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Bite Force Evaluation time through out for Patients Wearing Mandibular Screw Retained Hybrid Complete Denture (All on Four Implant Concept) supported with Glass fiber reinforced composite resin CAD \ CAM Milled Framework Material

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Abstract— Purpose: The aim of this study was to evaluate the bite force value time through out between patients wearing Glass fiber reinforced composite resin frameworks fabricated by CAD-CAM in mandibular hybrid screw retained implant-supported prosthesis with all on four concept. Materials and Methods: This study was a comparative clinical trial. It was conducted on six completely edentulous patients according to the calculated sample size each patient received hybrid prostheses reinforced with Glass fiber reinforced composite resin framework. Biting force was assessed by a bite force transducer. All assessments were carried out nine months after hybrid denture insertion as follows: - 1 week, 1 month, 3 months, 6 months, 9 months follow-up periods Results: The mean ±SD of bite force for glass fiber is 82.25±9.18 at 1 week ranging from 68.75 to 91.67 , 88.49±6.31 at 1 month ranging from 76.14 to 92.06 , 90.59±3.95 at 3 months ranging from 83.04 to 93.85, 93.96±3.66 at 6 months ranging from 88.12 to 96.04 and 96.02±4.02 at 9 months ranging from 91.03 to 99.06. The repeated Measures ANOVA test was used to assess change in bite force during follow up from 1 week to 1 month to 3 months to 6 months to 9 months and demonstrates statistically significant difference between different follow up periods.
Conclusion: Within the limitation of this study, the bite force value increases over time. The use of glass fiber is very important in improving the bite force value and has proven highly effective in these cases.

Keywords: GFR, All-On-Four.

1. Introduction

Edentulism exerts a detrimental impact on both oral and systemic health, as well as the overall quality of life. Functional impairments associated with the edentulous state, such as compromised denture retention and reduced masticatory efficiency, are well-documented [1]. While complete dentures offer patients an aesthetically acceptable and relatively cost-effective solution, their limitations in providing satisfactory function due to instability and discomfort, particularly exacerbated by alveolar bone resorption, are significant. Individuals utilizing conventional dentures frequently report issues including discomfort or pain, inadequate retention and stability, and difficulties in mastication [2, 3].

Dental implants have emerged as a viable clinical treatment modality for completely edentulous patients, demonstrating favorable outcomes concerning functional capacity,

comfort, and social integration. However, implant-supported fixed prostheses represent a high-cost treatment option due to the complexity inherent in the surgical and prosthetic phases, the expense of the implants and prosthetic components, and associated laboratory fees [3]. Immediate implant-supported rehabilitation of edentulous jaws has been reported as a dependable alternative to conventional dentures, yielding significant improvements in the quality of life for edentulous individuals [4].

The "all-on-four" treatment concept was developed to address edentulism, aiming to circumvent the need for bone augmentation and mitigate postoperative costs and complications. This widely adopted concept involves a fixed prosthesis supported by four endosseous implants: two axially placed in the anterior segment and one distally positioned and posteriorly tilted in each posterior segment, with the implant apices engaging cortical bone anterior to the maxillary sinuses [5, 6]. The increased anterior spread achieved through the tilted implants typically facilitates first molar occlusion for patients with short cantilever extensions [5]. The All-on-four treatment concept was conceived to optimize the utilization of existing bone volume and is considered a suitable alternative to ridge augmentation and complex surgical procedures, particularly in cases of severely resorbed mandibles and maxillae [6], thereby enabling immediate loading and function while obviating bone augmentation procedures that elevate costs and increase the risk of complications [7].

An immediately loaded, screw-retained prosthesis supported by implants placed immediately following extraction or after a healing period represents a reliable and predictable modality for the clinician and offers significant advantages for the patient, including immediacy, dependability, and functional and esthetic efficacy [8].

The clinical performance of fiber-reinforced composite (FRC) prostheses has been shown to be contingent upon appropriate framework dimensions, geometry, and three-dimensional positioning, adhering to a structural relationship with the distribution of occlusal forces [9]. FRC systems for computer-aided design/computer-aided manufacturing (CAD/CAM) applications have garnered increasing interest. This is attributed to the industrial fabrication of discs under controlled parameters of temperature and pressure, resulting in a reduced prevalence of defects and enhanced structural reliability. Furthermore, fiber alignment can be more precisely oriented in various directions [10], and the anatomical fabrication of tooth- and implant-supported prosthetic components can be planned [11]. However, the existing literature provides limited information regarding the performance of FRC CAD/CAM systems [12].

Bite force represents a critical variable in the evaluation of masticatory performance [13]. Bite force assessments have proven to be informative and are thus widely employed in dentistry. Such measurements are conducted to determine muscular activity and jaw movements during the masticatory process and are also valuable in evaluating masticatory efficiency [14]. A decline in the masticatory ability of elderly individuals has been identified as a potential long-term risk factor for mortality [15]. Limited research has investigated the bite force efficiency of glass fiber-reinforced composite resin when utilized as a framework. The present investigation was designed to evaluate the bite force values in patients wearing glass fiber-reinforced composite resin frameworks fabricated via CAD/CAM in hybrid screw-retained implant-supported prostheses.

2. Methodology

2.1 Participant selection

This study was a comparative clinical trial. It was conducted on six completely edentulous patients (three men and three women, age range 55-65 years) according to the calculated sample size each patient received hybrid prostheses reinforced with Glass fiber reinforced composite resin framework. Inclusion criteria were (1) Completely edentulous with the residual alveolar ridges covered by healthy mucosa. (2) All patients suffered from decrease of retention and stability from conventional dentures due to atrophic ridges. Patients presented a clear preference for hybrid implant-supportedrehabilitation.(3) Sufficient bone quantity (in the inter foraminal area of the mandible to receive standard implants of at least 11 mm length and 3.75 mm in diameter. Bone quantity and quality were verified by preoperative cone beam computerizedtomography.Exclusion criteria were (1) General contraindications for surgical procedures such as patients with head and neck radio therapy, patients with bleeding disorders, hepaticpatients. (2) Patients with metabolic disorders that affect osseointegration such as diabetes mellitus, hepatic disorders, andosteoporosis.(3) Long term immunosuppressive and corticosteroid drugtherapy. (4) Abnormal detrimental habits, e.g., bruxism andclenching. (5) Heavy smokers more than 10cigarettes/day.

The patients were informed about the line of treatment and the need for regular and frequent recalls; they all signed a written consent. The study was conducted according to the ethical principles stated and approved by the ethical committee of the faculty of dentistry. The study was conducted following CONSORT principles for clinical trials. All selected patients received new maxillary and mandibular dentures (CD). Then all patients received four implants according to the All on four concept and the implants were immediately loaded with lowerdenture. After 3 months of healing, each patient received complete mandibular fixed hybrid prostheses.

Ethics consideration for Clinical Studies (In - vivo Studies):

The present research was conducted after the approval of the Research Ethics Committee (REC) of the Faculty of Dentistry, Suez Canal University. It was conducted on 6 patients receiving Removable Prosthodontic treatment in the out-patient clinic of Removable Prosthodontic Department, Faculty of Dentistry, Suez Canal University. Ethical considerations regarding patient well-being and confidentiality were undertaken by the researcher and an informed written consent was signed by the patients before commencing the study explaining all clinical examinations, procedures and follow up.

2.2 Surgical and prosthetic interventions

The new mandibular denture was used as an acrylic resin radiographic template (with gutta perchae radiopaque markers fitted to the polished surface). Patients underwent CT scans to accurately assess the quantity of bone for prosthetically driven implantplacement [16]**.** The patients were double scanned (Dual scan protocol). using Cone Beam Computed Tomography (CBCT) following the All-on- 4 protocol. The first scan was made with the radio graphic stent out of the patient mouth. The second scan was performed while the patient was occluding on the radiographic stent. Using 3-D image treatment planning software

(OnDemand), every patient's surgery was virtually planned with the OnDemand 3D software, resulting in an individualized surgical template. All planning was performed and checked by the prosthodontist. The four implants are placed virtually in the guide software; Anterior implants were placed at canine/ lateral incisor area parallel to each other and perpendicular to occlusal plane. Posterior implants were inserted in premolar areas just anterior to mental foramina with safety margin from the foramina, posterior implants were tilted distally to form a 30-degree angle to the occlusal plane. Virtual model planning software was used to define the sites for implant placement and anchor pins for the surgical guide. A mucosal supported 3D print surgical fully guided template was designed by software with 4 sleeves positioned over proposed implant sites which guide drilling in the proper planned angulation and position of implant in thebone., and the template was constructed by rapid prototyping technology.

Four implants (Neobio Tec, Korea) were inserted in the inter foraminal area of the mandible using one stage flapless surgical implant protocol by the same oral and maxillofacialsurgeon [16]. A minimum 40Ncm torque was obtained at implant insertion to allow primary stability for immediate loading of the implants. In cases of reduced bone quality, the final drill was omitted to obtain high primarystability. Measurement of initial stability of inserted implants with osteal **(fig. 1)** The abutment angulations were selected to compensate for the divergence between anterior and posterior implants and to place the prosthetic screw access holes in occlusal or lingual locations. **(fig. 2).**Post-operative panoramic radiograph was performed to verify implant position, passive seating of abutments in their place.**(fig.3).**

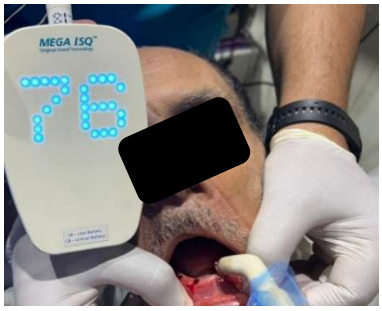


Figure 1: Measurement of initial stability with MEGA ISQ

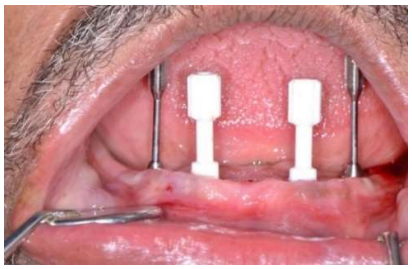


Figure2: Abutment parallelism check up

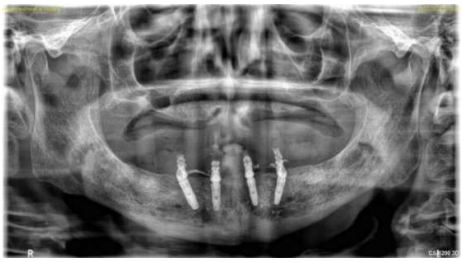
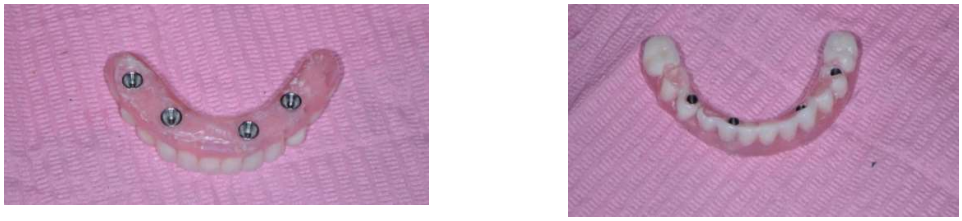


Figure 3: Post-operative panoramic radiograph

Implants were immediately loaded by provisional acrylic dentures. The old mandibular denture was modified by removal of all denture flanges and removal of the second molar artificial teeth. Titanium cylinders were screwed to the multiunit abutments. The lower denture base opposite the cylinders was hollowed. The cylinders were picked up to the modified denture using auto polymerized acrylic resin. The cylinders were unscrewed, the denture was removed, excess acrylic resin was finished and polished. The occlusal contact of the first molar with opposing denture was removed to relieve the pressure on the inclined posterior implants. An acrylic temporary prosthesis **(fig. 4,5)** with 12 teeth was delivered within the same day of surgery with centric and lateral contacts limited at the intercanine zone.



A **b**

Figure 4: a. A modified denture (fitting surface) and b. modified denture with four metal caps (polished surface)

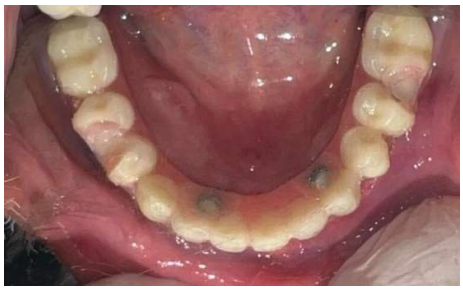


Figure 5: A modified denture insitue

Participants were informed to eat a soft diet and avoid hard foods which may become lodged in the surgicalsite, oral hygiene procedures as follows: gently brush the healing abutments with soft brush, use mouth wash and meticulous clean the mucosa around implants to avoid plaque accumulation.

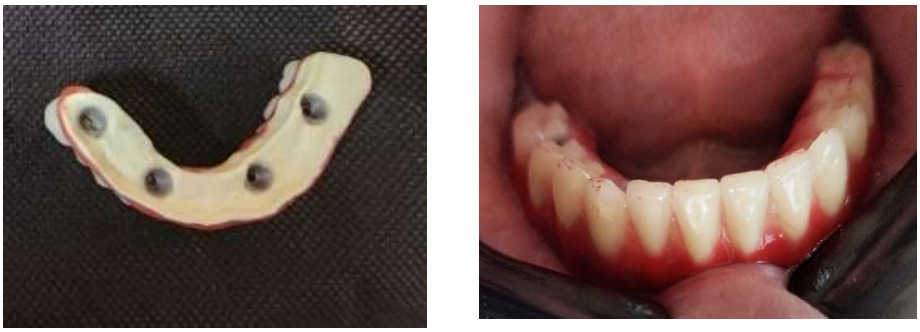
After 3 months of osseointegration period, digital impression procedure was started. Scanning via extraoral desktop scanner (SHERA eco-scan 7, shera worst-off technologies, Germany) was preformed firstly for theprovisional lower acrylic denture and upper conventional complete denture separately and when the patient in occlusion.The provisional acrylic denture was unscrewed from the multi-unitabutments; the scan bodies were screwed to the multi-unit abutment of the lower arch and the scanning was done for lower arch. **(fig. 6)**

The scanned file was converted to an STL (Standard Tesselation Language) formation. The STL format was uploaded to an Exocad designing program. Then designing the framework with distal molar cantilever was made. A full contour mock-up of the definitive prosthesis (fig. 20) was made with definitive PMMA composite veneers(Novo. lign, Bredent GmbH & Co. KG, Senden, Germany) to verify the aesthetic and occlusive effects. The acrylic resin interim framework needs to be of more thickness buccally/lingually, and vertically (at least 5 mm), special retentive elements for veneer materials should be designed as integral parts, and a calix shape was applied. The acrylic resin interim framework was scanned and transferred using system-specific software. Glass fiber reinforced composite resin blanks (Italian) directly inserted in the same 5 axis milling machine (shera eco-mill 5 axis machine, SHERA work stoff technologies, Germany). After completion of the milling, the blank was removed from the machine and the discs was retrieved finished and polished according to manufacturer instructions and check for a passive fit using schieffeld Test (single screw test).

A b **C**

Figure 6: A. Scanning of upper arch with scanner, B. Digital impression of lower arch, C. Digital impression of upper complete denture, g. bite registration

The framework was returned to the cast, then prepared the framework for denture veneers made from composite teeth and pink gingiva (Novo-lign A2, bredentsendes, Germany). Then the adhesivewas applied on the framework and the inner side of the veneers light cured for 90 seconds. Final prosthesis was screwed in place at 15 Ncm torque and verify phonetics and adequate pressure on the tissue. After torquing the prosthesis to place, make any occlusaladjustments. The screw access holes were filled with light cure composite or acrylic to prevent bacteria build-up. All centric and eccentric contacts were assessed by 40 µm articulating paper (Bausch Articulating Paper, Koln,Germany), until light occlusal contacts, uniformly distributed on the entire prosthetic arch, were obtained. **(fig. 7)**



A b

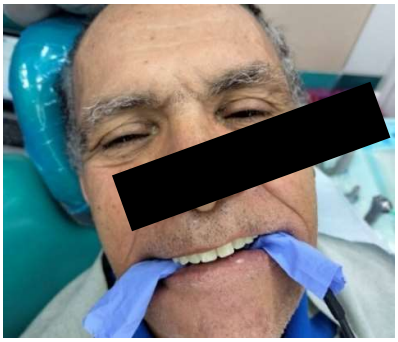
Figure 7: A. Fitting surface of definitive prosthesis with titanium slaves. B. Definitive prosthesis insitue

2.3 Evaluation of biting force:

Interocclusal vertical biting force was performed bilaterally using FSR 151 sensor(Tekscan, South Boston, MA, United States) and Arduino microcontroller with a crystal display which appeared force unite askilogram-force.Calibration of the sensor was performed several times using an object with a known weight. A layer of 3 mm thickness of putty rubber base impression material (Zetaplus C-silicone putty, Zhermac, Italy) was used to cover the sensor [17,18].

The sensor was then placed inter-occlusally between the denture teeth at the area of upper and lower first molar. Patients were then instructed to bite as hard as possible for 3 seconds. The measurements were done three times with a resting period of 20 seconds between each bite. The highest biting force of the three measurements was verified, and the average bite force between the right and left sides was calculated and statisticallyanalyzed. All assessments were carried out nine months after hybrid denture insertion as follows: - 1 week, 1 month, 3 months, 6 months, 9 months follow-up periods**(fig. 8)**

A



B C

Figure 8: a. Evaluation system of biting force, b. Flexiforce sensor, and c. Flexiforce sensor placed bilaterally

2.4 Statistical analysis:

All data was calculated, tabulated, and statistically analyzed using suitable statistical tests as follows. A normality test (Kolmogorov- Smirnov) was done to check normal distribution of the samples. Statistical analysis was performed using the computer program SPSS software for windows version 26.0 (Statistical Package for Social Science, Armonk, NY: IBM Corp) at significant levels < 0.05 (P-Value). Descriptive statistics were calculated in the form of Mean ± Standard deviation (SD), range (Max-Min). One -way ANOVA (Analysis of variance) was used to compare between the groups under study. Duncan's or other post hoc test was performed for the evaluation of statistical significances among the groups. P value < 0.05 was considered statistically significant. Independent Student's T-test or Mann-Whitney was performed for pair wise comparison in each two groups at P value < 0.05.

Finance and resource use

The research was fully funded by the researcher.

Results

The present study was clinical trial that is carried out to evaluate the bite force value in newton (N) between patient wearing Glass fiber reinforced composite resin when used as framework fabricated by CAD-CAM in hybrid screw retained implant supported prosthesis. Six cases were retrieved within each of the studied groups. All patients presented with osseointegrated implants, and no implant loss occurred during the study period. All patients attended the follow-up visits without dropouts due to the short duration of the study.

Biting force

There was a statistically significant in the biting force at 1w, 1m, 3m, 6m and 9m follow-up periods, where (p > 0.005) as shown in (Table 1, Figure 9).

Table (1): comparison of bite force change during follow up:

	1week	1month	3 months	6 months	9 months	Test of sig.

Bite force	82.25±9.18 ab	88.49±6.31 cd	90.59±3.95 ef	93.96±3.66 acei	96.02±4.02 bdfi	F=2242.26 P=0.001*

Similar superscripted letters in same row denote significant difference within groups by Post Hoc Tukey test
F: One Way ANOVA test, *statistically significant
Table (1): The mean ±SD of bite force for glass fiber is 82.25±9.18 at 1 week ranging from 68.75 to 91.67 , 88.49±6.31 at 1 month ranging from 76.14 to 92.06 , 90.59±3.95 at 3 months ranging from 83.04 to 93.85, 93.96±3.66 at 6 months ranging from 88.12 to 96.04 and 96.02±4.02 at 9 months ranging from 91.03 to 99.06. The repeated Measures ANOVA test was used to assess change in bite force during follow up from 1 week to 1 month to 3 months to 6 months to 9 months and demonstrates statistically significant difference between different follow up periods. Repeated Measures ANOVA test was used to assess change in bite force during follow up from 1 week to 1 month to 3 months to 6 months to 9 months and demonstrates statistically significant difference between different follow up periods.

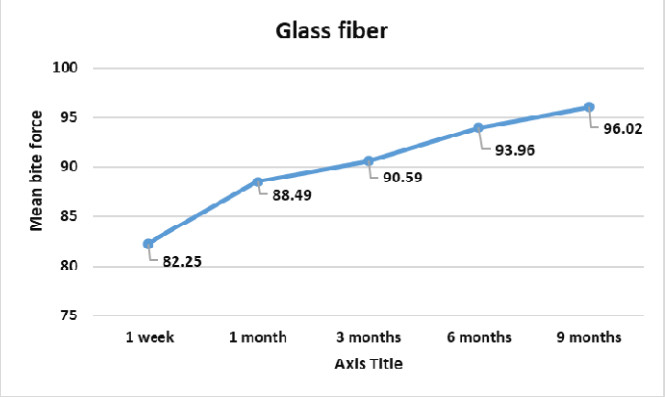


Figure 9: Mean bite force change during follow up

2.5.Discussion:

This in vivo study aimed to evaluate the bite force generated by patients wearing a glass fiber-reinforced composite resin framework fabricated via CAD/CAM in a hybrid screw-retained implant-supported prosthesis. Stringent inclusion and exclusion criteria were applied. Patients with metabolic diseases known to affect bone metabolism, such as osteoporosis, hyperparathyroidism, or diabetes, were excluded due to the potential for these conditions to interfere with osteoprogenitor cell migration, woven bone formation, and lamellar bone deposition, thereby impacting the osseointegration process [19].

To minimize detrimental stresses on the implants, only patients exhibiting Class I maxilla-mandibular relations were selected. Furthermore, patients with parafunctional habits such as clenching or bruxism were excluded to avoid excessive forces on the implants. Literature indicates that parafunctional habits can generate forces up to 15 times greater than those exerted during mastication, particularly relevant in immediate loading protocols [20]. All smokers were excluded from the study due to the reported association between smoking and

higher implant failure rates, increased complications, and altered peri-implant tissue conditions. A minimum restorative space of 12 mm at the canine region was required to ensure adequate space for implant abutment and superstructure placement. This aligns with Misch et al.'s observation that 15 mm of restorative space between the soft tissue ridge and the occlusal plane is sufficient for denture tooth arrangement without modification and accommodates the restoration [21].

The implant-supported screw-retained full-arch prosthesis was employed for mandibular rehabilitation in this study as a viable option for completely edentulous patients. This type of prosthesis is suitable for patients undergoing advanced implant prosthetic rehabilitation and can address the needs of those requiring the shortest possible treatment time without compromising esthetic and functional outcomes [22]. The All-on-four concept was utilized for patient restoration to address challenges associated with insufficient bone volume and to avoid critical anatomical structures in the posterior mandible, such as the mandibular nerve. Posterior implant tilting was implemented to reduce cantilever lengths, broaden the prosthetic base, and enhance the implant-to-bone surface area due to the use of longer implants [23].

Flapless-guided surgery was employed, offering advantages such as reduced surgical time, intraoperative bleeding, postoperative discomfort, pain, and edema. Given the critical role of primary stability in osseointegration, higher insertion torque is preferred. Splinting implants through a full-arch immediate loading restoration demonstrates better outcomes compared to single crowns, where immediate loading can be more precarious for implant survival. However, a study comparing flapless and conventional surgery reported no significant differences in bone loss between the two techniques [24].

Digital impression techniques were utilized in this study, offering enhanced accuracy for the All-on-four implant concept. Full-arch digital implant impressions using a True Definition scanner demonstrated significantly higher accuracy compared to conventional impressions using a splinted open-tray technique. Digital impressions also proved more efficient in terms of total treatment time, requiring less preparation work and allowing for rescans without complete repetition, thus shortening the impression phase. Furthermore, digital impressions were reported to have a lower level of difficulty for less experienced clinicians [25]. Implant-retained prostheses can be screw-retained, cement-retained, or a combination thereof. The European Association of Osseointegration recommends screw-retained frameworks for extensive implant-supported reconstructions [26].

Consistent with the classic All-on-four concept, immediate loading was implemented in this study, aligning with the findings of Esposito et al. [27], who reported high success rates for all loading strategies (immediate, early, and conventional) with no significant differences in implant survival and complications, provided that an insertion torque exceeding 40 N is achieved for early or immediate loading. They favored immediate and early loading due to patient demand for rapid prosthetic rehabilitation. This contrasts with Schimmel et al. [28], who concluded that while all loading protocols exhibit high survival rates, early and conventional loading are better documented and appear to result in fewer implant failures during the first year in implant-supported overdentures.

The provisional denture comprised 10 teeth, and cantilevers distal to the last implant were avoided to minimize fracture risk. Cantilever length was reduced by distally tilting the posterior implants to emerge in the second premolar/first molar region, thereby increasing the anteroposterior (A-P) prosthetic spread [29]. Clinical studies have indicated that distal implant tilting can reduce cantilever length by approximately 6.5 mm in the mandible and 9.3 mm in the maxilla. For the final restoration in this study, the cantilever length was less than 1.5 times the anteroposterior spread, as suggested by Mericske-Stern [30].

The within-patient study design facilitated the standardization of patient-related factors such as gender, age, ridge morphology and relation, and muscle power/tone, enhancing the reliability of chewing efficiency and bite force measurements [31, 32]. A 3-month period was deemed sufficient for adequate neuromuscular adaptation to complete dentures, as previous research indicates that masticatory muscle activity returns to near-original levels after this adaptation period following new denture insertion [33]. While some controversy exists regarding the optimal timeframe for neuromuscular adaptation after implant-supported overdenture and fixed restoration rehabilitation, Gartner et al. [34] reported 1 month as sufficient for well-coordinated muscle activity, Feine et al. [35] assessed masticatory function with fixed and removable implant-supported mandibular prostheses after a 2-month adaptation period, and Van Kampen et al. [36] demonstrated that 3 months post-implant overdenture rehabilitation was adequate for achieving good neuromuscular control, with maximum bite force approaching that of dentate individuals.

Bite force varies intraorally, with the maximum force typically recorded in the first molar region, representing approximately 80% of the maximum bite force (MBF) [37, 38]. Therefore, multiple recordings were performed in this area to enhance measurement reliability [39].

Previous studies have indicated no significant difference in maximum bite force between males and females [40]; consequently, both genders were included in this study. Moreover, bite force has been utilized to evaluate prosthetic devices in adults and to establish reference values for biomechanical research in prosthodontics [41]. Lepley et al. [42] highlighted occlusion and maximum bite force as the most critical factors influencing masticatory performance in their study of 30 adults [43].

The FSR 151 sensor, characterized by high sensitivity, rapid dynamic response, high measurement accuracy, good stability, a wide operating temperature range, small dimensions, and ease of mass production, has been widely adopted. It overcomes limitations associated with strain gauge transducers by integrating resistance, compensation circuits, and signal conversion circuits on silicon chips, and can even incorporate calculation processing circuits and sensors [44].

Overall, the null hypothesis was rejected. The limitations of the present study include small sample size and short follow-up period. Further clinical studies with long-term follow-up period and larger number of participants are recommended for evaluation of bite force. Additional studies are needed to evaluate if any other factors may affect the biting force like the teeth material and bonding strength between teeth and different denture base materials. Also, patient related outcomes and prosthetic complications can be assessed in further

studies.

Conclusion

Within the limitation of this study, the bite force value increases over time. The use of glass fiber is very important in improving the bite force value and has proven highly effective in these cases.

Clinical implication

Glass Fiber composite as a framework material for construction of the Screw Retained Hybrid complete denture are an effective treatment option for rehabilitation of completely edentulous patients especially, if the main concern of patients is the ability of biting and chewing.

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