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ORIGINAL ARTICLE

# Class I and Class II Patients Treated with Damon System: A Study of Transversal, Sagittal and Torque Values Variations

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**ABSTRACT**

**Objective:** To analyze the transversal and anterior-posterior changes obtained in patients treated only with the Damon system. **Material and Methods:** 51 patients with either class I or class II division 1 sagittal relationship treated with the Damon system and the same archwire sequence were retrospectively selected. Dental casts of each patient before (T0) and after treatment (T1) were scanned and analyzed using NEMOCAST 3D software. Inter-molar, inter first-premolar, inter-second premolar and inter-canine distances were measured in both upper and lower arches. Initial and final lateral cephalograms were traced using the OrisCeph program. Pre and post-treatment measurements were compared using the t-test for repeated measurements. The Pearson Correlation Index and Linear Regression Analysis were used to determine the dependence between continuous variables. The significance level was set at 0.05. **Results:** Transversal diameters in the upper arch increase statistically significantly, especially in the bicuspid area. Initial intra-arch diameter was the only statistically significant variable correlated with the final expansion obtained. A linear negative correlation between the initial latero-posterior torque and the final expansion was observed in both arches. **Conclusion:** Using identical arches in patients with very different initial characteristics, the changes in bicuspids' diameters remain the most predominant. Patients with initial more negative torque in the posterior region had a higher expansion amount.

**Keywords:** Orthodontics; Orthodontic Brackets; Malocclusion, Angle Class I.

## Introduction

In 1998, Dr Damon presented his low-friction system consisting of brackets (Damon SL) and high-tech wires [1]. The Damon SL is a low-friction self-ligating bracket with a dual configuration and a 0.022x0.028 slot that respects the basis of the straight wire technique described by Andrews, which can be used to solve different types of malocclusions [2].

It is claimed that using passive self-ligating brackets has the advantage of determining more expansion of dental arches if compared with other brackets [3,4] and removable appliances [5]. However, this statement is controversial in the literature. Indeed, if passive self-ligating and conventional brackets are compared, a statistically significant difference between the groups is found at intermolar width only, which is wider in the low-friction self-ligating cases [6,7]. The bracket placement has to consider the significant diversity in a number of clusters in the maxillary to have the information expressed [8].

Statistically significant changes in arch width were found in the first and second bicuspid areas (respectively + 3.6 and 4.3 mm) and molar areas (+ 1.8 mm) in patients treated with Damon low friction self-ligating brackets. These results are similar to those obtained with a rapid maxillary expander and fixed appliance [9].

Most recent studies have analyzed the transverse effects of self-ligating brackets using virtual models. A more accentuated dental expansion is observed mainly at the bicuspids level, for both maxillary and mandibular arches, with no statistically significant relapse, except for a tendency to restriction, especially in the most expanded region [10]. This effect is due to a vestibular inclination component, as it was observed that torque values are all significantly increased [11].

The objective of this retrospective study is to deepen the topic by analyzing the transverse and anterior-posterior changes obtained in the upper and lower arch of patients treated only with the Damon system. In particular, the following controversial aspects will be clarified:

1) What modifications are obtained using identical arches in patients with very different initial characteristics?
2) Is it possible to establish patients' initial characteristics that influence transversal changes?
3) Do patients with a more negative initial torque in the latero-posterior sectors expand more?
4) Given the hypothesis that the expansion with arches is due to an increase in torque values, is it possible to find a relationship between degrees and millimeters that can be used in the diagnostic phase?.

## Material and Methods

### Study Design and Ethical Approval

This retrospective study was reviewed and approved by Ethical Committee of the Post-graduate School of Orthodontics of the University of Ferrara and assigned number 2/2020.

### Sample Selection

From the archive of an orthodontic specialist, IBO certified, all patients in either class I or class II division 1 were selected. Exclusion criteria applied were: a) presence of crossbite; b) previous use of expansion device; c) mixed dentition; d) need of dental extractions; e) presence of impacted teeth; f) missing teeth due to agenesia; g) combined orthodontic-surgical cases; h) absence of complete initial and final record: orthopantomography, lateral cephalogram, digital models, extra and intra-oral photos; i) presence of tooth wear.

Patients treated with implants were excluded [12,13] to avoid any kind of influence on the final position of teeth. The sample size was determined according to a previous study. A minimum of 18 participants was needed to achieve an 80% power and a significance level of 0.5 [14].

Damon 3MX self-ligating brackets (Ormco Corporation, Orange, CA, USA) and Damon arch form were used with the same arch shape and size for all patients in both arches, an individual selection of anterior torque on the base of the initial crowding and the biomechanics needed. The archwire sequence was respected as follows:

- Alignment phase: 0.014 CuNiTi or 0.013 CuNiTi, then 0.016 CuNiTI in most crowded cases.
- Levelling phase: 0.014x0.025 CuNiTi.
- Working phase: 0.019x0.025 SS.

Dental Casts Analysis

Initial (T0) and final (T1) dental casts were analyzed by the same operator with the use of a digital caliper, recording transversal diameters in both arches: 6-6 distance, 5-5 distance, 4-4 distance, and 3-3 distance. All the measurements were taken from the apex of the vestibular cusps of these teeth (Figure 1). The Little's Irregularity Index was measured [15].

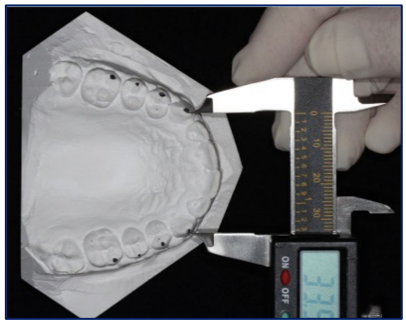

**Figure 1. Transversal diameters measurements on dental casts.**

Then, all dental casts were scanned using the Optical revEng Dental scanner (Open Technologies SRL, Brescia, Italy), maintaining the parallelism between the base and the occlusal plane, with a resolution of 1280x1024 pixels. The images obtained were then imported into the Nemocast 3D software (Nemotec, Madrid, Spain), which allowed us to acquire tip and torque values for each tooth, following the FA (facial axis) points and FACC (facial axis of the clinical crown) position according to Andrews' indication (Figure 2 A-C) [16].

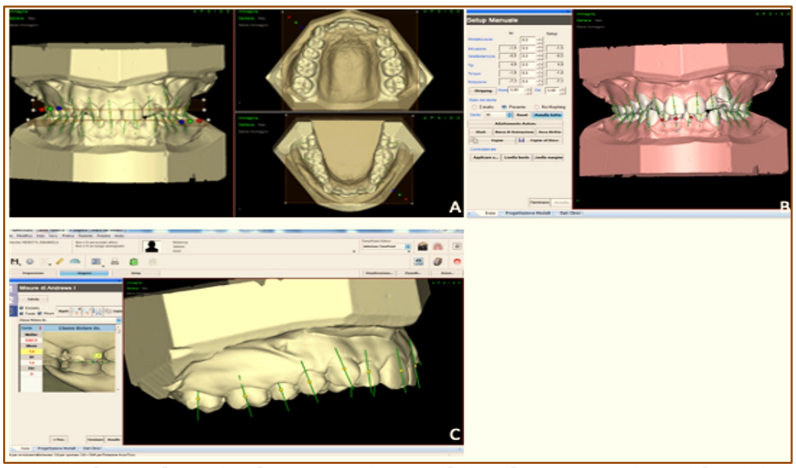


**Figure 2. A: The yellow dots identify the FA points, while the green lines identify the FACCs on the teeth' surface. FACC is the vestibular axis of the clinical crown; FA is the point on the FACC that separates the clinical crown's gingival half from the occlusal half; Andrew's plane is the surface or plane in which the mid-transverse planes of each crown are positioned when the teeth are in an ideal position. B: example of the procedure of In-out, tip and torque values calculation. C: lateral view of FAC points and FACC placement.**

Using the "grid" function, once oriented on the occlusal plane of dental casts, the upper and lower arch length were measured (Figure 3).

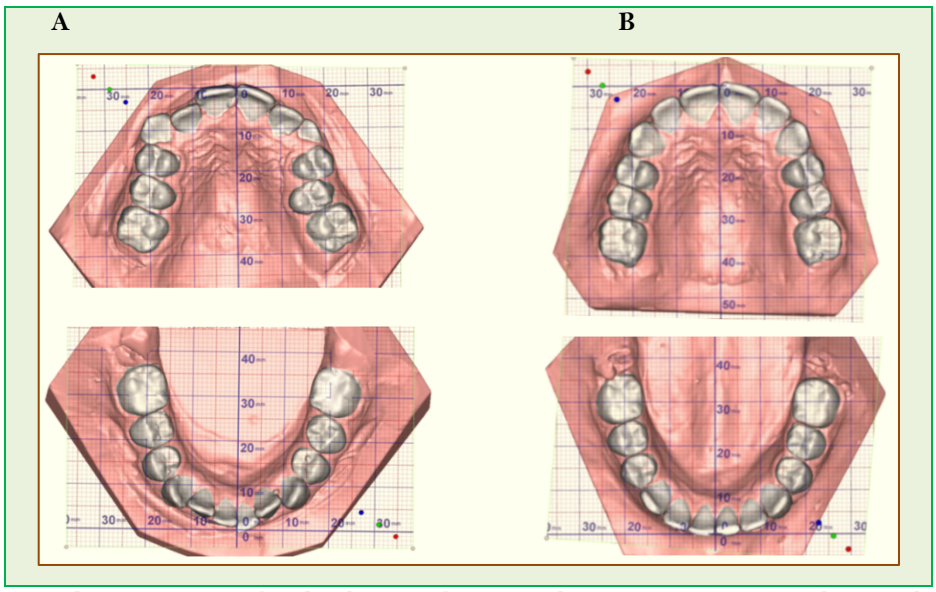


**Figure 3. Arch length measurement by the distance between the central incisors' midline and the transversal line connecting the first molars' distal margins. A: initial arch length; B: final arch length.**

Cephalometric Analysis

The cephalometric measurements were performed on the initial and final lateral cephalogram by the same operator with the OrisCeph program (Elite Computer Italia S.R.L., Vimodrone - Italia) (Figure 4). The following values were considered:

- ANB and Witts appraisal (millimeter distance between the orthogonal projection of point A and point B on the occlusal plane) for sagittal class relation identification;
- FMA (Frankfort mandibular angle);
- IMPA (incisor-mandibular plane angle);
- Upper incisor/Palatal plane.

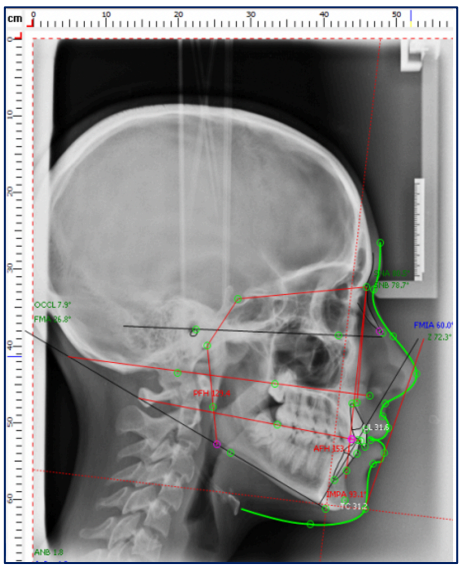

**Figure 4. Example of cephalometric tracing using OrisCeph program.**

Statistical Analysis

The method measurement error was calculated using the Dahlberg formula with repeated double measurements on 10 randomly selected cases. R software statistics program (R Core Team, 2014) was chosen. Descriptive statistical analysis was performed, calculating means and standard deviations of the measurements obtained. When pre and post-treatment measurements of the same subject were compared, the t-test for repeated measurements of paired samples was used. Otherwise, the Student's test for independent samples was used to compare the means of two groups, while Fisher's F ANOVA test was used when three independent groups were considered. The Pearson Correlation Index and Linear Regression Analysis were used to determine the dependence between continuous variables. To identify if some significant predictive factors exist among the candidate variables, a Regression tree analysis was used [17]. The significance level (p-value) was set at 0.05.

## Results

After applying the exclusion criteria, the final sample comprised 51 young Caucasians from the north of Italy (23 males and 28 females, mean age 14 years SD 6.94). Before treatment, eighteen of them were in dental class I, thirty-three in dental class II division 1, assessed through ANB value and the Witts index. The mean Little irregularity index was 5.9 mm in the upper arch (SD 3 mm) and 5.4 mm in the lower arch (SD 2.7 mm).

What modifications are obtained using identical arches in patients with very different initial characteristics?

All transversal diameters in the upper arch (6-6 diameter, 5-5 diameter, 4-4 diameter and 3-3 diameter) increase statistically significantly, especially at premolars' level. Even in the lower arch, all transverse diameters increase as well, and the average expansion of the inter canine diameter is 1.03 mm. Large variations in minimum and maximum expansion values are observed among patients (Table 1). Arch length decreases in the upper arch and tends to decrease in the lower arch. As long as the cephalometric analysis is concerned, IMPA angle has decreased from a mean value of 97.4° to 94.9°, while U1-PP angle has remained the same (Table 2).

**Table 1. Arch length and transversal diameters' mean variation after treatment in both arches.**

| Outcome | Variation (mm) | p-value | Minimum | Maximum |
|---|---|---|---|---|
| Upper arch length | -0.98 | 0.00 | -4.50 | +3.00 |
| 6-6 upper diameter | +2.68 | 0.00 | -2.57 | +7.77 |
| 5-5 upper diameter | +3.86 | 0.00 | -1.00 | +9.05 |
| 4-4 upper diameter | +3.36 | 0.00 | -3.05 | +8.81 |
| 3-3 upper diameter | +2.08 | 0.00 | -1.22 | +6.77 |
| Lower arch length | -0.32 | 0.07 | -4.00 | +3.00 |
| 6-6 lower diameter | +2.61 | 0.00 | -0.04 | +6.30 |
| 5-5 lower diameter | +3.11 | 0.00 | -0.42 | +7.12 |
| 4-4 lower diameter | +3.00 | 0.00 | -1.04 | +7.57 |
| 3-3 lower diameter | +1.03 | 0.00 | -0.70 | +4.14 |

**Table 2. Descriptive statistics of changes in IMPA and U1-PP before (T0) and after (T1) treatment.**

| Variables | T0 | | | | | T1 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | Mean | SD | Maximum | Minimum | Mean | SD | Maximum | Minimum |
| IMPA | 51 | 97.4 | 6.3 | 111.7 | 82.5 | 94.9 | 5.8 | 110.0 | 84.6 |
| U1-PP | 51 | 108.1 | 7.2 | 127.0 | 94.00 | 108.7 | 5.2 | 119.0 | 94.00 |

Torque variations for all teeth at the end of treatment is statistically significant (Table 3). Torque variation for pair of teeth was calculated by taking the average of the torque variation of the individual teeth (for example tooth 16) plus the average of the variation of the same contralateral tooth (tooth 26).

**Table 3. Torque variation between T1-T0 for single teeth and couple of controlateral teeth.**

| Upper Arch Torque | Variation° | p-value | Lower Arch Torque | Variation° | p-value |
|---|---|---|---|---|---|
| 16 Torque | +3.51 | 0.00 | 46 Torque | +5.00 | 0.00 |
| 15 Torque | +6.90 | 0.00 | 45 Torque | +7.58 | 0.00 |
| 14 Torque | +5.19 | 0.00 | 44 Torque | +8.06 | 0.00 |
| 13 Torque | +1.02 | 0.28 | 43 Torque | +4.64 | 0.00 |
| 12 Torque | +4.77 | 0.00 | 42 Torque | +5.41 | 0.00 |
| 11 Torque | +2.63 | 0.01 | 41 Torque | +5.38 | 0.00 |
| 21 Torque | +3.48 | 0.00 | 36 Torque | +4.98 | 0.00 |
| 22 Torque | +4.53 | 0.00 | 35 Torque | +6.49 | 0.00 |
| 23 Torque | +2.16 | 0.07 | 34 Torque | +5.56 | 0.00 |
| 24 Torque | +5.98 | 0.00 | 33 Torque | +4.94 | 0.00 |
| 25 Torque | +6.08 | 0.00 | 32 Torque | +5.40 | 0.00 |
| 26 Torque | +1.69 | 0.10 | 31 Torque | +4.68 | 0.00 |
| 16-26 Torque | +5.20 | 0.00 | 46-36 Torque | +9.68 | 0.00 |
| 15-25 Torque | +12.97 | 0.00 | 45-35 Torque | +12.98 | 0.00 |
| 14-24 Torque | +11.17 | 0.00 | 44-34 Torque | +13.00 | 0.00 |
| 13-23 Torque | +3.13 | 0.08 | 43-33 Torque | +10.20 | 0.00 |

Is it possible to establish patients' initial characteristics that influence transversal changed?

A regression analysis was done to find a relation between different diagnostic initial characteristics and the possible final expansion obtainable. The statistical analysis chosen allow us to verify if one of the following initial variables can determine a variation of the parameter Y (expansion):

- Upper and lower initial crowding index;
- Dental/skeletal sagittal class;
- Initial skeletal growth pattern;
- Initial intra-arch diameter (6-6 diameter, 5-5 diameter, 4-4 diameter and 3-3 diameter).

The regression and classification tree resulting from this analysis indicate that the initial intra-arch diameter is the only statistically significant variable correlated with the final expansion obtained. In the upper arch, if the initial 3-3 diameter is less than 32.68 mm, the final expansion will be about 3 mm; if higher, the final expansion will be about 1.5 mm. In the lower arch, if the initial 3-3 diameter is less than 24.61 mm, the final expansion will be about 2 mm, if less than 0.5 mm (Figure 5). The same trend was found for 4-4 diameter and 6-6 diameter. On the other hand, transversal final changes were not affected in any significant way by the initial 5-5 diameter.

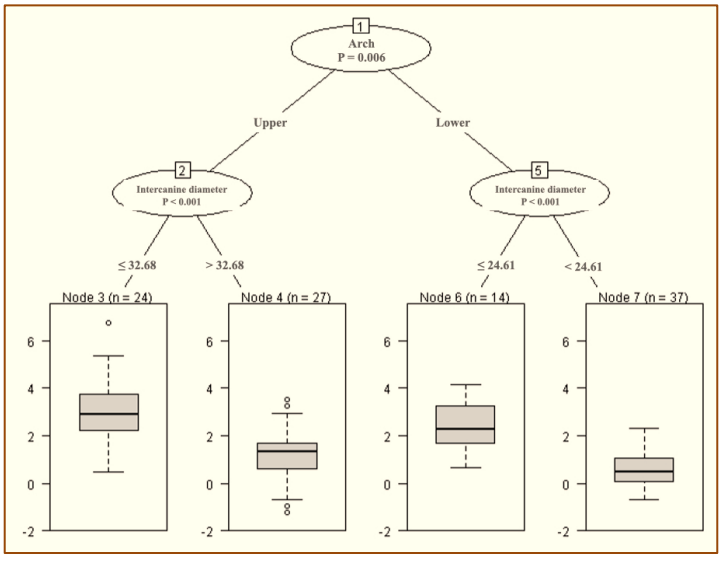


**Figure 5. Regression tree related to 3-3 diameter.**

Do patients with a more negative initial torque in the latero-posterior sectors expand more?

In both arches, we have found a linear negative correlation between the initial latero-posterior torque and the final expansion: this is more accentuated if the initial torque is more negative. COR is a number between -1 and 1 and it's the linear correlation index between the two compared parameters. If it is -1, there is a perfect negative linear correlation; that is, as one of the two parameters (expansion) increases, the other decreases in the opposite way (initial torque). We have found that the initial more negative torque are the less negative ones at the end (Table 4).

**Table 4. Correlation between the initial latero-posterior torque and the final expansion.**

| Initial Mean Torque | Arch | Cor | p-value |
|---|---|---|---|
| Initial Molar Torque | Upper | -0.09 | 0.36 |
| Initial Second Bicuspid Torque | Upper | -0.27 | 0.01 |
| Initial First Bicuspid Torque | Upper | -0.15 | 0.13 |
| Initial Canine Torque | Upper | -0.24 | 0.01 |
| Initial Molar Torque | Lower | -0.14 | 0.15 |
| Initial Second Bicuspid Torque | Lower | -0.25 | 0.01 |
| Initial First Bicuspid Torque | Lower | -0.19 | 0.05 |
| Initial Canine Torque | Lower | -0.24 | 0.01 |

Given the hypothesis that the expansion with arches is due to an increase in torque values, is it possible to find a relationship between degrees and millimeters that can be used in the diagnostic phase?

The variation of each diameter analyzed was correlated to the torque variation of the respective tooth pairs (Figure 6) (Table 5). A further statistical regression analysis was done (Table 5). A relationship between the increase in torque values and expansion for all diameters considered exists because the p-value results are always significant. The R2 values in Table 5 indicate that about 30% of the expansion can be explained by the torque variation for all diameters, except for the lower 4-4 diameter, which increases up to 50%.

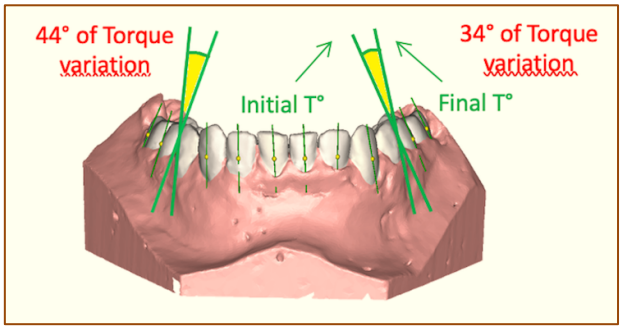


**Figure 6. Calculation of the torque variation after treatment using Nemocast 3D software.**

**Table 5. Delta torque coefficient.**

| Delta Torque *vs.* Delta Diameter# | Intercept | Delta Torque Coefficient | R2 | p-value |
|---|---|---|---|---|
| Upper 6-6 | 2.173 | 0.097 | 0.240 | 0.000 |
| Lower 6-6 | 2.370 | 0.025 | 0.055 | 0.099 |
| Upper 5-5 | 2.731 | 0.087 | 0.309 | 0.000 |
| Lower 5-5 | 2.161 | 0.073 | 0.247 | 0.000 |
| Upper 4-4 | 2.551 | 0.073 | 0.140 | 0.007 |
| Lower 4-4 | 1.384 | 0.125 | 0.505 | 0.000 |
| Upper 3-3 | 1.822 | 0.071 | 0.281 | 0.000 |
| Lower 3-3 | 0.526 | 0.050 | 0.321 | 0.000 |

#The intercept values and DeltaTorque coefficient are statistical values that derive from the application of this analysis to our sample; R2 is a strength index of a linear relation between 0 and 1 that explains the percentage in which the variation of torque is responsible for the expansion.

In the following graphs, the lines' slope indicates the angular coefficient (Delta torque coefficient): if the line's slope is greater, it means that a torque variation on the abscissa axis corresponds to a greater expansion on the ordinate axis (Figure 7).

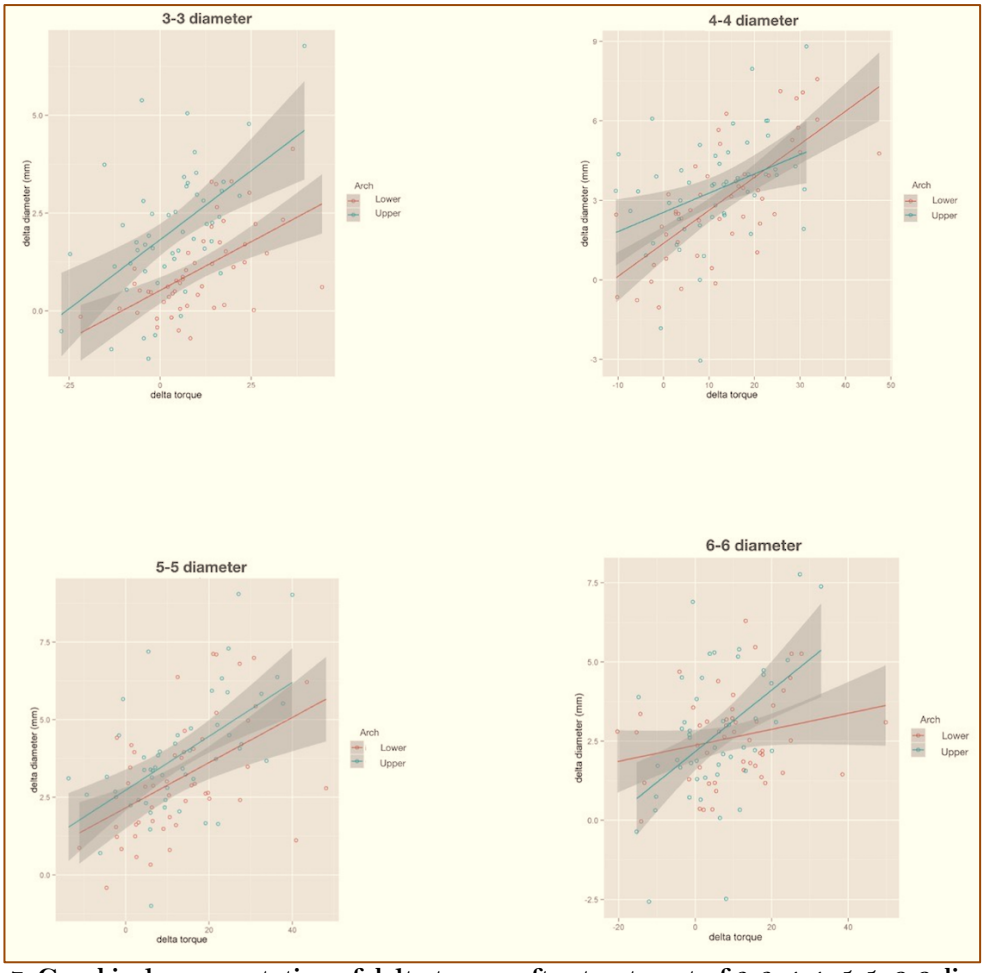


**Figure 7. Graphical representation of delta torque after treatment of 3-3, 4-4, 5-5, 6-6 diameters.**

The mean method's error was not significant ($p<0.05$), while the reliability coefficient confirms the validity of the method. Interclass correlation coefficient (ICC) for arch length, 3-3 diameter, 4-4 diameter, 5-5 diameter and 6-6 diameter was 1.00, meaning the measurements had a good reproducibility.

## Discussion

The above study shows that the patients treated with the Damon system underwent an upper and lower arch expansion, mainly at the bicuspids' level, which agrees with previous studies [18]. Cattaneo et al. [19] analyzed CBCT scans to assess maxillary transverse changes after orthodontic treatment with the Damon system. They confirmed that the greater expansion is always at the bicuspid level. In this case, the average increase of bicuspids' diameter is higher than in our sample (4 mm *versus* 3.36 mm).

To obtain a pure skeletal expansion in adult patients assessable by CBCT scans, a bone-borne expander has to be chosen [20-22]. The same dentoalveolar expansion is reported in the cases treated with clear aligners [23,24]. The average expansion of inter canine diameter is equal to 1.03 mm, in accordance with the modifications obtained with the other straight-wire techniques [25].

The maximum increase of 2 mm is recorded in cases with high initial crowding and very low torque, where a "straightening" of lingual inclined canines is recorded. The final mean torque values are higher if compared to the Andrews values. It is interesting to observe how the use of the Damon technique applied to different patients leads to different results: in subjects with normocclusion, slight or null misalignment, the transverse variations obtained are minimal. Even though the Damon system uses archwires with identical shape and size, we observed that different expansions are obtained if initial conditions change.

The data that emerged from a further statistical analysis state that the only variable which predominates over all the others is related to the initial intra-arch diameters: the arch wires expand more initially contracted teeth while the minor expansion occurs if initial diameters are greater. This result doesn't depend from other initial variables, like sagittal class relationship, growth pattern or crowding.

On the other hand, there is always a statistically significant relationship between expansion and increased torque values ($p<0.05$). The linear regression analysis indicates that, on average, only 30% of the final expansion is justifiable by the torque increase. Moreover, data are different in the upper and lower arches: we observe a greater Delta Torque in the lower arch compared to the upper arch.

Different works considered in a meta-analysis of 2013 [26] analyze the arch width of patients with initial characteristics similar to our sample with the same measurements' protocol [27]. A research was chosen that presented a study sample similar to ours by age, subdivision of malocclusion, absence of crossbite and which used the same references for the measurements of the arch diameters [27]. First of all, our sample shows reduced initial diameters with respect to the average values reported for classes I. The patients of our sample have an increased final diameter of about 2 mm at bicuspids' level compared to the values reported for classes I in the literature. However, it should be emphasized that the control sample was made up of females only, which have reduced transversal diameters compared to males [28,29]. It would be interesting to compare the passive play and torque expression in self-ligating brackets applied on the lingual or the vestibular surface [30-32].

A great limit of this study is the absence of a follow-up, so we miss long-term stability. It is reported that transverse expansion doesn't show any statistically significant relapse, but just a tendency of restriction due to the pressure of lips and cheeks [11,33]. However, stability is very different to reach: little's studies report that just 30% of orthodontic cases are stable at 10 years and drop to 10% at 20 years [34].

Additionally, a 40-year follow-up on dentoalveolar physiological changes in untreated subjects also demonstrates an increase in the mandibular Little irregularity index of 1 mm, a reduction in arch length in both maxillaries of 0.5-0.9 mm, and a reduction of the maxillary inter canine distance of 0.8 mm and mandibular of 1 mm [35,36].

Therefore, although Little's Irregularity Index was null at the end of treatment, it has to be considered that with the aging process, it tends to increase and relapse. Further studies may have the purpose of investigating the long-term follow-up to better understand these variations.

## Conclusion

Using identical arches in patients with very different initial characteristics, different expansions are obtained, but the changes in bicuspids' diameters remain the most predominant ones. Patients with initial more negative torque in the posterior region expand more. The initial torque influences the final expansion in a statistically significant way. It was not possible to find a degree-millimeter relationship: the increase in arch width is just in part due to an increase in torque values. Finally, the final transverse diameters tend to "normalize".

## Authors' Contributions

| | | |
|---|---|---|
| FC | https://orcid.org/0000-0002-4641-2196 | Conceptualization, Methodology, Formal Analysis, Investigation, Data Curation, Writing - Original Draft and Writing - Review and Editing. |
| DG | https://orcid.org/0000-0002-8211-9747 | Methodology, Formal Analysis, Investigation, Writing - Original Draft and Writing - Review and Editing. |
| EP | --- | Data Curation and Writing - Review and Editing. |

All authors declare that they contributed to critical review of intellectual content and approval of the final version to be published.

## Financial Support

None.

## Conflict of Interest

The authors declare no conflicts of interest.

## Data Availability

The data used to support the findings of this study can be made available upon request to the corresponding author.

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