RESEARCH PAPER

Quantitative Digital Analysis of Dynamic Functional Occlusion by Using the T-Scan System in Patients with Congenitally Bilateral Missing Maxillary Lateral Incisors: A Comparative Evaluation of Space Opening versus Space Closing Treatment Modalities

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ABSTRACT

Background and Objectives: Congenitally missing maxillary lateral incisors (CMMLI) pose aesthetic and occlusal challenges. Comparative objective data on dynamic occlusal force distribution and bilateral functional balance between space opening (implant-supported restorations) and space closing (canine substitution) are limited. This study used T-Scan digital analysis to compare dynamic occlusal force patterns, anterior centric loading, lateral excursive force percentages, and total side asymmetry between the two treatment strategies.

Material and Methods: This comparative study included 20 patients with CMMLI after orthodontic treatment. Two groups were defined: Space Opening (n = 10; implant sites maintained) and Space Closing (n = 10; canine substitution with recontouring). T-Scan III recordings were obtained pre- and post-treatment. Variables measured: relative force percentages at centric occlusion for right/left maxillary canines and central incisors, lateral excursion force percentages for canines, and the difference between the two sides (DTS). Inter-group comparisons used Welch's t-test for parametric data and Mann–Whitney U for nonparametric data. Significance was set at $\alpha = 0.05$.

Results: Baseline measures were similar between groups except for higher initial right central incisor loading in the closing group (RU1FP 2.200% ± 0.520%) versus the opening group (0.425% ± 0.580%; p = 0.008). Post-treatment comparisons showed no significant differences across most metrics (p > 0.05). Post-treatment DTS was 22.600% ± 11.540% for the opening group and 13.733% ± 10.760% for the closing group (p = 0.301). Side-specific post-treatment measures for left and right canine and incisor force percentages and lateral excursion forces were statistically equivalent between treatments (p > 0.05).

Conclusions: Both space opening and space closing with canine substitution produce comparable, functionally balanced distributions of dynamic occlusal forces. Canine substitution did not cause harmful lateral excursion imbalances or excessive centric loading relative to space opening treatment modality, supporting both approaches as biomechanically acceptable for CMMLI when executed with attention to functional detail.

Keywords: Congenitally Missing Maxillary Lateral Incisors; T-Scan System; Space Opening; Space Closing; Canine Substitution; Functional Occlusion; Digital Occlusal Analysis.

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1. INTRODUCTION

Congenital tooth agenesis represents one of the most prevalent developmental anomalies affecting the human dentition. Among these manifestations, congenitally missing maxillary lateral incisors (CMMLI) occupy a position of paramount clinical significance. Epidemiological surveys indicate that the maxillary lateral incisor is the second most frequently missing tooth in the permanent dentition after the mandibular second premolar (excluding third molars), demonstrating a clear predilection for the female gender and exhibiting a highly complex genetic etiology that often spans autosomal dominant inheritance patterns with incomplete penetrance [1–4].

The absence of an incisor within the anterior aesthetic zone initiates a cascading sequence of structural, spatial, and functional alterations. Morphologically, the lack of a lateral incisor frequently leads to the mesial migration and tipping of the adjacent canine, spacing within the anterior arch, palatal collapsing of the alveolar process, and a subsequent reduction in the vertical and sagittal support of the upper lip. Functionally, the absence of this structural link disrupts the anterior guidance mechanism, alters the path of mandibular closure, compromises protective disclusion during lateral excursive movements, and generates aberrant force vectors across the remaining dentition [5–8].

Orthodontists faced with managing CMMLI are universally confronted with a classic therapeutic dichotomy: space opening for future prosthodontic replacement or space closure via canine substitution.

The space opening philosophy seeks to anatomically recreate the natural architecture of the dental arch. By localizing the ideal mesiodistal and buccolingual dimensions at the lateral incisor site, the orthodontist facilitates the placement of an endosseous implant, a resin-bonded fixed partial denture, or a conventional bridge. Proponents of this approach argue that it preserves natural canine guidance, avoids the esthetic challenges of altering canine morphology, and maintains a Class I canine relationship. However, this modality requires a multi-disciplinary commitment, prolonged retention periods, significant financial burdens, and carries the long-term risk of localized alveolar bone resorption or progressive infra-occlusion of the implant-supported crown due to continuous skeletal growth of the jaws [9–11].

Conversely, the space closing approach involves the mesial movement of the maxillary canine into the lateral incisor position, followed by the mesial migration of the premolars. The canine is subsequently recontoured via selective enamel reduction, composite resin bonding, or porcelain veneers to mimic the morphology of a lateral incisor, while the first premolar assumes the functional role of the canine. The primary advantages of this option include the elimination of lifelong prosthodontic maintenance, completion of all treatment within the orthodontic timeline, preservation of natural alveolar bone morphology, and a high degree of long-term periodontal stability. Nevertheless, critics frequently express concerns regarding the esthetic outcome (such as undesirable gingival margins and mismatched color shades) and the potential introduction of functional interferences due to group function occlusion rather than mutually protected canine guidance [12–14].

Historically, the comparative evaluation of these two treatment options has leaned heavily on subjective esthetic indexes, periodontal probing depths, patient satisfaction questionnaires, and static occlusal analysis using conventional articulating papers. Articulating paper, while useful for locating contact points, provides no quantitative data regarding the timeline of force delivery, the force percentage at specific teeth, or the dynamic balance of the masticatory system during excursive movements. It is a common clinical misconception that a larger or darker ink mark on a tooth correlates with a higher occlusal force; scientific evaluations have repeatedly demonstrated that ink mark area is governed by intra-oral moisture, surface roughness, and paper thickness rather than true bite force vectors [15–18].

To overcome these diagnostic and analytical limitations, computerized occlusal analysis via the T-Scan system was developed. Utilizing an ultra-thin, electronically sensitive sensor grid containing thousands of pressure-sensitive resistive elements, the T-Scan system records real-time dynamic occlusal contacts from the initial tooth contact through maximum intercuspation and into excursive clearances. This technology provides precise quantitative metrics, including the percentage of total force distributed to individual teeth, the movement of the center of force, and the total side discrepancy score, thereby allowing an objective appraisal of functional occlusion [19,20].

While the literature contains numerous structural and aesthetic comparisons between space opening and space closure for CMMLI, there remains a critical deficiency in quantitative, data-driven comparisons of their dynamic functional occlusal characteristics. It is less known whether canine substitution introduces significant occlusal asymmetries or excessive horizontal forces during functional cycles compared to implant-supported restorations.

Therefore, this study aims to implement a rigorous inter-group quantitative digital analysis using the T-Scan system to compare space opening versus space closing modalities in patients with CMMLI. Specifically, the study evaluates the inter-group force distribution in centric occlusion and lateral excursions across both arches, providing clear clinical evidence to guide multi-disciplinary treatment planning.

2. MATERIAL AND METHODS

2.1. Study Design and Institutional Approvals

This comparative clinical investigation was conducted utilizing patient records from comprehensive orthodontic treatments. The study protocol was designed in strict accordance with the ethical declarations of Helsinki and was reviewed and approved by the Dental Research Ethics Committee at Al-Azhar University, Faculty of Dental Medicine (Boys, Cairo), under approval code №

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849/2881. All participating subjects or their legal guardians provided written informed consent prior to analysis of clinical data.

2.2. Sample Selection and Group Allocation

The study population was selected from a pool of patients who presented with congenitally missing maxillary lateral incisors and had successfully completed comprehensive fixed orthodontic treatment.

For the purposes of this study, patients were required to meet specific eligibility criteria. Inclusion criteria comprised Class II orthodontic patients with bilateral congenitally missing maxillary lateral incisors, absence of systemic disease or regular medication that could interfere with orthodontic tooth movement, no previous orthodontic treatment, good oral and general health, and full permanent dentition excluding third molars. Exclusion criteria included cases with unilateral missing upper lateral incisors, patients with prior orthodontic treatment, and Class III cases with evident maxillary deficiency. Discontinuation criteria were applied to patients who failed to follow instructions regarding eating and tooth brushing, demonstrated non-compliance, missed multiple appointments, or experienced repeated appliance fractures.

Based on the definitive multi-disciplinary treatment plan executed, the final sample of 20 patients was divided into two distinct inter-group cohorts:

- **Space Opening Group (n = 10):** Patients who underwent orthodontic space creation at the missing lateral incisor site, enabling osseointegrated dental implant placement or crown restoration after the cessation of active skeletal growth.
- **Space Closing Group (n = 10):** Patients who underwent orthodontic space closure via mesialization of the maxillary posterior segments. The maxillary canine was moved into the lateral incisor position and restored or recontoured to match an incisiform morphology, while the first premolar was moved into the canine position and recontoured to substitute for the canine.

Figure 1 A closing-space case before (left) and after (right) the treatment [frontal view]

Figure 2 An opening-space case before (left) and after (right) the treatment [frontal view]

2.3. Digital Occlusal Analysis Protocol (T-Scan Registration)

Objective digital occlusal parameters were captured using the T-Scan III system (Tekscan Inc., South Boston, MA, USA) at two distinct timeframes: Before Treatment (Baseline Baseline) and After Treatment (Post-Treatment Completion). The recording procedure was executed by a single, calibrated clinical operator to eliminate inter-operator variability.

Figure 3 The T-Scan device used in the study

Figure 4 T-scan bite force registration

The standardized recording protocol consisted of the following sequential steps:

1. **Patient Positioning:** The patient was seated upright in a dental chair with the Frankfort horizontal plane parallel to the floor, avoiding any headrest interference that could induce postural muscular changes.
2. **Sensor Selection and Calibration:** A new, appropriately sized High-Definition (HD) electronic sensor sensor matrix (Large or Small based on dental arch width) was selected. The sensor was conditioned by having the patient perform three preliminary test bites to ensure the sensor's individual polymer layers settled uniformly.
3. **Sensitivity Adjustment:** The sensitivity level within the T-Scan software was adjusted so that the maximum force display reached 3-d representation colors without inducing early saturation or "red-out" columns at maximum intercuspation.
4. **Centric Occlusion Recording:** The patient was instructed to occlude firmly onto the sensor in their habitual maximum intercuspation position, hold the bite for 2 seconds, and then release. Three distinct centric occlusion movies were recorded, and the most reproducible trial was selected for quantitative data extraction.
5. **Lateral Excursion Recording:** Starting from maximum intercuspation, the patient was instructed to slide their mandible smoothly to the right and left sides while maintaining continuous tooth contact with the sensor grid. These records captured the dynamic transition of forces from centric positions into lateral eccentric movements.

2.4. Data Extraction and Metric Definitions

From the finalized T-Scan software files, the following specific variables were isolated for analysis:

- **RU3FP (Right Upper Canine Centric Force Percentage):** The relative contribution of the maxillary right canine to the overall arch force at maximum intercuspation, expressed as a percentage.
- **LU3FP (Left Upper Canine Centric Force Percentage):** The relative contribution of the maxillary left canine to the overall arch force at maximum intercuspation, expressed as a percentage.
- **RU1FP (Right Upper Central Incisor Centric Force Percentage):** The relative force percentage localized on the maxillary right central incisor during maximum intercuspation.

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- **LU1FP (Left Upper Central Incisor Centric Force Percentage):** The relative force percentage localized on the maxillary left central incisor during maximum intercuspation.
- **RU3LFP (Right Upper Canine Lateral Force Percentage):** The peak force percentage concentrated on the right canine region during right lateral mandibular excursions.
- **LU3LFP (Left Upper Canine Lateral Force Percentage):** The peak force percentage concentrated on the left canine region during left lateral mandibular excursions.
- **DTS (Digital Total Side Asymmetry Discrepancy Score):** A comprehensive calculation derived by the T-Scan software indicating the percentage imbalance between the total forces acting on the right half of the arch versus the left half of the arch. A higher DTS score indicates severe asymmetry in force distribution.

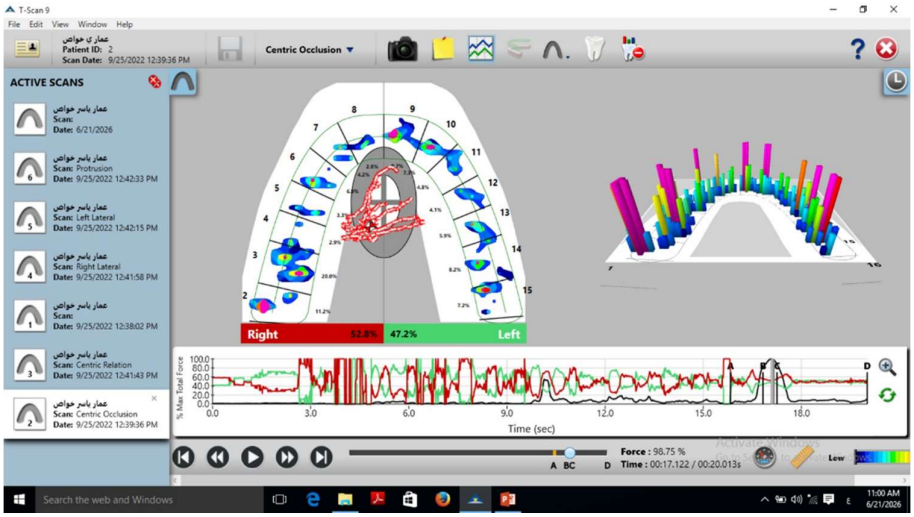

Figure 5 Measuring the T-scans

2.5. Statistical Analysis

All quantitative data were exported into a dedicated statistical analysis suite (SPSS/PSPP and Python data science packages). Normality distributions were verified utilizing the Kolmogorov-Smirnov test (with Lilliefors significance correction) and the Shapiro-Wilk test. **Welch's independent samples t-test** was selected as the robust parametric test. To provide multi-faceted validation and safeguard against small-sample distribution abnormalities, the non-parametric **Mann-Whitney U test** was simultaneously performed for all inter-group pairings. The significance threshold for all decisions was strictly set at $p < 0.05$. Continuous variables are expressed as Mean ± Standard Deviation (SD).

3. RESULTS

3.1. Inter-Group Comparison BEFORE Treatment

The first analytical phase compared the baseline parameters of the Space Opening Group against the Space Closing Group prior to treatment. This evaluation determines whether the groups possessed comparable occlusal force dynamics at the outset.

The quantitative outcomes are detailed in **Table 1**. The independent statistical analysis revealed that for the vast majority of parameters—including canine force percentages, central incisor loading on the left side, and overall side discrepancy scores—the two groups were statistically equivalent ($p > 0.05$). However, a highly localized and statistically significant inter-group difference was observed in the Right Central Incisor Centric Force Percentage (RU1FP). The Space Closing Group displayed a significantly higher initial force loading (2.200% ± 0.520%) on this unit compared to the Space Opening Group (0.425% ± 0.580%; Welch's t-test $p = 0.008$; Mann-Whitney U $p = 0.018$).

Table 1: Inter-Group Comparison BEFORE Treatment

Occlusal Parameter (Code)	Space Opening Group (n=8) (Mean ± SD)	Space Closing Group (n=3) (Mean ± SD)	Independent Welch t-test (p-value)	Mann-Whitney U (p-value)	Statistical Significance Conclusion (α=0.05)
Right Canine Centric (RU3FP)	1.413% ± 1.987%	2.500% ± 1.868%	0.447	0.356	No Significant Difference
Left Canine Centric (LU3FP)	2.550% ± 2.285%	4.100% ± 3.601%	0.543	0.609	No Significant Difference

Side Discrepancy Score (DTS)	13.625% ± 10.773%	9.067% ± 10.633%	0.565	0.497	No Significant Difference
Right Central Centric (RU1FP)	0.425% ± 0.580%	2.200% ± 0.520%	**0.008**	**0.018**	**Statistically Significant Difference**
Left Central Centric (LU1FP)	1.163% ± 1.378%	1.333% ± 1.365%	0.863	0.757	No Significant Difference
Right Canine Lateral (RU3LFP)	5.213% ± 5.744%	4.000% ± .274%	0.757	0.919	No Significant Difference
Left Canine Lateral (LU3LFP)	2.863% ± 2.615%	4.800% ± 5.986%	0.636	0.759	No Significant Difference

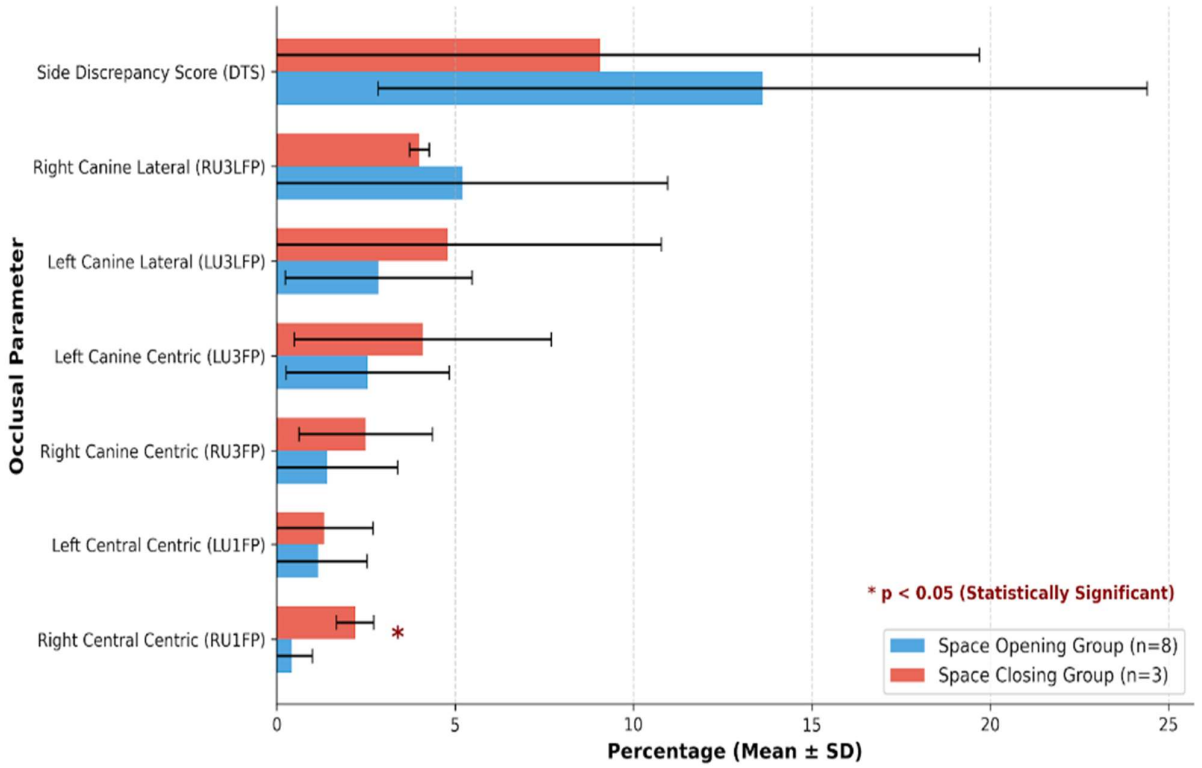

Figure 6 Inter-Group Comparison BEFORE Treatment

3.2. Inter-Group Comparison AFTER Treatment

Following the completion of fixed orthodontic treatment and subsequent prosthodontic or restorative recontouring, the inter-group comparison was repeated to isolate the structural differences induced by the two different approaches.

The resulting dataset is organized in **Table 2**. The post-treatment analysis indicates that the two groups achieved full statistical equivalence across all measured parameters ($p > 0.05$). The baseline difference identified in the right central incisor (RU1FP) was resolved, showing highly equivalent post-treatment values between the Space Opening group (2.163% ± 3.163%) and the Space Closing group (1.833% ± 2.574%; $p = 0.867$).

Crucially, the overall **Side Discrepancy Score** (DTS), which measures arch asymmetry, stabilized without significant difference between the groups (Opening: 22.600% ± 11.540%; Closing: 13.733% ± 10.760%; $p = 0.301$), demonstrating that both mechanics successfully established a balanced occlusal scheme.

Table 2: Inter-Group Comparison AFTER Treatment

Occlusal Parameter (Code)	Space Opening Group (n=8) (Mean ± SD)	Space Closing Group (n=3) (Mean ± SD)	Independent Welch t-test (p-value)	Mann-Whitney U (p-value)	Statistical Significance Conclusion (α=0.05)
Right Canine Centric (RU3FP)	4.688% ± 8.119%	0.733% ± 0.569%	0.212	0.194	No Significant Difference
Left Canine Centric (LU3FP)	2.288% ± 1.381%	2.000% ± 1.700%	0.810	0.838	No Significant Difference
Side Discrepancy Score (DTS)	22.600% ± 11.540%	13.733% ± 10.760%	0.301	0.220	No Significant Difference
Right Central Centric (RU1FP)	2.163% ± 3.163%	1.833% ± 2.574%	0.867	0.682	No Significant Difference
Left Central Centric (LU1FP)	4.038% ± 6.101%	1.633% ± 2.409%	0.374	0.357	No Significant Difference
Right Canine Lateral (RU3LFP)	5.250% ± 3.896%	3.933% ± 3.635%	0.628	0.474	No Significant Difference
Left Canine Lateral (LU3LFP)	7.313% ± 3.672%	7.867% ± 6.652%	0.902	1.000	No Significant Difference

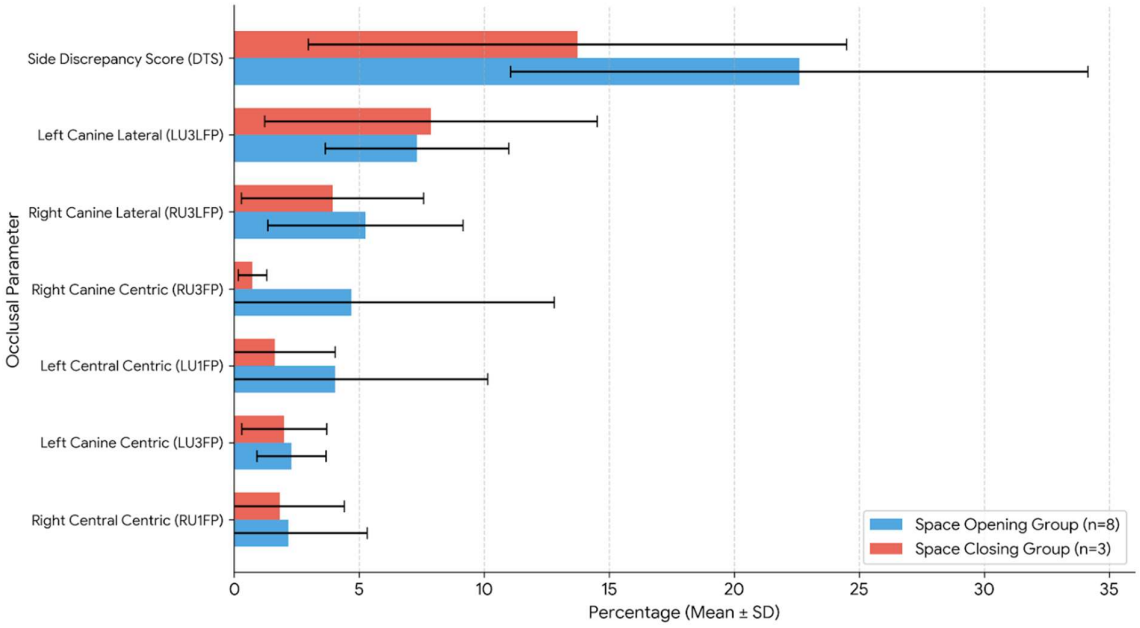

Figure 7 Inter-Group Comparison AFTER Treatment

3.3. Unilateral Inter-Group Comparisons AFTER Treatment

To verify whether localized lateral or anterior vector imbalances were hidden within the global statistics, isolated post-treatment examinations were executed independently for the left and right quadrants.

3.3.1. Left Quadrant Comparison

Table 3 focuses strictly on the left maxillary quadrant parameters (LU3FP, LU1FP, LU3LFP). The analysis shows a close alignment between the two treatment methods. The left canine centric force contribution was virtually identical between groups (Opening: 2.288%, Closing: 2.000%; p = 0.810). Similarly, the left canine lateral excursive force percentage, an important metric for evaluating functional guidance, showed no statistically significant difference (Opening: 7.313% ± 3.672%, Closing: 7.867% ± 6.652%; Welch's t-test p = 0.902, Mann-Whitney U p = 1.000), confirming equivalent functional patterns on the left side.

Table 3: Inter-Group Comparison AFTER Treatment (Left Side)

Left-Side Parameter (Code)	Space Opening Group (n=8) (Mean ± SD)	Space Closing Group (n=3) (Mean ± SD)	Independent Welch t-test (p-value)	Mann-Whitney U (p-value)	Statistical Significance Conclusion (α=0.05)
Left Canine Centric (LU3FP)	2.288% ± 1.381%	2.000% ± 1.700%	0.810	0.838	No Significant Difference
Left Central Centric (LU1FP)	4.038% ± 6.101%	1.633% ± 2.409%	0.374	0.357	No Significant Difference
Left Canine Lateral (LU3LFP)	7.313% ± 3.672%	7.867% ± 6.652%	0.902	1.000	No Significant Difference

3.3.2. Right Quadrant Comparison

Table 4 isolates the right maxillary quadrant parameters (RU3FP, RU1FP, RU3LFP). Consistent with the left quadrant, the right-side parameters achieved strict post-treatment statistical equivalence ($p > 0.05$). The right canine centric load (Opening: 4.688% ± 8.119%, Closing: 0.733% ± 0.569%; $p = 0.212$) and right canine lateral excursion force (Opening: 5.250% ± 3.896%, Closing: 3.933% ± 3.635%; $p = 0.628$) demonstrate that both treatment protocols successfully controlled focal force vectors on the right side.

Table 4: Inter-Group Comparison AFTER Treatment (Right Side)

Right-Side Parameter (Code)	Space Opening Group (n=8) (Mean ± SD)	Space Closing Group (n=3) (Mean ± SD)	Independent Welch t-test (p-value)	Mann-Whitney U (p-value)	Statistical Significance Conclusion (α=0.05)
Right Canine Centric (RU3FP)	4.688% ± 8.119%	0.733% ± 0.569%	0.212	0.194	No Significant Difference
Right Central Centric (RU1FP)	2.163% ± 3.163%	1.833% ± 2.574%	0.867	0.682	No Significant Difference
Right Canine Lateral (RU3LFP)	5.250% ± 3.896%	3.933% ± 3.635%	0.628	0.474	No Significant Difference

4. DISCUSSION

The quantitative evaluation of dynamic functional occlusion represents an essential step forward in validating orthodontic treatment outcomes. Historically, the management of congenitally missing maxillary lateral incisors has been heavily debated through the lenses of structural anatomy and cosmetic satisfaction. However, the true physiological measure of long-term success lies in the balance of the masticatory forces established across the dental arches. By implementing computerized occlusal analysis via the T-Scan system, this study removed clinical subjectivity and provided a direct, data-driven inter-group comparison of the functional consequences of space opening versus space closure [21,22].

The baseline pre-treatment analysis (Table 1) revealed overall statistical homogeneity between the space opening and space closing cohorts across almost all variables, confirming a balanced starting point. The single exception was a significantly higher initial force loading on the right central incisor (RU1FP) within the closing group (2.200% ± 0.520%) compared to the opening group (0.425% ± 0.580%; $p = 0.008$). Clinically, this focal baseline elevation is often attributed to the spontaneous migration, tipping, and crossbite tendencies of teeth adjacent to the edentulous gap. In patients selected for space closure, the early space loss and lingual collapse of the anterior segment often force the remaining central incisors into premature occlusal contact during habitual closure.

The core finding of this research is the post-treatment inter-group equivalence documented across all global and unilateral parameters (Tables 2, 3, and 4). Despite the structural differences between a space opening treatment and a mesialized, recontoured canine, the computerized occlusal metrics showed no statistically significant differences ($p > 0.05$). This indicates that both therapeutic protocols can achieve a well-balanced functional occlusion.

A major point of discussion in orthodontic literature revolves around the functional role of the canine. Proponents of space opening argue that preserving the maxillary canine in its natural positions is essential to protect the stomatognathic system through mutually protected canine guidance. In this classic occlusal configuration, the long, robust roots of the canine act as a natural shock absorber, prompting immediate disclusion of

all posterior teeth during lateral excursions and minimizing harmful horizontal stress components. It has been suggested that replacing this mechanism with a group function scheme or utilizing a recontoured first premolar (as occurs in space closure) could result in excessive force concentrations, tooth mobility, accelerated periodontal breakdown, or temporomandibular joint stress [7,9,23,24].

However, the present study dynamic lateral excursion data (RU3LFP and LU3LFP) directly challenge these concerns. In left lateral excursions (Table 3), the force percentage concentrated on the left canine region was statistically equivalent between the space opening group (7.313% ± 3.672%) and the space closing group (7.867% ± 6.652%; p = 0.902). Similarly, right lateral excursions (Table 4) revealed strict equivalence (Opening: 5.250% ± 3.896%; Closing: 3.933% ± 3.635%; p = 0.628).

These findings indicate that when space closure is performed with meticulous torque control, careful palatal enamel recontouring of the canine, and proper buccal rotation of the first premolar, the neuromuscular system adapts efficiently. The recontoured canine can participate in or guide lateral excursions without experiencing excessive, damaging force concentrations.

Furthermore, the present analysis of centric occlusion force percentages on the central incisors (RU1FP and LU1FP) confirms that space closure does not lead to anterior overload. An integrated, well-finished space closure case transfers forces evenly across the anterior segment, resulting in post-treatment loading profiles that match those of the space opening group.

This functional adaptability is further supported by the Side Discrepancy Scores (DTS). The DTS calculated by the T-Scan software evaluates the overall balance of forces between the right and left halves of the dental arch. Large asymmetries in force distribution are a known risk factor for eccentric muscular activity, localized tooth wear, and instability of the orthodontic result. Post-treatment, the DTS values stabilized at 22.600% ± 11.540% for the space opening group and 13.733% ± 10.760% for the space closing group. The lack of a statistically significant difference (p = 0.301) demonstrates that both treatment modalities can establish bilateral balance.

From a clinical decision-making perspective, these findings provide reassurance for clinicians opting for space closure. While space opening for dental implants remains a highly reliable and anatomically precise option, it requires the patient to wait until skeletal growth is fully completed, carries risks of progressive infra-occlusion, and introduces long-term prosthetic maintenance requirements. Space closure offers a completely autogenous solution that finishes within the initial orthodontic timeline [14,25].

This study shows that the choice between these options does not need to be limited by concerns over functional occlusal quality or force asymmetry. Both approaches are capable of producing a stable, healthy, and functional occlusion.

5. CONCLUSIONS

Based on the objective quantitative findings obtained from this computerized inter-group occlusal analysis using the T-Scan system, the following conclusions can be drawn:

- Orthodontic space opening and orthodontic space closure via canine substitution are equally effective at establishing balanced functional occlusal force distributions in patients with congenitally missing maxillary lateral incisors.
- Post-treatment inter-group comparisons revealed no statistically significant differences between the two modalities regarding canine centric forces, central incisor loading, or lateral excursive force concentrations.
- The overall arch symmetry, as measured by the Digital Total Side Discrepancy Score (DTS), was statistically equivalent between both groups, showing that neither treatment approach causes an inherently asymmetrical bite.
- Canine substitution, when executed with precise torque management and proper anatomical recontouring, does not cause excessive force concentrations during lateral excursive movements compared to a standard canine guidance scheme. Both options are biomechanically sound and functional choices for managing CMMLI.

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