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Correlation Between Dynamic Postural Balance and Masticatory Efficiency in Completely Edentulous Patients Rehabilitated with All on Four Fixed Prostheses

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Abstract:

Background: Total loss of teeth alters trigeminal afferent feedback and compromises systemic postural stability. While conventional dentures may have an effect improving this function, their instability often impairs full recovery of body balance. All on four implant restorations providing better fixation serving efficient functionality may be the proper solution.

Objective: To evaluate masticatory efficiency in completely edentulous patients treated with all on four fixed restorations and its correlation with dynamic postural balance.

Materials and Methods: Sixteen completely edentulous patients received mandibular and maxillary all on four fixed restorations. Occlusal schemes were standardized using a lingualized arrangement. Masticatory efficiency was assessed with color changing chewing gum, while dynamic body balance was measured with the Timed Up and Go (TUG) test three times. After the restoration, at three months post-loading, and six months post-loading. Data was tabulated and statistically analyzed.

Results: After three months, the correlation between the two parameters tested was found to be statistically highly significant with enhanced masticatory efficiency and postural balance. After six months there were better values for both parameters with strong, highly significant correlation.

Conclusions: There was a strong correlation between masticatory efficiency and dynamic postural body balance in patients treated with all on four restorations with significant enhancement after three and six months of use.

Trial registration: This study was conducted in accordance with the principles of the Declaration of Helsinki (WMA, 2008), and approved by the ethical committee of the Faculty of Dentistry, Beni-Suef University Research Ethics Committee (FDBSU-REC) Approval number: # REC-FDBSU/10042025-01/SR.

Keywords: All on four - Masticatory efficiency – Dynamic postural balance.

Trial registration: ClinicalTrials.gov,NCT07873983. Registered on October 13, 2026. Retrospectively registered.

Introduction:

Global population aging is increasing with advancements in health care, dictating attention to the problems and needs of geriatric population. One of the major problems associated is the irreversible and debilitating edentulism. Despite regression in complete tooth loss through the last decade, edentulism still represents a considerable global problem affecting patient quality of life, and may restrict motion range, alterations in head posture, and patient imbalance(1). Falls among geriatric population are a considerable public health burden, leading to significant injuries, lowered quality of life, with increased health care costs of using the smart wearable technologies alleviating the problem(2).

Mastication and its efficiency are important considerations for individuals requiring prosthodontic replacement of teeth. Individuals with compromised masticatory function suffer from higher risk of systemic diseases and postural balance control, increasing the risk of repeated falls specially in older individuals(3). Chewing performance depends on teeth number, occlusal scheme, maximum bite force, and restoration type. Functional efficiency of mastication might be apprised utilizing food particles reduced by mastication or color changing chewing gum(4, 5).

Furthermore, edentulism and loss of masticatory function are associated with dramatic disruption of oral proprioceptive feedback, impairing the trigeminal-cervical reflex arc, frequently leading to increased postural sway, impaired spatial orientation, and falls(6). The physiological link between stable occlusion, efficient mastication and dynamic body balance is driven by a highly specialized, multi-synaptic circuit known as the trigeminal-cervical-vestibular axis. This axis regulates the contraction of antigravity muscle throughout the body(7).

The physiologic head posture is sustained by equalizing the cranio-cervical complex, myofascial tissues, and occlusal contacts controlling masticatory efficiency. Total tooth loss obliterates the periodontal mechanoreceptive feedback loop. Without these specialized mechanoreceptors, the central nervous system loses its primary source of oral proprioceptive data. Loss of occlusal integrity may influence the head posture with respect to the neck. These alterations in head orientation might impair neuromuscular interaction and vertebral alignment(8). They may also potentially alter physiological activities, as chewing, speech, and respiration. Moreover, they possibly influence the center of body mass and might result in postural instability(9). Chronic stomatognathic conditions as malocclusion, mandibular midline displacement, and posterior edentulism demonstrate a significant association with established global asymmetries, including forward head position, lateral flexion of the torso, and perpetuation of postural defects(10-12).

Findings imply that prosthetic reconstruction with complete dentures may enhance mastication, esthetics, speech, head orientation, and postural equilibrium, leading to increased gait velocity and patient balance during both static and kinematic states(13, 14). They can influence body alignment by encouraging cephalic elevation and diminishing cervical lordosis(15). Although removable dentures might enhance dynamic balance, but owing to its inherent drawbacks as unstable sliding on resilient mucosa creates unpredictable, asymmetric sensory signals that confuses central processing centers, causing increased postural sway, and altered gait velocity(14).

On the other hand, implant-supported fixed restoration is a well proven treatment option for edentulism that offers a rigid, bone-anchored solution, with better aesthetics, stability, and efficient

masticatory functional results than conventional dentures(16). By ensuring structural immobility of the lower arch, fixed all on four restorations maximize occlusal efficiency and re-establish standard mechanoreceptor pathways, providing the brain with a reliable reference point for spatial coordination. Although all on four implant prosthesis is usually used with moderate bone loss and all its proven advantages, it is associated with increased cost, prosthetic maintenance, necessitate meticulous occlusal configuration to avoid risk of potential complications as overloading the implants, prosthetic breakage, or peri-implant bone reduction(17, 18).

Fully digital workflow and motion tracking data used in prosthetic rehabilitation serve as a marked shift from static to dynamic accusation offering minimization of the postural modulation related to edentulism. Utilizing these strategies might enhance patient wellbeing and promote more physiologically aligned intervention and better masticatory efficiency(15, 19). Moreover dynamic postural balance or capacity to keep center of mass stability while actively changing positions is much more clinically relevant to a patient's functional independence than static measurements(20). Considering the variations in biomechanics between natural teeth and implants, it's crucial to offer a routine protocol for sustainable success of implant restorations which are not yet well established(18, 21). The sophisticated biomechanical connection between the craniomandibular system and axial skeleton represent a crucial importance in patient's rehabilitation, nevertheless is clinically underestimated(10).

Few studies evaluated chewing efficiency in all on four restorations and as far we know none have evaluated its correlation with dynamic body balance. Therefore, the objective of this research was to bridge the gap in research by analyzing the correspondence between masticatory efficiency and dynamic postural balance in completely edentulous patients restored with mandibular and maxillary all on four fixed restorations. The null hypothesis was that there is no change in masticatory efficiency or body balance and no correlation between them.

Materials and Methods:

Patient cohort and study design: Sixteen male edentulous patients, with the age range of 50-60 years were chosen from the out-patient clinic of the Prosthodontic Department, Faculty of Dentistry, Beni Suef University. The sample size was calculated following power analysis of a previous study(22). Each patient included in the study had been informed about the treatment strategy and agreed to it, then signed a written consent before the beginning of the treatment.

Inclusion criteria:

- Age: Between 50 - 60 years.
- Completely edentulous patients with complete removable dentures.
- Sufficient inter-arch height for the restoration (at least 12 mm).
- Proper oral hygiene.

Exclusion criteria:

- Patients with any medical condition that endanger implant insertion like liver, heart, autoimmune diseases, irradiated arches, or uncontrolled systemic or neurologic diseases.
- Dysfunction related to temporomandibular joint (TMJ) and neuromuscular disorders.
- Smokers.
- History of traumatic jaw injuries.
- Flabby ridges.
- Orthopedic problems.
- Patient unable/unwilling to maintain follow-up.

Panoramic x-ray was conducted for each patient to examine the presence of any pathological lesions, impacted tooth or remaining roots, then gutta percha were attached labially and buccally on the existing denture in the location of lateral incisors, canines, premolars then cone beam computed tomography (CBCT) was taken once for the denture alone, then another one for each patient while wearing the denture and occluding (dual scan), to obtain fully guided tissue supported surgical stent for implant placement based on all on four concept; the two anterior implants were planned to be perpendicular on the occlusal plane and parallel to each other, and the two posterior implants with 30 degree angulation(23).

Under local anesthesia, the surgical stent was fixed to the mandible with fixation pins, tissue punch was used to remove tissue in the planned osteotomy sites (flapless technique), then osteotomy sites were drilled fully guided by the metal sleeves in the stent to preserve implant position and angulation. Surgical stent was removed, and each patient received four implants 3.7mm diameter and 11mm length (Vitronex Elite, Italy). Implants were placed at crestal bone level with torque 35Ncm to guarantee proper initial stability and safe immediate loading. Multiunit abutments were threaded into implant fixtures (two straight abutments with anterior vertical and parallel implants and two 30° abutments were used with posterior angled implants). The sites of the multiunit abutments over the posterior angled implants were at the first molar area.

A provisional restoration that was previously prepared was then adjusted and attached to the abutments with auto polymerizing acrylic resin. Soft diet was prescribed to the patients with strict oral hygiene measures. After osteointegration a fixed prosthesis was designed on digital software (Exocad GmbH, Darmstadt, Germany) to replace soft and hard missing tissues, with a cantilever of one tooth distally on each side. The occlusion was properly balanced and standardized with lingualized occlusion concept as shown in (Figure 1).



Figure 1: Showing all on four restoration of the mandible and maxilla in place.

Measurement of masticatory efficiency:

Chewing gum that changes its color in relation to masticatory quality (Masticatory Performance Evaluating Gum XYLITOL, Lotte Co. Ltd., Tokyo, Japan) was chosen to assess masticatory efficiency(24). Color changing gum was used to evaluate masticatory efficiency, the process simulates natural and stable chewing without sticking to the restoration, with consistent quality of uniform consistency, weight, and adhesiveness. This color changing gum (70 mm × 20 mm × 1 mm, 3.0 g) contained red, yellow, and blue dyes. The gum before use appeared yellowish green. When the gum is chewed, blue and yellow dyes seep and vanish into the saliva, to make the red

color show up because of citric acid excretion into the salivary fluid to turn the color according to the power of mastication(3).

The patients were instructed to rinse their mouths with water for at least 15 seconds before starting, then they allowed to chew the gum for 3 minutes on both sides of the mouth. Each subject was seated upright on a chair and chewed the gum freely. The chewing gum was retrieved and dried immediately after chewing and compressed between two glasses lined by cellophane sheets, the gum was flattened until it reached uniform thickness of 1mm., to evaluate its color. Using a five-point color scale provided by the manufacturer, the operator assigned each gum a score (1–5) representing the degree of color change, in which a higher score indicates better masticatory efficiency(3).

Any change in salivary flow rate, chewing rate, or prosthetic complications should be taken into consideration during the test conduction.

Each chewed specimen was assigned a number score according to the degree of color change; (1) green, (2) yellow, (3) pale pink, (4) pink, and (5) red. Color readings were performed by the same examiner. These measurements were performed for each patient three times just after the restoration, then after 3 and 6 months of the final restoration.

Measurement of dynamic postural balance:

Timed up and go test (TUGT) was employed to quantify the dynamic balance for each participant. This test is an appropriate method to recognize older people susceptible to falling. It is consistent, user friendly, and it needs no additional equipment.

Each participant sat on with his back upright in contact with the back of a stable chair with armrests. The subjects were instructed to wear regular footwear but use it in all the evaluation sessions and did not receive help from another person during the test. Three meters away from the chair, a tape was stuck on the floor for easy visualization and walk to reach this point. After receiving a “start” signal, each patient stood up, walked the 3 meters, then turned around, walked back to the chair, and sat down again. Each patient was instructed to walk at their regular pace. The time taken to conduct the test was recorded 3 times to create an average (1 minute interval between each measurement). Each patient had a TUG test three times, after the restoration, three and six months after the restoration as shown in (Figure 2).



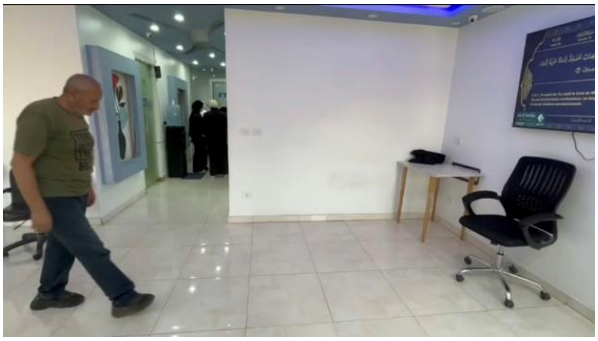


Figure 2: Patient performing the TUG test.

To standardize all records: each patient used the exact same shoes every time, records were executed at the same time of the day each time, the same chair and walkway were used each time. Any change in patient physical activity, musculoskeletal pain, medical alteration, or fluctuating body weight were taken into consideration to standardize the experiment conditions.

Statistical analysis:

Wilcoxon Signed test was used to evaluate the normality data distribution. The data were parametric and met the normal distribution. Spearman correlation test was used to correlate dynamic postural balance and masticatory efficiency three times, after the restoration, three and six months after denture insertion. Both tests were followed by the Tukey test for multiple comparisons. SPSS software (version 25.0) was utilized for data analysis. The threshold of significance was adjusted at P value ≤ 0.05.

Results:

All patients presented with osseointegrated implants, and no implant loss occurred during the study period. All patients attended the follow-up visits without dropouts.

Patients showed a drastic increase in chewing efficiency, compared to their previous complete denture state. Patients demonstrated improved body stability, reduced body sway, and better dynamic balance control during movement. The core finding revealed a statistically significant negative correlation between masticatory efficiency scores and TUG completion time .As masticatory efficiency improved, dynamic postural balance also improved. Conversely, patients who achieved the highest biting forces and best chewing parameters exhibited the most stable postural control.

The mean values and the standard deviation of dynamic postural balance were15.52 (± 2.61), 12.41 (±3.48), 10.69 (±2.40) just after restoration, three and six months respectively; and those of masticatory efficiency were 2.23(± 0.39), 3.71 (± 0.47), 4.13 (±0.65) just after restoration, three months and six months respectively as shown in (Table 1) and (Figures 3 & 4).

Correlation between dynamic postural balance and masticatory efficiency at three and six months after restoration is shown in (Table 2). The correlation coefficient value ranges from (−1) which means inverse relation between the two variables under investigation, to (+1) which demonstrates direct proportion between them. While (0) implies that there is no correlation between the two variables.

Table 1: The mean values of dynamic postural balance (s) and masticatory efficiency (1-5 scale)

after restoration, at 3 and 6 months

	Mean TUG time (s)			Mean Masticatory Efficiency		
Time (month)	**After restoration**	**3 Months**	**6 Months**	**After restoration**	**3 Months**	**6 Months**
Mean±SD	**15.52± 2.61**	**12.41±3.48**	**10.69±2.40**	**2.23± 0.39**	**3.71±0.47**	**4.13±0.65**

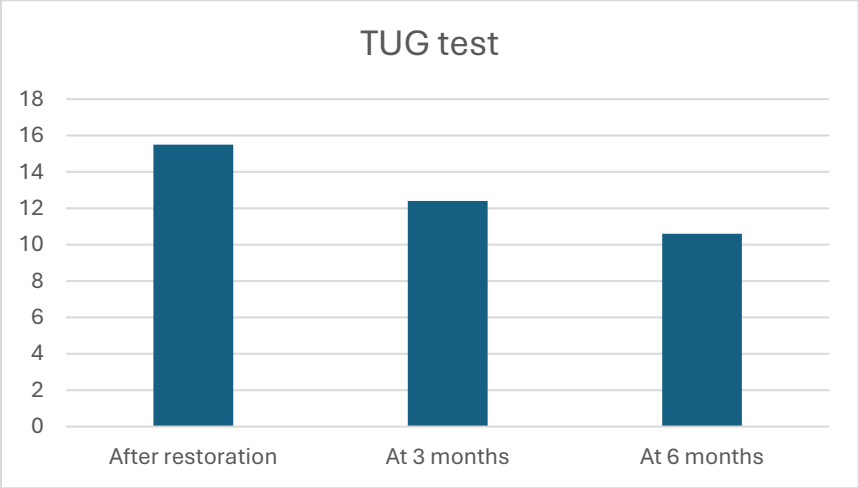


Figure 3: Showing comparison of the mean values of dynamic postural balance after restoration, at 3 and 6 months

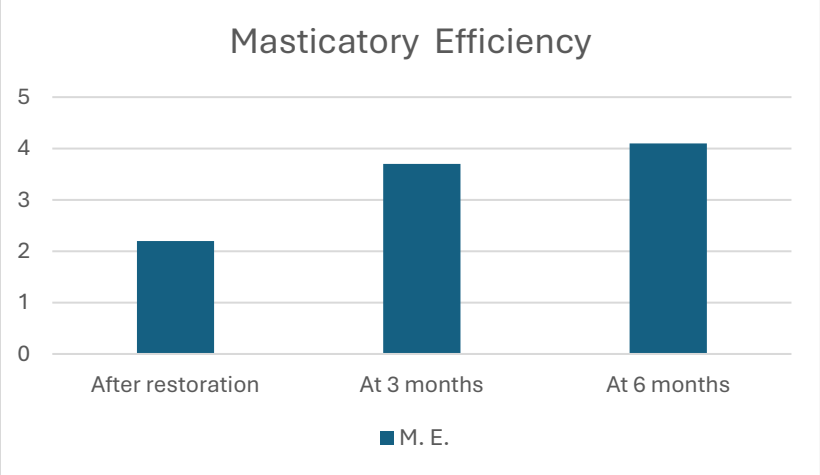


Figure 4: Showing comparison of the mean values of masticatory efficiency after restoration, at 3 and 6 months

Table 2: Correlation between dynamic postural balance and masticatory efficiency 3 and 6 months

Time duration (month)	Spearman's correlation coefficient	p-value	Interpretation
3 months	- 0.762	0.027	High negative, statistically significant
6 months	- 0.588	0.031	Moderate negative, statistically significant

At three months, as the P value (P = 0.027), the correlation between the two parameters tested was found to be statistically highly significant (- 0.762). Meaning that the correlation strength was high. The correlation between the values of dynamic postural balance and masticatory efficiency was negative, shown as sharp increase in masticatory efficiency and decrease in time taken to perform the TUG test.

At six months, as the P value (P = 0.031), the correlation between the two parameters was also statistically significant. The correlation between the values of dynamic postural balance and masticatory efficiency was also negative (- 0.588), and statistically significant but it was shown as smaller and gradual increase as compared to the three months' results (- 0.762).

A statistically significant negative correlation was found between the TUG test times and masticatory efficiency as shown in (Figure 5). This indicates that as masticatory performance scores increased (better chewing), the duration of time to complete the TUG test decreased (better dynamic balance).

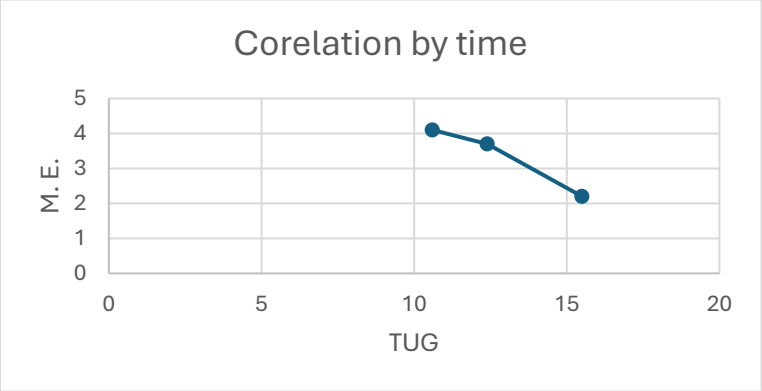


Figure 5: Showing the correlation between the dynamic postural balance and masticatory efficiency

Discussion:

The findings of this study confirmed a strong correlation between masticatory efficiency and dynamic postural body balance. Stabilizing the occlusion with a fixed implant supported all on four prostheses led to a statistically significant progressive enhancement of masticatory efficiency and dynamic body balance. This improvement demonstrates that rigid stabilization and precise occlusal balancing can restore neural pathways that regulate whole-body equilibrium. Thus, the null hypothesis was rejected.

Despite the advancements in rehabilitation of completely edentulous patients, the systemic consequences of such treatments on somatic sites, cranio-cervical posture, and pulmonary volumes received limited investigations(15). Especially all on four fixed restoration and its influence on enhancing masticatory efficiency that was not explored in relation to dynamic body balance, which was a research gap chosen to be investigated in the present study.

Masticatory efficiency was assessed using color changing chewing gum as it was proven to be an optimal assessment for geriatric individuals with prosthetic treatment. In contrast to conventional dietary samples, chewing gum closely simulates the natural chewing process and not swallowable; therefore, no sample would be lost(24). This type of chewing gum was used in several previous studies (3, 5, 22, 24) and proven to have robust precession in objectively assessing the efficiency of mastication.

Timed up and go test (TUG) was employed to measure the dynamic balance for each subject in the present study, as it was a reliable way to identify subjects at risk of falling, with high validity, it is also user friendly, with no need for additional equipment(3, 25, 26). Posture is governed by the prolonged muscle contraction of the extensor muscles that resist gravity, permitting joints to bear the body mass. The elevator muscles of the jaw stabilize mandibular orientation via the myotatic reflex, which functions via the triggering of proprioceptive receptors of the same muscles, TMJ, and periodontal receptors(13). The rotational malalignment between the skull C1, and C2 vertebrae that is usually present with TMD patients, can provoke local nerves irritation and mechanoreceptors, manifest as vestibular symptoms such as vertigo, localized suboccipital pain, and dynamic imbalance(10, 12).

Mandibular reposition may influence gait stability through affecting the gait cycle, and the relative standard deviation, thus gait velocity changes notably(12). Alterations of occlusion impacts postural stability in adults, and falling is frequently observed in persons with compromised occlusion than in those with proper occlusion(27). Several studies concluded that occlusion impacts the tone of masticatory and postural muscles involved in preserving body balance especially in centric relation(11, 20, 28). Masticatory problems may as well lay an effect on the foot dynamics and anti-gravity muscles throughout the body and alter their function(11).

Results emphasized the idea of positive influence of dentures on occlusion and postural control. Cervical alignment and postural accommodation play crucial roles in the rehabilitation mechanism(9, 13, 15). Rehabilitation of edentulism with complete dentures improves mastication and body balance but is still not enough to approximate natural dentition state. When a patient exhibits asymmetric or unstable occlusion as seen with some removable dentures, the trigeminal inputs become erratic. This uneven feedback triggers compensatory, asymmetric motor firing patterns in the neck musculature. This localized distortion can misalign the head and neck, disrupting the vestibulo-ocular and vestibulo-collic reflexes. Consequently, the brain miscalculates the body's true position in space, leading to increased postural sway(29). On the contrary, another study compared older people with and without dentures, and they concluded that using removable denture weakens the neck muscles, supports forward head posture, and decreases the body balance(30). This means that removable dentures may not have the ultimate rehabilitation effect, implying that a more stable restoration would solve the problem, which was concluded in our present study stating that stable balanced efficient mastication is crucial for proper dynamic balance.

Another study concluded that masticatory efficiency improves when the patient uses implant overdentures rather than conventional dentures(31). Furthermore, it was evidenced that as number of implants increases, the masticatory efficiency consistently increase which suggests clear

correlation between both(32, 33). Dental implants also increase osseo-perception, stimulate the sensory cortex as natural teeth, enhance tactile sense and stereognosis, leading to improved chewing ability(34).

The efficiency of mastication is a technique used to follow adaptation of prosthetic restorations, indicating proper serviceability of the restoration. It is multi-factorial and does not depend only on the number of implants or the design of supra-structure(35). As stated by several studies, all on four restorations significantly improve chewing ability compared to overdentures and conventional dentures(22, 35, 36). That may be attributed to increased control of the patient on the prostheses, as the more retentive and stable restoration with regaining of the proper vertical dimension(22). It was also evidenced that all on four restorations provide bite force similar or sometimes even higher than fully dentate conditions. This would be attributed to the fact that patients show elevated confidence with the fixed prosthesis and apply higher biting force(16, 37, 38) or it may be related to the habitual protrusion of the implanted mandible that increase occlusal force(37). These researches' results were in accordance with the results obtained in the present study.
There was a strong correlation between reduced mastication time or good masticatory efficiency and shorter dynamic body movement execution time, observed in our study with the use of fixed all on four restoration because symmetrical forces excreted during mastication prevent asymmetric muscle firing in TMJ, head, and body muscles which is essential in assisting inner ear and visual systems tracking spatial movement supporting balance during rapid movements.
All assessments were conducted at the time of restoration, after 3 months, and after 6 months. The first assessment was considered base line, 3 months period was chosen as it was deemed sufficient to achieve optimal neuromuscular remodeling for a new restoration because masticatory muscle activity reaches approximately its original level after an adaptation period of 3 months(39). At 3 months the patient's body is still adapting to the sudden changes leading to enhanced mastication and body balance, but after 6 months the link between optimal mastication and stable walking balance becomes tighter and more predictable. Masticatory efficiency was found to be significantly better after 6 months than after 3 months restoration(3). That was in consistence with what we found in the present research which was attributed to increased adaptation of the patient with the restoration. By 6 months, patients maximize their muscle coordination and biting force, resulting in the high color change values of the chewing gum. Balance might take longer to fully optimize than chewing because the vestibular system and postural muscles require prolonged neuromuscular reprogramming, so after 6 months, patients achieve their fastest, safest TUG times.
An interdisciplinary paradigm is mandatory for optimizing patient outcomes and producing novel treatment strategies for comorbid spinal and jaw dysfunctions(10). This finding is very important to take into consideration in all dental treatments, especially with the recent developments in technology that permit easy optimization of treatment.

The limitations of this study are the small patient sample size, the short term follow up period, the uni-center study, and the use of only one type of dynamic balance evaluation. Therefore, longer-term randomized controlled clinical trials with sufficient sample size are needed to confirm the results of our clinical study, future use of more than one method of testing the postural balance is recommended.

Conclusion:

The present study demonstrates the impact of fixed all on four restorations with completely edentulous patients, on enhancing masticatory efficiency, which has proven to have a strong correlation with the improvement of dynamic postural balance and functional mobility specially in elder patients which support long-term functional independence. Dynamic postural balance and masticatory efficiency underwent increased enhancement and adaptation after 6 months of use than after 3 months with better patient adaptation.

Declarations

Ethics approval and consent to participate

The study was conducted in accordance with the principles of the Declaration of Helsinki (40) and was approved by the Research Ethics Committee of the Faculty of Dentistry, Beni-Suef University (FDBSU-REC), with approval number **REC-FDBSU/10042025-01/SR**. Written informed consent was obtained from all participants prior to treatment.

Consent for publication

Written informed consent for publication of the patients' clinical images was obtained from the patients.

Availability of data and materials

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

RAE: Conceptualization, methodology, clinical investigation, data collection, data analysis, and manuscript preparation.

SEM: Methodology, clinical investigation, data collection, and critical revision of the manuscript.

MOM: Methodology, investigation, and critical revision of the manuscript.

MMH: Clinical investigation, data collection, and critical revision of the manuscript.

All authors read and approved the final version of the manuscript and agreed to be accountable for all aspects of the work.

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