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Evaluation of Occlusal Forces in Distal Extension Removable Partial Denture – An in Vivo Study

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KEYWORDS

: Kennedy Class II , Digital occlusal analysis , Prosthodontic rehabilitation , Unilateral distal extension , Implant-supported RPD

ABSTRACT:

Introduction: Unilateral distal extension mandibular edentulism (Kennedy Class II) presents a biomechanical challenge in prosthodontic rehabilitation. Age-related changes such as diminished bone quality, reduced neuromuscular coordination, and compromised proprioception may influence occlusal force distribution and prosthesis performance. Digital tools like Occlusense offer a dynamic, quantitative method for evaluating occlusal contacts and force patterns, which is crucial for optimizing prosthetic outcomes in this population

Objectives: To evaluate the occlusal force distribution in patients rehabilitated with unilateral distal extension mandibular removable partial dentures (RPDs) using the Occlusense digital occlusal analysis system

Methods: A total of 10 patients with Kennedy Class II mandibular RPDs were selected. Occlusal force distribution was recorded using the Occlusense device at the time of prosthesis insertion and after occlusal adjustments. Parameters assessed included total occlusal contact area of force distribution between natural teeth and prosthetic areas, and inter-arch balance. Subjective feedback on comfort and chewing efficiency was also obtained.

Results: The study compared bite force distribution between the intervention and contralateral sides in both RPD and implant-supported RPD groups over time. In both groups, the intervention side consistently showed significantly lower bite force than the contralateral side at all time points (baseline, 1st month, and 3rd month). However, a progressive increase in bite force was observed on the intervention side after implant placement, indicating functional improvement over time. Despite this improvement, statistical differences between sides remained significant at each interval ($p < 0.05$).

Conclusions: Selective grinding based on digital occlusion analysis with OccluSense significantly improved occlusal force distribution in complete denture wearers. This approach provides a practical, efficient, and patient-friendly alternative to conventional clinical remounting. However, larger sample sizes and long-term follow-up are recommended to validate these findings.

1. Introduction

Occlusal force refers to the force exerted by teeth during biting and chewing. It is a critical factor in dental function, influencing masticatory efficiency, temporomandibular joint (TMJ) health, and prosthetic dental treatments. Occlusal force varies based on age, sex, muscle strength, and dental health.

In adults, the maximum occlusal force in the molar region typically ranges from 300 to 600 N due to fully developed jaw muscles and bone structure[1], while in children it ranges between 100 and 200 N.[2] Males generally exhibit higher occlusal forces than females.[3]

The occlusal force area refers to the surface where opposing teeth make contact during mastication. It plays a crucial role in force distribution, chewing efficiency,

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and dental restoration longevity. In adults, the total occlusal contact area ranges from 10 to 40 mm² per arch, depending on dentition, occlusal scheme, and muscle activity. Contact area increases with stronger bite forces as cusps and fossae engage more fully, with the molar region contributing the most and anterior teeth the least.[4-6] Bruxers often develop wider, flatter contacts due to wear, increasing the contact area but placing stress on the TMJ.[7] In full denture wearers, the contact area is reduced by 30–50% compared to natural dentition, affecting bite force.[8]

Tooth pulps contain mechanoreceptors that reflexively limit bite force by monitoring dentin stress. Softer foods require higher bite force due to their chewing pattern, as demonstrated by S. Okiyama et al. in 2003.[9,10]

Bite force evaluation in humans is reliable for assessing prosthetic function and diagnosing stomatognathic system disturbances.[11] Devices for bite force evaluation are categorized based on their transducers: strain gauge, piezoelectric, and pressure transducers. Strain gauges measure voltage changes, piezoelectric transducers use deformable crystals to generate electrical charges, and pressure transducers rely on pneumatic or hydraulic changes. Commercially available devices include Dentoforce 2, IDDK Digital Dynamometer, GM10 (Nagano Keiki, Japan), Prescale System, MPX 5700, FSR 151, MPM 3000, FlexiForce, and T-Scan (Tek Scan System) .[12]

A recent innovation is the OccluSense system by Bausch, which features a 60-micron-thick, flexible, colour-coated sensor that records digital data and leaves a visible mark on the tooth for easy clinical identification.[13]

In distal-extension removable partial dentures (RPDs), occlusal forces tend to move the denture base tissue-ward due to the lack of distal abutment support. This can cause rotational forces on the abutment teeth and soft tissues. Ill-fitting retainers, occlusal disharmony, and soft tissue pain under the connector or denture base are common with prolonged use.[14,16] Edentulous ridge resorption continues due to the constant pressure from the denture base.

These issues can be addressed by incorporating implants.[17] Implant-supported removable partial dentures (ISRPDs) enhance the stability, retention, and function of RPDs by using implants as additional support .[18] Implants help distribute occlusal forces more evenly, reducing the load on natural teeth and improving comfort and function.[19] Attachment systems—such as ball, locator, bar, and magnetic attachments—secure the denture and limit functional movement.[20] Studies report ISRPDs significantly improve patient satisfaction, chewing efficiency, and speech over conventional RPDs, especially in patients unsuitable for fixed prostheses .[21] However, ISRPDs require higher costs and periodic maintenance due to wear of attachment components.[14] Implant-retained prostheses may have smaller occlusal contact areas due to reduced proprioception and lack of periodontal ligament feedback, although no significant difference in occlusal load exists between natural teeth and implant prostheses.[22,23] Overall, ISRPDs represent a functional and esthetic advancement over conventional RPDs, enhancing prosthetic stability and preserving residual dentition. The null hypothesis states that there is no significant difference in the occlusal force distribution percentage between conventional mandibular unilateral distal extension removable partial dentures and implant-supported counterparts.

2. Objectives

To evaluate the occlusal forces of the patients wearing unilateral mandibular distal extension removable partial denture using OCCLUSENSE

1. At the time of insertion
2. 1st month post insertion review
3. 3rd month post insertion review

To evaluate the occlusal forces of the crossover patients wearing implant supported unilateral mandibular distal extension removable partial denture

1. At the time of insertion
2. 1st month post insertion review
3. 3rd month post insertion review

3. Methods

Our experimental study was conducted in the Department of Prosthodontics, Crown and Bridge, Thai Moogambigai Dental College and Hospital, Dr. MGR Educational and Research Institute, Chennai – 600107. Ethical approval was obtained from the Institutional Ethics Committee (Ethical clearance no: 167854).

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Sample Selection & Eligibility criteria

A total of 10 patients requiring mandibular unilateral distal extension prosthetic rehabilitation (Kennedy's Class II) were enrolled. All patients were treated by the same prosthodontist to ensure standardization. Informed consent was obtained from each participant. Patients included in the study had a partially edentulous mandible (Kennedy Class II) with an intact opposing dentition, absence of localized inflammation and oral mucosal diseases, no history of radiotherapy, sufficient residual bone volume to accommodate implants of at least 10 mm in length and 3.75 mm in diameter, adequate inter-arch space, and sound periodontal health in the remaining dentition. Patients were excluded if they had systemic or chronic diseases, insufficient bone volume, oral pathologies, bruxism, dependence on caregivers, a history of chronic smoking (more than 10 cigarettes per day), or were immunocompromised.

Clinical Protocol

Patients reporting to the Outpatient Department were screened based on the inclusion and exclusion criteria. Detailed medical and dental histories were recorded, followed by clinical examination. Preoperative investigations included orthopantomogram, cone beam computed tomography (CBCT), and blood tests. Bone morphology was assessed through CBCT.

Removable Partial Denture (RPD) Fabrication

Diagnostic impressions were made with alginate (Algitex, DPI), and casts were poured with Type II dental stone (Kalabhai - Kaldent Class 2). Casts were surveyed to determine the path of insertion. Mouth preparation and necessary abutment modifications were carried out. Final impressions were taken using polyvinyl siloxane, and master casts were poured using Type IV dental stone.

The framework was designed on a refractory cast and cast in cobalt-chromium using an induction casting machine. The framework was polished and checked for passive fit.

The altered cast technique was used to record functional impressions of the distal extension areas using a custom tray and light body elastomeric impression material. The edentulous portion of the master cast was re-poured. Jaw relations were recorded, followed by wax trial evaluation. Heat-cure acrylic resin was used for denture processing. Final insertion and adjustment were carried out, and instructions on denture maintenance were given.

Implant Placement and ISRPD Conversion

Implant planning was done using CBCT. Implants were placed freehand in the mandibular first molar region under local anesthesia (Lignox 2% with 1:100,000 adrenaline, Indoco Remedies Ltd.), following prophylactic antibiotic coverage (Amoxicillin 2 g, 1 hour preoperatively). A flapless technique was employed, with sequential osteotomy performed under guidance. Implants (Neodent Implant Systems, Straumann Group) were placed and torqued to final position. Implant stability was measured using a resonance frequency analysis device (Osstell ISQ, W&H).

Once osseointegration was confirmed, the RPD was converted to an implant-supported RPD (ISRPD) using a locator abutment. The denture base was relined with auto-polymerizing acrylic resin (Uni-fast, GC) under occlusal pressure and excess material was trimmed.

Occlusal Force Evaluation

Occlusal force distribution and occlusal contact area were evaluated using the OccluSense digital occlusal analysis system at three time points:

1. At denture insertion
2. one month post-insertion
3. Three months post-insertion

Occlusal contact was measured on both the intervention side and contralateral side. Clinical and radiographic examinations were performed at each follow-up to assess implant prognosis. All ten patients completed the study with no dropouts (Figure 1).

EVALUATION OF PERCENTAGE OF OCCLUSAL FORCE DISTRIBUTION

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Statistical analysis

All the data was analysed using SPSS version 26. Descriptive statistics were used for the demographic variables, including age and gender. Repeated measures ANOVA was performed for intragroup comparison of bite force over time, while the independent t-test was used for intergroup comparison between the control and intervention groups. A significance level of $p < 0.05$ was considered statistically significant.

4. Results

The age distribution among participants ranges from 35 to 80 years, with a mean age of 49.70 years and a standard deviation of 13.752. The gender distribution is equal, with 50% males and 50% females, indicating a balanced representation of both genders in the study.

The repeated measures ANOVA showed a statistically significant change in bite force over time on both sides ($p < 0.05$). On the intervention side, the mean bite force decreased from 44.30 at baseline to 41.10 at 1 month and further to 39.20 at 3 months ($p = 0.00$, $F = 31.087$), indicating a significant reduction over time. On the contralateral side, the mean bite force increased from 54.10 at baseline to 58.90 at 1 month and further to 60.80 at 3 months ($p = 0.001$, $F = 22.465$), showing a statistically significant increase (Figure 2).

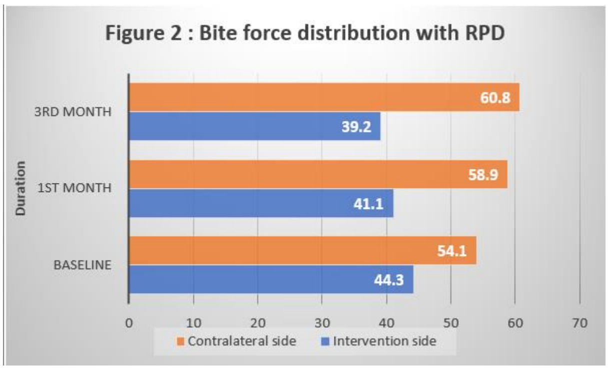

Figure 2 : Bite force distribution with RPD

Repeated measures ANOVA was performed to evaluate changes in bite force over time on both the intervention and contralateral sides after implant placement. Intervention side: The mean bite force increased from 39.60 ± 2.875 at baseline to 46.20 ± 2.821 at 1 month and further to 49.70 ± 1.947 at 3 months. The difference was statistically significant ($F = 54.254$, $p = 0.00$). Contralateral side: The mean bite force decreased from 60.40 ± 2.798 at baseline to 53.80 ± 2.745 at 1 month and further to 50.30 ± 1.895 at 3 months. This change was also statistically significant ($F = 114.537$, $p = 0.00$).The results indicated a significant increase in bite force on the intervention side and a decrease on the contralateral side over the 3-month period (Figure 3).

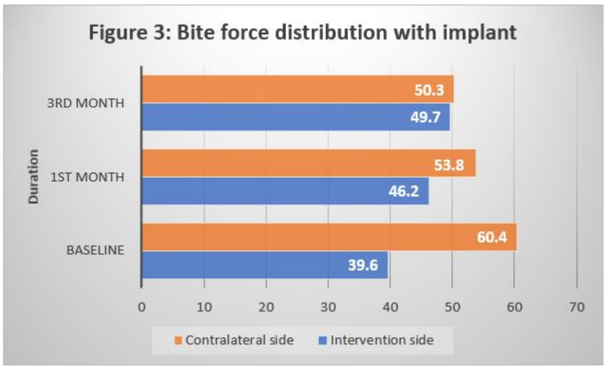

Figure 3: Bite force distribution with implant

An independent t-test revealed significant differences in bite force distribution between the intervention and contralateral sides at all time intervals in both groups ($p < 0.05$). In the control group, the intervention side consistently showed lower bite force compared to the contralateral side at baseline, 1 month, and 3 months. Similarly, in the intervention group, the intervention side had significantly lower bite force at baseline. However, there was a progressive increase in bite force on the intervention side at 1 and 3months post-implant placement, indicating functional improvement, though differences between sides remained statistically significant (Table 1).

TABLE 3: Distribution of the occlusal force on both sides in the control group from baseline to 3 months

Bite force distribution without implant		Mean	Standard deviation	df	F value	P value
Intervention side	Baseline	44.30	2.058	2	31.087	0.00*
	1^{st} month	41.10	1.729			
	3^{rd} month	39.20	2.150			
Contralateral side	Baseline	54.10	4.383	2	22.465	0.001*
	1^{st} month	58.90	1.729			
	3^{rd} month	60.80	2.150			

5. Discussion

This in vivo study aimed to evaluate the changes in occlusal bite force over a three-month period in individuals rehabilitated with distal extension removable partial dentures (RPDs), both with and without implant support. The findings revealed that in the control group (conventional RPDs), there was a consistent decline in bite force on the edentulous intervention side over time, while the contralateral side showed a compensatory increase. This suggests patients tend to rely more on the

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non-edentulous side due to greater stability and support, consistent with prior observations by Thai et al. and others.[18]

Conversely, in the implant-assisted RPD (IARPD) group, the intervention side demonstrated a progressive improvement in occlusal force from baseline to three months, indicating enhanced functional efficiency with implant support. The contralateral side in this group showed a reduction in bite force over the same period, reflecting a more balanced bilateral occlusal load distribution post-implant placement. These findings are supported by studies such as those by Marcela et al.[24] and Canan et al.[25], which also documented adaptive improvements in occlusal load and muscle coordination over time with implant-supported prostheses.

Furthermore, the increase in occlusal force on the implant-supported side underscores the biomechanical advantages of implant placement, effectively transforming a Kennedy Class I scenario into a more stable Class III situation. This allowed better dissipation of occlusal loads and minimized soft tissue displacement—an outcome similarly emphasized in studies by Kei et al.[26] and others evaluating implant-supported prostheses. Studies by Anandapandian et al.[27]] further support the current findings, highlighting the role of proper prosthetic design in improving load transfer and functional performance.

Despite some contrasting views in the literature, especially regarding compromised ridges the favorable results in the current study may be attributed to careful patient selection, gender balance, and strict adherence to prosthodontic principles. Additionally, although demographic factors such as age and gender showed no significant correlation with occlusal forces in our study, previous literature[28] has shown mixed opinions, with some suggesting that prosthetic adaptation and neuromuscular coordination are more influential.

Functionally, the progressive increase in bite force observed in the present study points to improved masticatory performance, aligning with findings by campous et el [29], who reported enhanced muscle coordination and activity following prosthesis use. The consistent development of force on the intervention side reflects effective load sharing between abutments and residual ridges, echoing the importance of design elements such as RPI systems and clasp configurations as described by Sabzo[30]. The results also resonate with studies on neuromuscular adaptation even in the absence of specific training or chewing guidance.

Overall, the study confirms that distal extension RPDs—particularly those with implant support—enhance occlusal force and masticatory performance over time. While findings align broadly with existing literature, especially regarding adaptive muscle behavior and load distribution, the study's strength lies in demonstrating these benefits even without complex modifications or patient retraining protocols. The improvement in bilateral force symmetry over time may also help reduce the risk of abutment overload and ridge resorption.

6. Conclusion

Implant-supported removable partial dentures (ISRPDs) significantly enhanced occlusal force distribution in unilateral mandibular distal extension (Kennedy Class II) cases compared to conventional RPDs. The addition of a single posterior implant led to more balanced occlusal loading over time, reducing stress on abutment teeth and soft tissues while improving function, comfort, and prognosis. The OccluSense device proved effective in objectively evaluating occlusal dynamics, and ISRPDs present a promising alternative for patients seeking functional improvement without full-arch fixed solutions. Further studies with larger samples and longer follow-up are warranted.

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