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Original Research Article

Comparative 3-dimensional evaluation of dental and skeletal changes in the maxillary arch during levelling and aligning between Damon and 3M ceramic self-ligation brackets with cone beam computed tomography – An in-vivo study

Pooja Radhakrishnan[1], Veena Promod Menon[1], Mahendra S[1], Arun AV[2], Aravind S Raju[1], Meghnaa Subbarayalu[1]*

[1]Dept. of Orthodontics and Dentofacial Orthopaedics, Krishnadevaraya College of Dental Sciences, Bengaluru, Karnataka, India.
[2]Dept. of Orthodontics and Dentofacial Orthopaedics, Danta Vinyas Dental & Orthodontic Clinic, Bengaluru, Karnataka, India.

Abstract

Aim: This study aims to compare the dental and skeletal changes in maxillary arch during levelling and aligning with volumetric analysis during orthodontic treatment with Damon system and 3M Clarity Ultra Brackets aided by CBCT.
Materials and Methods: Twenty patients with mild to moderate crowding were included, with 10 treated with Damon ceramic self-ligating brackets and the other 10 were treated with 3M Clarity Ultra brackets.
Results: Results of this study showed significant arch length increase in both groups, with Damon clear brackets demonstrating greater arch width expansion, arch volume and more bodily movement than Clarity Ultra brackets.
Conclusion: The Damon Clear group showed significant arch length increase, greater maxillary arch width expansion, more bodily movement based on inter-arch width changes, and a larger maxillary volume increase compared to Clarity Ultra.

Keywords: CBCT, 3-D evaluation, Self-ligating brackets

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1. Introduction

The human dental arch's evolution has long influenced orthodontics, particularly in extraction versus non-extraction treatments. Self-ligating brackets (SLBs) have gained popularity since the 1930s, with the Damon system being a notable advancement in the mind 1990s. Damon's system emphasizes low-friction, low-force technology, claiming benefits like faster treatment, increased patient comfort, and fewer need for extractions.[1,2]

The Damon system's philosophy aims to mimic natural tooth movements, promoting arch development and alignment without excessive force. However, debate still exists regarding its efficacy and potential effects on arch dimension.[3]

Orthodontic treatment requires careful force management to avoid detrimental effects like periodontal ligament necrosis. The Damon system, among other self-ligating bracket systems, is praised for reducing force related complications while improving treatment efficiency.[4]

Cone beam computed tomography (CBCT) and other technological advancements have transformed orthodontic evaluation by offering precise three-dimensional images of dental structures, which facilitate treatment planning and efficiency.[5]

With the aid of CBCT, the study aims to investigate the effects of orthodontic treatment using the Damon and 3M Clarity Ultra Bracket systems on changes in volume, dental, and skeletal arch dimensions. The objectives of this research

*Corresponding author: Meghnaa Subbarayalu
Email: meghnaarsray@gmail.com

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include evaluating changes in dental and skeletal arch width, length, and tooth angulations in patients treated with the Damon system after leveling and alignment compared to those treated with 3M clarity ultra-brackets, assessing changes in arch dimension using CBCT in orthodontic cases treated without extractions, and performing 3D reconstruction of CBCT to compare volume differences in the maxilla before and after leveling and alignment procedures**.**

Thus, this study focuses on the 3-dimensional changes in maxilla, including linear measurements, to enhance orthodontic understanding and treatment outcomes. It builds upon technological advancements like CBCT to improve orthodontic practice and patient care.

2. Materials and Methods

This study involved 20 patients seeking orthodontic correction for mild to moderate crowding (3-6mm) at the Department of Orthodontics and Dentofacial Orthopedics, Krishnadevaraya College of Dental Sciences and Hospital, Bangalore. After obtaining informed consent, routine records and CBCT scans were conducted for all patients, CBCT images were taken for all 20 patients before and after levelling and alignment procedures. Damon ceramic self-ligating brackets were bonded to 10 patients, while the others were bonded with 3M clarity ultra-brackets. Non- growing patients between age group of 18 – 30 having Angles Class I occlusion or mild Angles Class II/III malocclusion with no surgical intervention were included in this study. If the cases required extraction at any point of time during treatment, missing teeth and pathological conditions in the head and neck area were excluded in this study.

2.1. Methodology

Bonding of the brackets were done following the recommended bonding protocol for Damon Clear and 3M Clarity Ultra brackets as shown in **Table 1**.

Wire sequence for Damon ceramic brackets:

1. 0.013 CuNiTi Upper and Lower
2. 0.014 CuNiTi Upper and Lower
3. 0.014 X 0.025 CuNiTi Upper and Lower
4. 0.018 X 0.025 CuNiTi Upper and Lower
5. 0.019 X 0.025 SS Upper and Lower

Table 1: Wire sequence for 3m clarity ultra brackets

Treatment Phase	**Objectives**	**Recommended**
Aligning	Initial vertical alignment De-rotation	Nitinol SE .014
Leveling	Initial space closure Refine vertical and rotation alignment	Nitinol SE .018
	Level Curve of Spee	
Working	Arch form correction Torque correction Refine space closure	Nitinol SE .014×.025
Finishing	Correct midlines Root alignment Class II or I correction Functional occlusion	Beta III .017×.025 Then Beta III .019×.025

Figure 1: Bonding of damon clear brackets & 3m ultra clarity brackets

Patients were evaluated every six weeks during the leveling and aligning phase of treatment. A 3D analysis was performed using CBCT (cone-beam computed tomography) scans taken before and after treatment for all 20 patients. Centric occlusion scans were used to assess inter-occlusal arch width by measuring the distances between cusp tips. Key measurement points included the first molars, first and second premolars, and cuspids in the maxillary arches. The evaluation encompassed occlusal segments and both buccal and lingual cortical plates. Additionally, inter-apical distances and angular measurements of each tooth were recorded.

3. Measurements of Dental Parameters in Maxilla

Arch Length (AL) - Perpendicular distance from line connecting the mesial of Maxillary permanent 1st molars to the contact point between maxillary central incisors. (as shown in **Figure 1**).

3.1. Arch Width

Inter-occlusal dimension (IOD) –

Distance between the maxillary canine tips (seen in **Figure 2**)
Distance between maxillary premolars buccal cusp tips.
Max M1: Distance between maxillary 1st molar buccal grooves

Inter-central fossa (ICF) (seen in **Figure 2***)*

M1: distance between 1st molars' central fossae

Inter-apical dimension (IAD) (Seen in **Figure 3**)

Canine: Distance between canine apices
Max PMs: Distance between maxillary premolar apices
Max M1: Distance between maxillary 1st molar palatal root apices

Inter-buccal alveolar crest dimension (IBACD) (seen in **Figure 4**)

Distance between buccal alveolar crestal bone

Inter-lingual alveolar crest dimension (ILACD) (as seen in **Figure 4**)

Distance between lingual alveolar crestal bone

Tooth Angulation (as seen in **Figure 5**)

Angulation of the tooth on the right/left side (R/L-angle)

1. Max canine: Angle between cusp tip to apex to nasal floor
2. Max PMs: Angle between buccal cusp to palatal root apex to nasal floor
3. Max 1st M: angle between central fossa to furcation to nasal floor.

In the maxilla, individual arch width measurements were made from cusp tip to cusp tip, as shown in Figure 2 of paired teeth. Non-functional cusps were selected

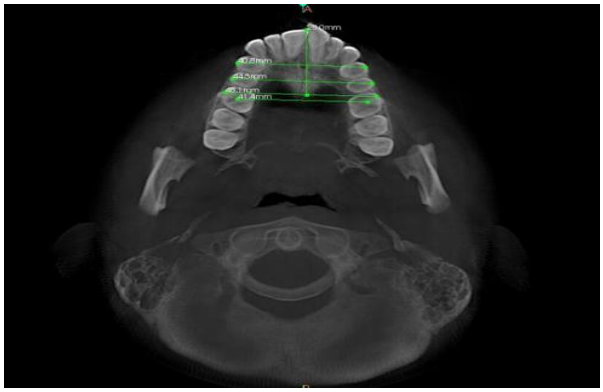

Figure 2: Measurement of arch length and arch width in different regions

Figure 3: Measurement of inter apical distance (IAD) in maxilla

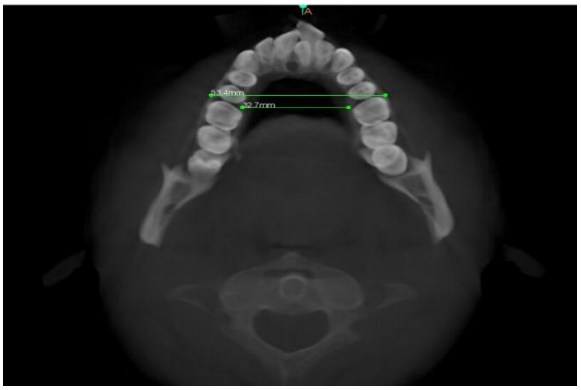

Figure 4: Measurement of IBACD and ILACD

The angulations of the maxillary teeth were measured relative to the point of intersection between the nasal septum and the nasal floor (**Figure 5**).

Angulations were measured separately on each tooth for the right (R) and left (L) side.

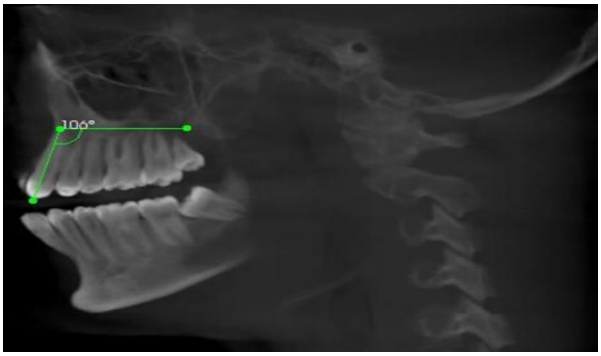

Figure 5: Measurements of angulations in maxilla

4. Skeletal Arch Width Measurements

Skeletal arch width measurements for each tooth were obtained by calculating the distance between corresponding points on the alveolar bone across the arch. Specifically:

1. IBACD (Inter-Buccal Alveolar Crest Distance): measured from the buccal crest of bone on one side to the buccal crest of bone on the contralateral side.
2. ILACD (Inter-Lingual Alveolar Crest Distance): measured from the lingual crest of bone on one side to the lingual crest of bone on the opposite side.

4.1. Arch length

Arch length was measured as the perpendicular distance from a line connecting the mesial surfaces of the first molars to the contact point between the central incisors. For the maxillary arch, measurements were taken using the volume view.

Inter-occlusal arch width measurements

To improve visualization and measurement precision, individual tooth data were also obtained using a three-dimensional coordinate system. Inter-occlusal arch width

measurements were recorded using both section and volume views, simulating an occlusal perspective similar to viewing a dental cast. This methodology facilitated the comparison of measurement accuracy between these imaging modalities and the previously acquired inter-occlusal distances based on the three coordinate planes.

The section view allowed for precise identification of anatomical landmarks by enabling manipulation across the frontal, sagittal, and coronal planes prior to measurement acquisition.

Maxillary arch measurements included:

1. Canine: cusp tip to cusp tip
2. First and second premolars: buccal cusp tip to buccal cusp tip
3. First molars: buccal groove to buccal groove

5. 3D Meaurements: Measurement of Volumetric Change in Maxilla

DICOM images were processed using MIMICS and MESHMIXER software (

Figure 6). STL files were derived from these images for 3D reconstruction, including sagittal, axial, and coronal volumetric slices to locate landmarks accurately. Volumes of the maxilla were calculated by comparing pre and post treatment CBCT scans (**Figure 7**) after standardizing bone densities.

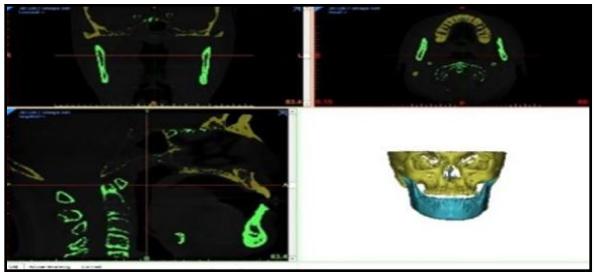

Figure 6: Convertion of dicom to stl file, softwar mimics innovation suite

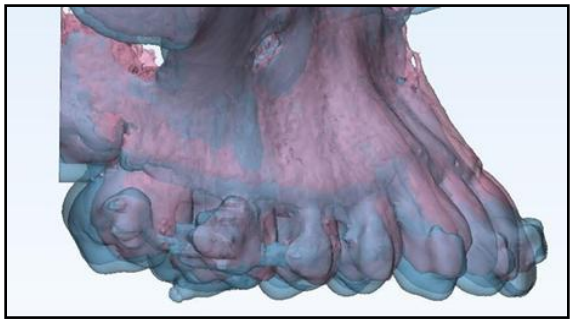

Figure 7: Super imposition to calculate volume differences (Pink- Pre-treatment, Blue- post levelling).

6. Results

All cases of Damon and Clarity ultra were evaluated after completion of levelling and alignment. The pre-treatment mean scores of Arch Width was compared in Damon as well as Clarity Ultra groups. No statistically significant difference ($p>0.05$) between the two groups (Damon and Clarity) in Maxilla for all AW variables (K9, PM1, PM2, M1) pre-treatment which means both the groups were comparable at beginning of treatment. Also, there was no statistically significant difference ($p>0.05$) between the two groups (Damon and Clarity ultra) in Maxilla for all Inter Apical Width (IAW) variables (Canine, PM1, PM2, M1) pre-treatment which means both the groups were comparable before the treatment.

Table 2 given below gives the comparison of pre and post treatment values of different variables in each group for the maxillary arch. It was observed that for AL, there was a statistically significant difference in both Damon and Clarity Ultra group. In the Damon group post treatment values were higher (30.37 ± 1.82) compared to pre-treatment values (28.12 ± 1.43) [$p < 0.001$]. In the clarity group also, the post treatment values (31.79 ± 2.17) were higher than pre-treatment values (28.71 ± 2.59) [$p = 0.004$].

Table 2: Comparison of the mean scores in maxilla using paired sample t test

	Groups	Time intervals	N	Minimum	Maximum	Mean	S.D	Mean diff	p value
AL	Damon clear	Pre	9	26.2	30.2	28.12	1.43	3.08	0.00*
		Post	9	27.4	33.2	30.37	1.82		
	Clarity ultra	Pre	10	24.5	33.1	28.71	2.59	2.24	0.004*
		Post	10	27.5	34.8	31.79	2.17		
IC FOSSA	Damon clear	Pre	9	41.7	47.8	44.81	2.62	1.48	0.00*
		Post	9	42.0	48.7	45.93	2.21		
	Clarity ultra	Pre	10	42.1	49.4	46.48	2.32	1.12	0.032*
		Post	10	43.2	50.9	47.96	2.15		
IBACD	Damon clear	Pre	9	44.7	58.5	53.63	4.36	2.04	0.001*
		Post	9	27.6	60.3	52.90	9.76		
	Clarity ultra	Pre	10	50.1	58.2	53.52	3.11	-0.73	0.819
		Post	10	50.9	59.6	55.56	3.00		
ILACD	Damon clear	Pre	9	23.7	33.8	29.11	3.13	1.48	0.02*
		Post	9	25	55.1	32.07	8.97		

	Clarity ultra	Pre	10	27.3	36.4	31.25	3.00	2.95	0.388
		Post	10	26.8	37.3	32.73	2.88		

Table 3: Comparison of the mean scores of aw in maxilla using paired sample t test

AW	Groups	Time intervals	N	Minimum	Maximum	Mean	S.D	Mean diff	p value
Canine	Damon clear	Pre	9	32.6	38.0	35.27	1.76	2.51	0.001*
		Post	9	32.3	38.0	35.26	1.69		
	Clarity ultra	Pre	10	31.3	37.1	33.79	2.08	-0.011	0.99
		Post	10	32.2	42.1	36.30	2.79		
PM1	Damon clear	Pre	9	38.4	44.1	42.00	1.80	2.62	0.00*
		Post	9	41.7	46.0	43.98	1.55		
	Clarity ultra	Pre	10	39.0	46.6	42.06	2.22	1.97	0.005*
		Post	10	40.6	48.4	44.68	2.71		
PM2	Damon clear	Pre	9	44.2	49.6	46.78	2.08	2.78	0.002*
		Post	9	46.3	51.1	48.97	1.93		
	Clarity Ultra	Pre	10	41.4	54.5	47.20	3.98	2.18	0.003*
		Post	10	47.0	54.8	49.98	2.50		
M1	Damon Clear	Pre	9	46.9	55.1	51.93	3.19	1.66	0.00*
		Post	9	49.9	55.1	52.73	2.18		
	Clarity Ultra	Pre	10	48.9	57.0	53.12	3.03	0.80	0.223
		Post	10	50.7	59.3	54.78	2.79		

These results are summarized in **Table 4**.

Table 4: Comparison of the mean scores of ang in maxilla using paired sample t test

ANG	Groups	Time intervals	N	Minimum	Maximum	Mean	S. D	Mean diff	p value
Canine	Damon clear	Pre	9	107.0	140.0	120.22	12.05	-1.40	0.519
		Post	9	110.0	130.0	121.67	6.14		
	Clarity ultra	Pre	10	104.0	130.0	114.90	8.72	1.44	0.652
		Post	10	109.0	136.0	116.30	8.04		
PM	Damon clear	Pre	9	99.0	135.0	114.00	11.25	-0.90	0.723
		Post	9	104	123	113.444	6.912		
	Clarity ultra	Pre	10	101.0	119.0	109.10	5.47	-0.55	0.898
		Post	10	92	120	108.2	8.053		
M	Damon clear	Pre	9	120.0	152.0	130.22	10.77	1.60	0.660
		Post	9	119.0	144.0	131.44	8.22		
	Clarity ultra	Pre	10	106.0	137.0	121.70	8.77	1.22	0.544
		Post	10	109.0	155.0	123.30	12.34		

Table 5: Comparison of the mean scores of iaw in maxilla using paired sample t test

IAW	Groups	Time intervals	N	Minimum	Maximum	Mean	S. D	Mean diff	p value
Canine	Damon clear	Pre	9	24.3	57.0	37.23	8.93	3.86	0.075
		Post	9	32.1	47.1	37.71	4.69		
	Clarity ultra	Pre	10	30.1	41.0	36.06	3.91	0.47	0.910
		Post	10	32.6	46.1	39.92	4.01		
PM	Damon clear	Pre	9	29.8	59.6	46.27	8.24	2.19	0.309
		Post	9	42.1	58.0	49.01	5.62		
	Clarity ultra	Pre	10	38.5	52.0	45.84	4.56	2.74	0.502
		Post	10	42.7	55.0	48.03	3.67		
M	Damon clear	Pre	9	33.4	83.7	65.61	14.57	4.64	0.026*
		Post	9	64.2	83.6	72.21	6.34		
	Clarity Ultra	Pre	10	62.5	74.8	69.18	4.80	6.6	0.323
		Post	**10**	**67.2**	**80.4**	**73.82**	**4.92**		

For arch width (AW) parameters in the maxilla, all regions including the canine, first premolar (PM1), second premolar (PM2), and first molar (M1) in both the Damon and Clarity groups demonstrated significantly higher post-treatment values compared to pre-treatment values, with the exception of the canine and M1 regions in the Clarity group. Notably, in the canine region of the Damon group, the post-treatment value (35.26 ± 1.29 mm) was slightly lower than the pre-treatment value (35.27 ± 1.76 mm), a difference that was nonetheless statistically significant ($p < 0.001$), as presented in **Table 3**.

No statistically significant differences were observed in any of the angular (ANG) measurements: canine, premolar (PM), or molar (M) regions within the maxillary arch ($p > 0.05$). In the canine region, the Damon group demonstrated a mean pre-treatment value of 120.22°, which increased slightly to 121.67° post-leveling and alignment. The 3M Clarity Ultra group showed a corresponding increase from 114.9° to 116.3°.

In the premolar region, the Damon group had a mean value of 114.0° at pre-treatment and 113.4° post-treatment, while the Clarity Ultra group decreased slightly from 109.1° to 108.2°.

In the molar region, the Damon group showed a mean angle of 130.22° pre-treatment and 131.44° post-treatment. The Clarity Ultra group increased from 121.7° to 123.30° over the same period.

All except Molar variable in the Damon group of the Inter apical width (IAW) parameter in different regions did not show a statistically significant difference (p>0.05) between pre and post treatment in the maxillary arch. In the molar region Damon group, the post treatment values (72.21 ± 6.34) were higher than pre-treatment values (65.61 ± 14.57) as seen in **Table 5.**

7. Discussion

Traditional 2D cephalometric analysis assesses skeletal relationships using craniofacial reference planes. Setting up a 3D coordinate system is crucial for accurate craniofacial skeletal structure evaluation. Head orientation and cranial reference planes are fundamental for cephalogram recording. 3D maxilla reconstruction provide clearer views for better identification and assessment compared to 2D methods.

This study compared Damon Clear System and Clarity Ultra bracket system cases using CBCT to assess volume, dental, and skeletal arch changes.

The study found significant inter-occlusal expansion in both arches with non-extraction treatment using Damon Clear and Clarity Ultra brackets. Damon cases showed greater changes, ranging from 1.8 mm at Molar ICF to 2.11 mm at PM2 in the maxilla. Clarity Ultra cases exhibited less significant changes, primarily in occlusal arch width.

Damon's philosophy aligns dental arches through posterior arch transverse expansion, aided by muscles like orbicularis oris and mentalis, reducing incisor anterior movement.[6,7] Studies consistently observe incisor proclination and advancement during crowding relief, particularly in non-extraction treatments without additional appliances.[8]

Looking into arch length in the current study, there was a statistically significant increase in the maxilla in all Damon cases. Arch length in the maxilla increased with statistical significance of 0.004. Arch length in the maxilla increased for both the 3M Clarity Ultra (maxilla: 2.24 mm) and Damon (maxilla: 3.08 mm, groups with changes in both groups being statistically significant. The study, therefore, does not support the claim that in Damon treated cases there is less tipping of the incisors as compared to 3M Clarity Ultra cases.[9]

Our findings contradict the belief that there's no variance in incisor proclination. The idea that Damon system reduces incisor advancement and proclination significantly was not supported in our study.

Gianelly[10] observed increased premolar and molar widths in non-extraction cases, but limitations in root position measurements hindered assessing expansion due to tipping or bodily movement.

Table 4 shows differing tooth angulations in Damon and 3M Clarity Ultra, though not statistically significant, suggesting less tipping and more bodily movement. Additionally, inter-apical widths were measured, revealing significantly more increase in Damon cases compared to 3M Clarity Ultra, indicating greater bodily movement in Damon cases.

Weinberg and Sadowsky, in their evaluation of multimodality non-extraction treatment, reported that transverse expansion was greatest at the second premolars (1.8 mm) and least at the canines (0.9 mm).[11] Consistent with their findings, the present study also demonstrated the greatest maxillary expansion at the second premolar (PM2) region. However, the region of least expansion varied between groups: in the 3M Clarity Ultra group, the canine region exhibited the smallest amount of expansion, while in the Damon group, the least expansion was observed in the molar region.

Atik et al.[9] compared three conventional systems in 46 patients with moderate crowding and class I malocclusion. Significant differences were found only in the distance between second premolars, while measurements between canines, first premolars, and first molars showed no statistical significance between the groups. Pandis et al. examined the width of the dental arches. In their study, the inter canine width was not significantly different after treatment, but the intermolar width was significantly different.[12] Similarly,

results of our study indicate significantly greater overall arch expansion in the Damon group during treatment in maxilla.

CBCT has limitations for analyzing alveolar bone thickness and volume. The voxel size and partial volume effect of CBCT can influence the accuracy of the measurement. In the maxilla, a line was drawn from opisthion to Anterior nasal spine (ANS) to standardize the slicing process and the slicing was done accordingly.[13-15]

Volumes of the maxilla were measured with consistent bone density across samples. Pre and post levelling CBCTs were superimposed for 3D reconstruction, calculating volume differences per patient. Maxillary volume significantly increased in both groups.

It's important to note that Damon Clear used CuNiTi wires, while Clarity Ultra used beta titanium wires. Damon Clear had wider arch wires, whereas Clarity Ultra had narrower ones. The wire material and size may have influenced arch expansion and study results. Additionally, patient age might have impacted bone remodeling, as younger patients typically experience faster tooth movement and remodeling, possibly leading to varied results between groups.

8. Conclusions

The study compared dental and skeletal changes during leveling and aligning with two self-ligation brackets.

Key findings were:

1. Both Damon Clear and Clarity Ultra groups showed significant arch length increase, with Damon Clear having a larger increase.
2. Both groups had arch width expansion in maxilla, with Damon Clear showing significantly greater expansion.
3. Damon Clear cases exhibited more bodily movement compared to Clarity Ultra cases based on inter-arch width changes.
4. Changes in inter-buccal and inter-lingual apical crown distances increased in both groups but were not significant.
5. In this study maxillary volume was increased in both the groups but with Damon system changes were significant.

9. Source of Funding

None.

10. Conflict of Interest

None.

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