-coloured boundaries (Fig. 4B). Since only the affected teeth or pontics were considered, the contact number per tooth (CNT) and contact area per tooth (CAT) were calculated. This involves the restored unit and the opposing unit. Therefore, such a calculation will ensure that the comparison between pre-treatment and post-treatment models will not be influenced by altering the occlusal unit number. The following equations were implemented:

CNT = Total number of contact/number of the affected unit.
CAT = Total contact area/number of the affected unit.

CNT and CAT were recorded at two levels: inter-arch level (maxillary vs. mandibular arches) and intra-arch level (anterior vs. posterior teeth).

2.4 Statistics

For the inter-arch and intra-arch comparison, the average CNT and CAT were calculated. To evaluate the significance of the differences, the Mann-Whitney test was performed (*P* value = .05). In addition, the relationship between the contact intensity and area intensity was blotted on a scatter diagram.

Table 1. Inclusion criteria

- Reproducible articulation in maximal intercuspation
- Few missing teeth that do not affect the occlusion stability (no loss of more than two teeth in one sextant of the arch)
- The prostheses are completely supported by natural teeth
- No removable or implant prostheses
- The teeth do not exhibit noticeable mobility

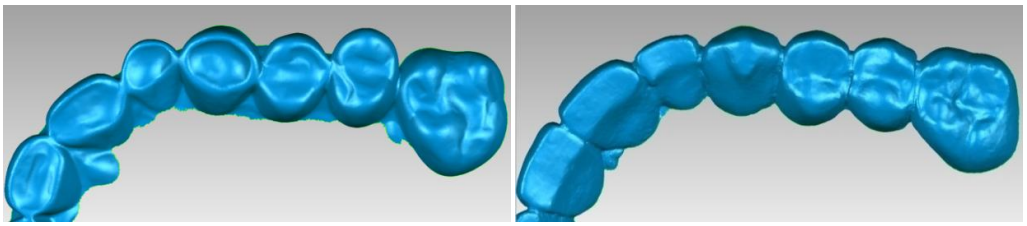

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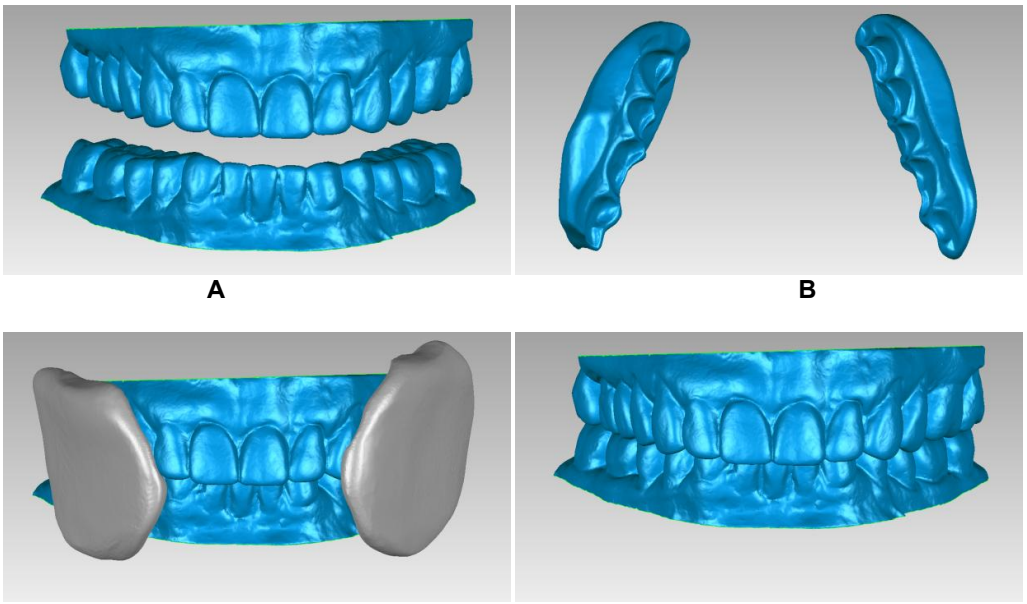
Fig. 1. An example of a pre-treatment model (A) and a post-treatment model (B) illustrating the morphological dental alterations



A B

C D

Fig. 2. The articulation process. The maxillary and mandibular virtual models before articulation (A). The virtual silicone registration indices that can fit on the buccal aspects of articulated models (B). The maxillary and mandibular models were repositioned according to the silicone indices by the process of image registration (C). The articulated maxillary and mandibular models after the removal of silicone indices (D)

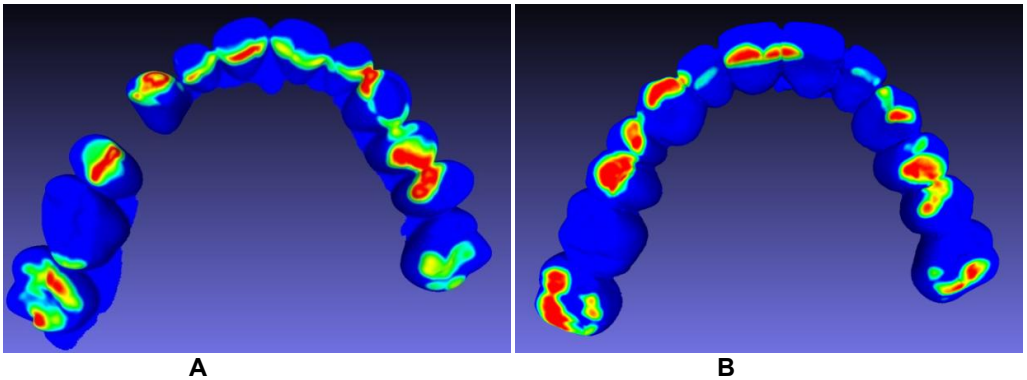


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Fig. 3. A colour-coded map for a pre-treatment model (A) and post-treatment model (B) was used to detect the occlusal contacts

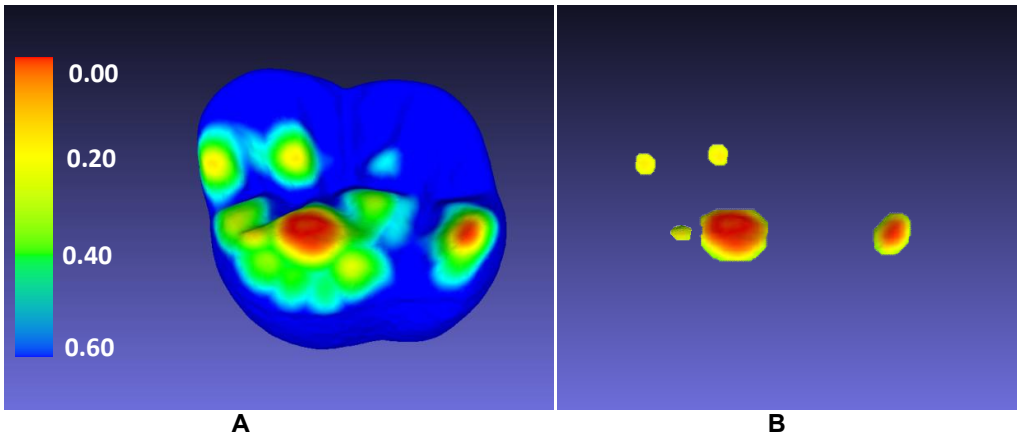


Fig. 4. Determination of the contact number and area according to the colour-`coded map. The number of occlusal contacts was established by counting the areas coloured with yellow or a warmer colour (A). The same areas were extracted (B) and measured to quantify the occlusal area

3. RESULTS AND DISCUSSION

For the pre-treatment models, a total of 257 dental units (133 anterior units and 124 posterior units) were included in the evaluation. Following the fixed prosthodontic treatment, the number of dental units was increased to 289 (138 anterior units and 151 posterior units). The increase of the units was due to the inclusion of pontics with a fixed partial denture.

3.1 Contact Number

For the maxillae, the average CNT (standard error) was 1.12 (0.15) contact for pre-treatment models and 1.51 (0.13) contact for the post-treatment models. The mandibular models had an average CNT of 1.02 (0.10) contact for pre-treatment models and 1.45 (0.12) contact for post-treatment models. The difference between the maxillary and mandibular models was insignificant. However, for the two arches, the post-treatment models had a significantly greater CNT than the pre-treatment models.

(Table 2) illustrates the inter-arch and intra-arch CNT outcome. For the pre-treatment and post-treatment models, the posterior teeth had a significantly greater CNT than the anterior teeth. For the anterior region, there was no significant difference between the pre-treatment and post-treatment CNT for the maxillary and mandibular teeth. On the other hand, the posterior teeth had a significantly greater CNT following treatment. This applied to the two arches. The effect of the inter-arch variable was insignificant for the anterior and posterior teeth.

3.2 Contact Area

The CAT averages for the maxillae and mandibles were 3.06 (0.48) mm^2 and 2.71 (0.37) mm^2 respectively for the pre-treatment models. For the post-treatment models, the CAT averages were 6.04 (1.00) mm^2 for the maxillae and 5.70 (0.96) mm^2 for the mandibles. There was no significant difference between the two arches; however, regardless of the arch, the post-treatment models had a significantly greater CAT than the pre-treatment models.

(Table 3) outlines the CAT values for the inter-arch and intra-arch locations. The CAT of the anterior teeth did not increase significantly following the treatment. This was observed for the maxillary and mandibular arches. On the contrary, the CAT of the posterior teeth increased significantly after the treatment for the maxillary and mandibular arches. The anterior teeth had lower CAT values for all the arches than the posterior teeth. This difference was significant except for the maxillary pre-treatment arches. In general, the maxillary and mandibular teeth had a similar CAT. This applied to the pre-treatment and post-treatment models.

Table 2. CNT mean and standard error (SE) for the pre-treatment and post-treatment models (n = 13)

Intra-arch location	Inter-arch location	Pre-treatment		Post-treatment	
		Mean	SE	Mean	SE
Anterior teeth	Maxillary teeth	0.85	0.11	1.01	0.13
	Mandibular teeth	0.78	0.08	0.90	0.12
Posterior teeth	Maxillary teeth	1.40	0.21	1.97	0.18
	Mandibular teeth	1.36	0.16	1.89	0.12

Table 3. CAT mean and standard error (SE) for the pre-treatment and post-treatment models (n = 13)

Intra-arch location	Inter-arch location	Pre-treatment		Post-treatment	
		Mean (mm^2)	SE (mm^2)	Mean (mm^2)	SE (mm^2)
Anterior teeth	Maxillary teeth	2.54	0.43	3.07	0.79
	Mandibular teeth	1.81	0.26	2.76	0.78
Posterior teeth	Maxillary teeth	3.93	0.71	8.48	1.40
	Mandibular teeth	4.01	0.69	8.12	1.32

3.3 CNT-CAT Relationship

For the pre-treatment models, it appeared that there was a direct relationship between the CNT and the CAT (Fig. 5A). The CNT and the CAT were clearly greater for posterior teeth than anterior teeth. Although there were some variations between the maxillary and mandibular CNT and CAT, the overall pattern was similar.

The post-treatment models showed a similar relationship between the CNT and CAT (Fig. 5B). However, the magnitudes of the CNT and the CAT were greater for the post-treatment models. Similarly to the pre-treatment models, the posterior teeth had greater CNT and CAT, however the magnitude of the increase was prominently greater than the pre-treatment models. The two arches exhibited a similar pattern for the anterior and posterior teeth.

4. DISCUSSION

This study supports that fixed prosthodontic treatment influences the number and area of occlusal contacts. Therefore, the hypothesis that the contact number and area will increase following prosthodontic treatment is accepted. It is clear that there is a tendency for the contact number and area to increase by about 30% and 50%, respectively, following fixed prosthodontic treatment. The lower occlusal contact number and lower area for the pre-treatment models were anticipated, as these arches required treatment and the morphology of the existing teeth were affected by large restorations or tooth wear, which could affect their anatomical form and natural occlusal contacts. Hence, loss of ideal and well distributed contacts might be more apparent [1,13]. On the other hand, when the dentition is restored, it is likely that a more natural tooth morphology will be obtained, thus re-establishing more occlusal contacts and larger area [12]. The greater contact following the treatment could be related to the establishment of a more ideal occlusal contour and anatomy [13]. For example, Owens et al found that participants with normal occlusion had greater contact and near contact area than those with malocclusion [3].

4.1 Contact Number and Area

The earlier studies that pertain to contact number and area evaluated the total contact number and areas for intact dentitions [6-9]. In the present study, the contact per tooth or area per tooth was measured. This was necessary to compensate for the effect of missing teeth. In order to compare the outcome of this study to earlier studies, approximate contact number and area per tooth were obtained from the studies by dividing the reported total contact number or area on the number of teeth per arch.

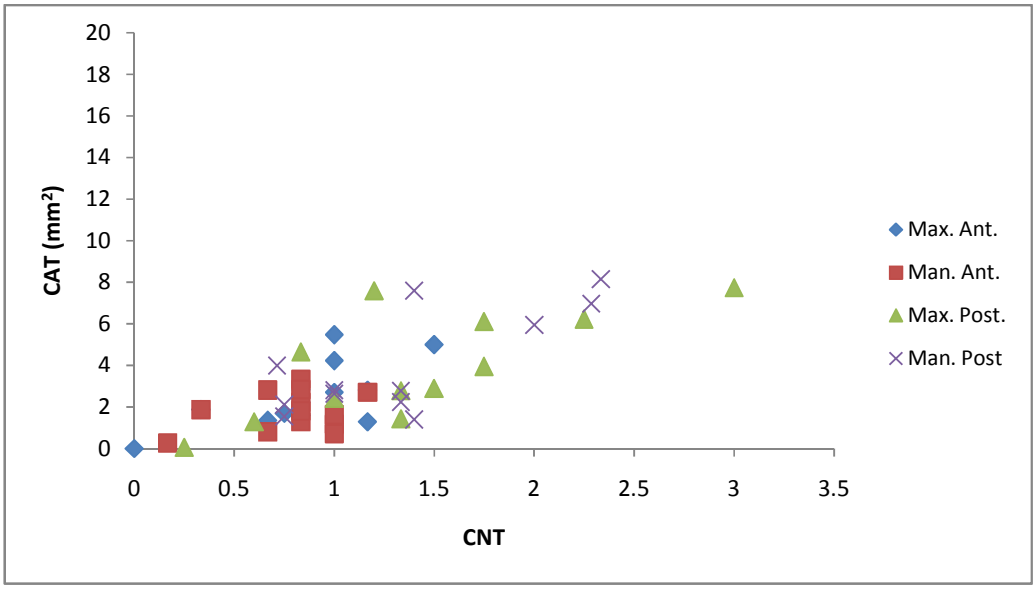
In relation to the contact number, it appears that the occlusal contacts observed following prosthodontic treatment in this study were similar to the occlusal contacts on natural and intact dentition [6-9]. For instance, DeLong et al and Korioth found that each tooth had about 1.5 – 1.75 contacts per tooth [7,17]. As a result, it could be speculated that the prosthodontic treatment returned the baseline occlusal relationship by shifting the pre-treatment

anatomy to a more natural anatomy. This observation supports the clinical recommendations for improving static occlusal contacts with prosthodontic treatment [13,18]. Gradually, the improved quality of the occlusal contacts will potentially contribute to a more stable and functional occlusion [3], and will be associated with a greater chewing efficiency [5].

Earlier studies on occlusal contact area revealed significant variations. While Hadika et al found a similar occlusal contact area on natural dentition to what has been detected by this study for the pre-treatment dentition [4], some studies have found a lower occlusal area [7,19], and another study found a large contact area [10], which was similar to the contact area for the post-treatment models of this study. It is important to note that the variation of the occlusal contact area measurements were very likely to be due to differences of the methods applied for area quantification [3]. Slight vertical discrepancies between the opposing models can lead to prominent alterations in the contact area [4,20]. A commonly applied method for recording the contact area is the use of occlusal medium. The drawback of this method is the ease of introduction of minimal vertical displacement, which can significantly underestimate the contact area. On the contrary, for virtual quantification of occlusal contact area, a threshold measurement is applied [10], and this can potentially cause slight overlapping of models. Thus, the contact area might be overestimated. However, the implication of overlapping was reduced by utilizing virtual registration indices which can maintain the models spatial orientation. The contact area outcome of this study may be comparable to the findings of the virtual study by Iwase et al, due to the similarity of the applied method of area quantification [10]. Interestingly, their study showed that natural and intact dentition had CAT of about 5 mm^2, which is similar to the CAT of the post-treatment models of this study. This supports the earlier assumption that prosthodontic treatment can restore the occlusal relationship to the baseline occlusal relationship.

4.2 Inter-arch and Intra-arch Locations Effect

Although there have been some differences between the maxillae and the mandibles, the contact number and area of the two arches were similar. As a result, the null hypothesis that inter-arch variable has no influence on the contact number and area following prosthodontic treatment was accepted. On the contrary, the location of the tooth in the arch appears to be a strong determinant of the occlusal contact number and area for the pre-treatment and post-treatment models. The posterior teeth exhibited about two times the contact number and area compared with anterior teeth. The dominance of posterior teeth was confirmed by earlier studies [21,22]. On natural young individual dentition, McNamara and Henry found 8 times more contact on posterior teeth compared with anterior teeth [9]. Similarly, another study found that the



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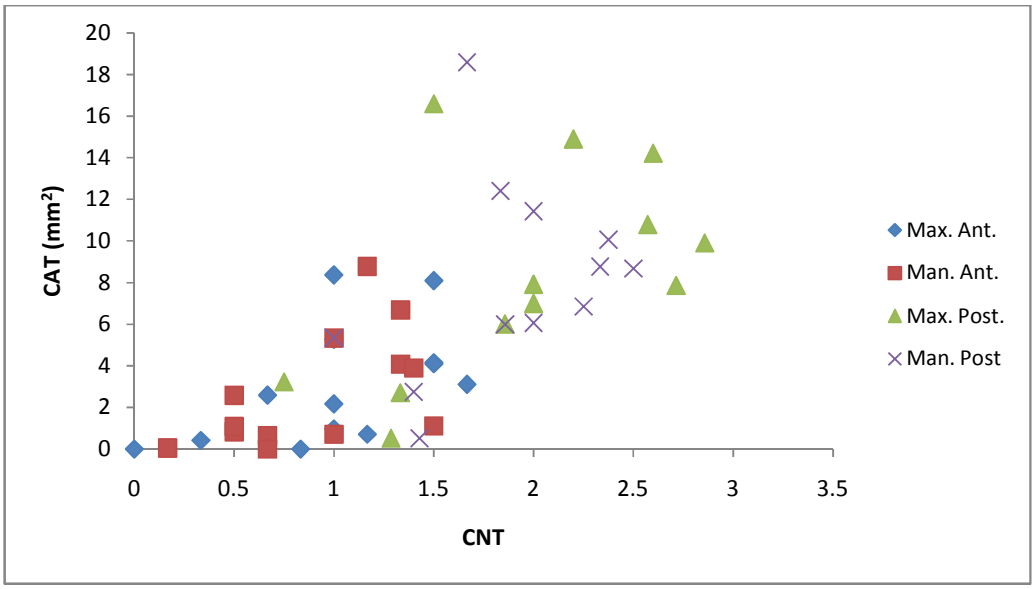

Fig. 5. Scatter diagrams of the relationship between CNT and CAT for the pre-treatment models (A) and post-treatment models (B). Max. Ant. = Maxillary anterior teeth, Man. Ant. = Mandibular anterior teeth, Max. Post. = Maxillary posterior teeth, Man. Post. = Mandibular posterior teeth

posterior teeth had 3 times more contacts than the anterior teeth [6]. On the restored dentition [11], it has been found that the posterior teeth had twice the contact number than the anterior teeth, which was similar to the values for the pre-treatment and post-treatment models of this study. In relation to the posterior teeth contact area, Yurktas and Manly found that the CAT on the posterior teeth tend to be about 7 mm^2 [2] which was close to the values of the post-treatment models of this study. On the other hand, Owens et al found that the contact area on posterior teeth tend to be lower than the post-treatment models of this study (about 3 mm^2), and close to the pre-treatment models [3]. Similarly to what has been mentioned earlier, it is likely that the implemented methodologies influence the area outcome. The more profound contacts on the posterior teeth are due to greater area, cuspal morphology and interdigitation of the opposing teeth. The anterior teeth, on the other hand, have more confined surfaces and incisal edges. This observation fits with the mutually protected occlusion concept, where the posterior teeth prevent excessive contact of the anterior teeth in maximal intercuspation [23]. Although this finding is correct for the pre-treatment and the post-treatment models, as shown in (Fig. 5), the difference between the anterior and posterior teeth was greater following the prosthodontic treatment, which indicates an idealization of the occlusion scheme following prosthodontic planning. Thus, it could be envisioned that the posterior teeth receive greater benefit in terms of contact number and area following the prosthodontic treatment. This is advantageous from the functional perspective as the posterior teeth are responsible for food chewing and grinding. Therefore, the null hypothesis that the location of the tooth in the arch will not influence the post-treatment contact number and area was rejected.

4.3 Further Considerations

Although a significant difference exists between the pre-treatment and post-treatment models, it is very difficult to assume that one occlusion contact pattern will induce pathological consequences. Further, the true impact of contact number and area is still to be determined. After more than 10 years of prosthetic treatment, Yi and Carlsson found an average of 1 contact per tooth which was similar to our pre-treatment contact rate [11], yet no abnormal physiological consequences were observed. This was further supported by several studies on shortened dental arch that confirmed that although the number of total occlusal contacts is less than the complete dentition contact, the patient can function within normal physiological abilities [24].

The digital approach of measuring the contact points and area has several advantages over the physical methods (e.g. articulating paper, photo-occlusion and T-Scan). For example, it allows precise quantification of contact number and measurements of contact area in multiple planes rather than in one plane. In addition, as occlusal medium is avoided in the virtual articulation, the risk of vertical models displacement is avoided [7,10]. However, the limitation of the technique for occlusion analysis is the lack of appreciation of the periodontal ligament impact on occlusion. Further, an inevitable degree of inaccuracy will be introduced by the impression, the scanning and virtual manipulation processes. It was reported that the clinical impression procedure and dental stone pouring can cause about 0.20 mm accumulated error in the form of shrinkage and expansion [15,25,26]. Due to the limited number of participating patients, it is recommended to validate the outcome of this study by a larger investigation for a longer duration.

5. CONCLUSION

Within the limitations of this study, it could be stated that prosthodontic treatment increases the contact number and area. The posterior teeth had a greater intercuspal contact number and area than the anterior teeth for the pre-treatment and post-treatment models. In addition, the posterior teeth exhibited greater improvements of intercuspal occlusal contacts than the anterior teeth. The intercuspal contact area and number of the anterior teeth were minimally affected by prosthodontic treatment. Although this study had identified a significant effect of prosthodontic treatment on intercuspal occlusal contacts, the clinical implication of this effect is yet to be determined.

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CONSENT

The author declares that 'written informed consent was obtained from the patient (or other approved parties) for publication of this case report and accompanying images.

ETHICAL APPROVAL

The author hereby declare that all experiments have been examined and approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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