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Chapter 4

Study of the Relationship of Smile Esthetics Between Torque and Dental Arch Width of Posterior Teeth in Orthodontics

Gaastra Carolin, Zamora Natalia, Paredes Vanessa, Tarazona Beatriz and Jose Luis Gandía

Additional information is available at the end of the chapter

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1. Introduction

There are different factors affecting smile aesthetics, with posterior dental torque and dental arch width as two of the most important ones [1-3]. Sarver et al.[4] affirmed that the orthodontic expansion of a compressed arch improved the smile transversal dimension, and that a wider arch shape in the premolar area resulted in lower buccal corridors and buccolingual inclinations of posterior teeth (or posterior torque) [4, 5].

There is few scientific evidence about the most favourable torque from an aesthetic point of view [5, 6], although it has been showed that the most appropriate one should extend up to the latest visible teeth in the smile. Therefore, a posterior torque close to 0º contributes greatly to this smile aesthetics. On the other hand, a negative torque in posterior sectors gives a compression appearance to the arch, with a negative effect on its aesthetics [6].

Torque can be defined from a mechanical point of view or from a clinical standpoint. From a mechanical standpoint, it relates to a structure torque through its longitudinal axis, resulting in the twist angle. Clinically, refers to bucopalatal or buccolingual inclination of the crown or root of a tooth, and is adapted explanation used to describe the rotation along an axial axis [7]. When applied to an interaction between an archwire and a slot of a bracket, it describes the activation generated when twisting an archwire in the slot of a bracket [7].

Preadjusted bracket systems allow the clinician preset torque values obtained directly from the information contained therein. Today there is a wide availability of brackets, and each of them has an individual prescription, according to the orthodontic technique followed.

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Sometimes these differences are minimal, sometimes the differences are greater. But it is known that all existing prescriptions currently available allow the brackets to get a negative coronal-palatine torque in posterior teeth [8], especially when the existing torque before treatment is remarkably negative [5].

According to authors such as Zachrisson [5, 6], to have a good occlusion there should not be a great difference between the molar and premolar lingual and buccal cusps. Hence, if posterior teeth present a high negative torque they would not allow a good posterior occlusion [5, 6]. As showed in Zachrisson [5, 6] research, a neutral posterior torque should be achieved, as it is a key factor for smile and face aesthetics. In accordance with the conclusions in the works of Zachrisson [5] and Badawi et al.[9], a negative torque in posterior sectors gives a compression appearance to the maxillary arch, as the crown inclination of this posterior superior area is a key factor for a bright and full smile [6].

2. Problem statement

Torque control is one of the weaknesses of the preadjusted bracket systems [6], and there is little data about what is the real capacity of the bracket systems to express the torque prescribed in brackets. Studies like Streva et al. [10] agree that the information that fails to express torque can exceed manufacturer estimated values by obtaining lower precision than expected. According Brauchli et al. [11] the time of treatment with high diameter archwires could influence the amount of torque expressed 6, but there are still no concrete data in the literature about this topic.

According Morina et al. [12] in self-ligating brackets torque is expressed in smaller amounts (up to seven times less) comparing with convencional brackets. However, these authors believe more importantly the use of a wire that completely fills the slot and have stiffness for proper expression torque [13]. Other authors have concluded in their studies that there are no clinical differences in the expression of torque between self-ligating brackets and convencional brackets [11].

Patient age and duration of treatment may be factors affecting the increase in the interdental widths and the final torque values, but there are few data in the literature to support this relationship.

On the other hand, some authors showed the added aesthetic value of wide smiles compared to narrow smiles [14, 15]. However, the ideal arch shape is not just one, as individual biologic diversity has an influence on it [16]. Some orthodontic techniques tend to increase dental arch width, which can cause instability (especially in intercanine and interpremolar areas), therefore it is recommended to individualize dental arches to their initial shape as possible [16].

Expansion due to orthodontic wires is dentoalveolar, and its effects are similar to those of the tipping described for quick expansion or disjunction [17]. This tipping movement implies that crowns in teeth of posterior sectors show a higher buccal inclination that at the beginning of the treatment. Authors such as Fleming et al. [18] observed that a higher increase in transversal

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expansion (0.91 mm more) occurred in cases with initial narrower arches [18]. This change in crown buccolingual inclinations of posterior teeth is a considering point when posterior neutral torques have to be achieved. However, few data referring to this concept can be found in the scientific literature.

Due to the lack of studies considering these aspects, the aims in our study where: firstly, to compare the tooth variation in torque depending on the type of bracket used among different bracket prescription techniques, and secondly, to compare the torque and arch width changes after orthodontic treatment, and to analyze the relationship between these changes with smile aesthetics.

3. Application area

A comparative, retrospective clinical study was carried out at the Orthodontics Teaching Unit of the University of Valencia, Spain from January to May 2012. This research was approved by the Ethics Committee on Human Research of the University of Valencia, Spain. Rights have been protected by an appropriate Institutional Review Board and written informed consent was granted from all subjects. The Helsinki declaration was considered and its guidelines were followed in our investigation. All patients agreed to participate in the study, even though the diagnosis material was gathered as part of their treatment protocol.

The present study is a cross-sectional observational human study and it has been conformed to the STROBE guidelines.

4. Material and methods

4.1. Sample

Two hundred and fifty patients attending the Orthodontics Department were randomly selected. Initial and final treatment plaster study models were available for all of them as part of their orthodontic records.

Inclusion criteria were as follows:

1. Permanent dentition from the first permanent molar, from one side to the other.
2. Absence of anomalies in number, size and dental shape.
3. Good quality of study models.
4. Patients previously treated with multibracket fixed appliances.

Exclusion criteria were:

1. Orthodontic treatment with extractions.
2. Use of two band expansive appliances through the treatment.

Subjects' age was not included as exclusion criteria, as it was initially supposed that it would not affect research results.

Of the initial 250 patients, a subsample of 76 was found to meet the described criteria.

The average age in the sample at the beginning of the treatment was 18.8 ± 8.8 years, ranging between 10.9 and 55.5 years. The average treatment length was 18.2 ± 7.0 months.

4.2. Material

Accordingly with the used orthodontic technique, the sample was divided in four groups (n=19): A, B, C and D:

Prescription A=brackets Victory® (3M Unitek©)

Prescription B=Tip-Edge® (TP Orthodontics©)

Prescription C=Smart Clip® (3M Unitek©)

Prescription D=Mini-Taurus® (Rocky Mountain©).

Bracket prescription for each of the techniques is showed in table 1. All brackets had a slot of 0.22 inches and the last used wire was a 0.021 x 0.025 inches stainless steel archwire. In all cases O-ring ligatures were used, except in technique C where the self-ligating system was applied.

TEETH	TECHNIQUE		
	A / C	B	D
Canines	0º	-4º	0º
First Premolar	-7º	-7º	0º
Second Premolar	-7º	-7º	0º
First Molar	-14º	-11º	0º

Table 1. Bracket prescription for each of the techniques of the study. Prescription A=brackets Victory® (3M Unitek©); Prescription B=Tip-Edge® (TP Orthodontics©); Prescription C=Smart Clip® (3M Unitek©); Prescription D=Mini-Taurus® (Rocky Mountain©).

The archwires in technique B are comparatively wider than the rest, particularly in the premolar area, and conversely, the technique D uses a narrower shape in the subsequent sectors. The archwires in A and C correspond to a form that could be considered intermediate between that of B and D.

4.3. Method

Occlusal and frontal photographs corresponding to the superior arch of all subjects were taken for the initial and final plaster study models (Figures 1 and 2). Initial and final plaster study models were cast through the same method, following the measures proposed by the Spanish Orthodontic Society (SEDO). Photographs were taken with a Canon EOS 400D camera, with

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a 100 mm Macro objective. A "ring" flash was used in order to avoid shadows in posterior sectors, and all the photographs were taken by the same operator.

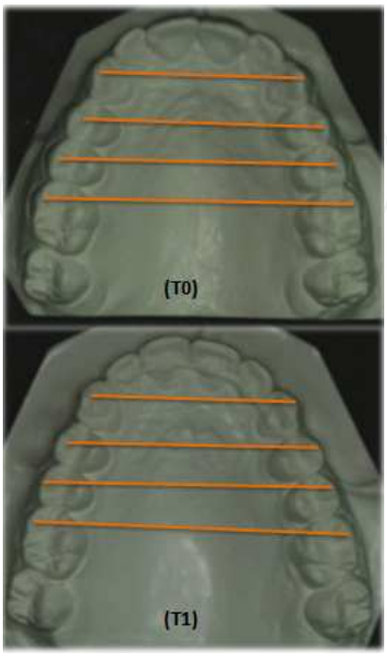


Figure 1. Dental arch widths (mm) in occlusal images of initial (T0) and final (T1) models.

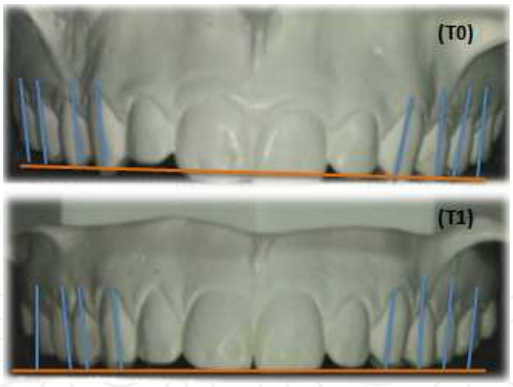


Figure 2. Initial (T0) and final (T1) torques (º) in both sides of canines, first premolars, second premolars and molars.

Occlusal images were used to measure intercanine, interpremolar and intermolar widths, whereas frontal photographs were used for the measuring of torques in bilateral posterior sectors. Images were taken perpendicularly to the ground, and a caliper was used for this purpose. A millimeter caliper was included in order to take scale measurements afterwards.

All measurements were carried out by the same operator (C.G). Interarch widths and torques for maxillary arches were measured before and after the treatment. T0 was assigned to values before treatment and T1 to values postreatment.

4.3.1. Occlusal photographs

Dental arch widths (mm) were measured in occlusal images of initial (T0) and final (T1) models (Figure 1):

- Intercanine width: distance between the cusp tips of bilateral canines.
- First interpremolar width: distance between the vestibular cusp tips of first bilateral premolars.
- Second interpremolar width: distance between the vestibular cusp tips of second bilateral premolars.
- Intermolar width: distance between mesiovestibular cusps of first bilateral molars.

4.3.2. Frontal photographs

- Initial (T0) and final (T1) torques (º) were measured by the same observer in both side of canines, first premolars, second premolars and molars (Figure 2).
- Parallel lines to the vestibular contour of the crown of canines, premolars and molars, going through the vestibular cusp and the highest point in the gingival margin visible from the frontal projection, were drawn in order to measure torques. Imaginary lines were designed to have a reference for the measurement of the different angles. The first line went through the mesiovestibular cusps of both first superior molars (right and left), and the second line, perpendicular to the first one, went through the centre of the papilla located between the two superior central incisors. The resulting angles in the intersection between the line going through the middle line and the crown axis previously described were measured with a Leone goniometer. Torque was measured with a positive, negative or 0º angle. Positive or negative values were assigned based on the clockwise or counterclockwise divergence of the lines. Whereas a 0 value was given when they were coincident or parallel. Angles were measured for both sides, right and left.

In order to estimate the measurement error and determine intraexaminer correlation, 5 cases of each bracket prescription system were randomly selected (a total subsample of 20 cases) and the main examiner repeated the measurements with an interval of two weeks after the first measurement. To estimate interexaminer correlation, 5 cases in each bracket system were randomly selected (a total subsample of 20 cases) and the same parameters described previously were measured with the same method by a second examiner (P.P). Both examiners performed the measurements blinded, without the knowledge of the examiners of each patient prescription.

4.3.3. Statistical analysis

The response variables in the research were: torques of the mentioned teeth (13, 23, 14, 24, 15, 25, 16, 26) and widths between pairs of teeth of the same kind (canines, first premolars, second premolars and first molars), measured before and after the treatment (T0 and T1).

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Model application hypotheses were verified: variance homogeneity (Levene and M-Box) and residuals normality (Kolmogorov test). Bonferroni test was used for multiple comparisons (post-hoc).

A general linear model (GLM) of repeated measures was developed to assess changes produced by the different techniques. A GLM of repeated measures was estimated for the variable chosen response. It was a mixed design (split-plot), including time as intrasubject factor, or of repeated measures (with 2 levels, T0 basal and T1 final), and technique as intersubject factor (with 4 levels).

For this MLG model, and considering a size of 0.25 (medium) in the effect to detect, the reached power was of 0.99 in intrasubject contrast and of 0.51 in intersubject contrast, with a confidence level of 95%. The linear correlation between torque variation and width was assessed through Pearson coefficient, whereas the assessment within each technique was performed through Spearman coefficient, due to sample reduction. Reference significance level was of 5% in all the analysis.

Through Kolmogorov-Smirnov test, all measurements, including T1-T0 differences, were shown to follow a normal distribution.

5. Results

5.1. Analysis intra and intersubjects

Intraexaminer and interexaminer errors are shown in Table 2 and 3.

Intraexaminer measurement error (d Dahlberg) ranged from 0.5 mm to 1.5 mm approximately in width measurements, increasing to ranges of 1.5º-3.0º for torques. Variability in measurement differences was higher in torques than in widths.

In interexaminer analysis, the measurement error (d Dahlberg) ranged from 0.8 mm to 2.0 mm approximately in width measurements, increasing to ranges of 2.0º-4.0º for torques. Variability in measurement differences was higher in torques than in widths.

	Intraexaminer			**Interexaminer**		
	Difference 1ª – 2ª measurement		**d Dahlberg**	**Difference measurements**		**d Dahlberg**
	Mean	**SD**		**Mean**	**SD**	
Torque 13 T0	-2,00º	2,53º	2,25º	-0,45º	3,43º	2,38º
Torque 13 T1	-0,35º	2,46º	1,71º	0,30º	3,37º	2,33º
Torque 23 T0	-0,70º	2,20º	1,60º	0,43º	2,74º	1,91º
Torque 23 T1	-1,20º	2,07º	1,66º	1,23º	2,90º	2,18º
Torque 14 T0	-0,45º	3,32º	2,31º	-1,85º	4,06º	3,09º

	Intraexaminer			Interexaminer		
	Difference 1ª – 2ª measurement		d Dahlberg	Difference measurements		d Dahlberg
	Mean	SD		Mean	SD	
Torque 14 T1	-0,10º	3,04º	2,10º	-2,20º	3,90º	3,11º
Torque 24 T0	-1,25º	3,13º	2,33º	-1,35º	5,36º	3,82º
Torque 24 T1	-1,25º	2,24º	1,78º	1,28º	2,78º	2,12º
Torque 15 T0	-1,30º	3,56º	2,62º	-1,53º	3,63º	2,73º
Torque 15 T1	-0,30º	2,32º	1,61º	-2,43º	4,49º	3,54º
Torque 25 T0	-1,55º	2,86º	2,25º	-1,45º	5,33º	3,81º
Torque 25 T1	-1,05º	2,44º	1,84º	0,35º	3,94º	2,72º
Torque 16 T0	-1,15º	4,00º	2,88º	-1,63º	3,57º	2,72º
Torque 16 T1	-0,85º	2,81º	2,03º	-0,95º	4,59º	3,24º
Torque 26 T0	-1,30º	4,13º	2,99º	-0,70º	5,66º	3,93º
Torque 26 T1	-1,55º	3,27º	2,50º	0,45º	3,53º	2,45º

Table 2. Intra and inter-examiner differences between torque measurements and D Dahlberg's method error in T0 and T1. All values are expressed in degrees.

	Intraexaminer			Interexaminer		
	Difference 1ª – 2ª measurement		d Dahlberg	Difference measurements		d Dahlberg
	Mean	SD		Mean	SD	
Canine width T0	-0,68mm	2,08mm	1,51mm	0,20mm	1,49mm	1,03mm
Canine width T1	-0,30mm	0,54mm	0,43mm	0,04mm	1,17mm	0,81mm
1st premolar width T0	-0,58mm	1,46mm	1,09mm	0,22mm	1,46mm	1,02mm
1st premolar width T1	-0,09mm	1,70mm	1,17mm	0,33mm	1,23mm	0,88mm
2nd premolar width T0	-0,38mm	2,08mm	1,46mm	0,60mm	1,00mm	0,81mm
2nd premolar width T1	0,42mm	1,49mm	1,07mm	0,79mm	1,30mm	1,06mm
1st molar width T0	-0,20mm	2,48mm	1,71mm	2,39mm	0,96mm	1,82mm
1st molar width T1	-0,33mm	0,76mm	0,57mm	1,65mm	2,26mm	1,95mm

Table 3. Intra and inter-examiner differences between width measurements and D Dahlberg's method error in T0 and T1. All values are expressed in mm.

5.2. Torque changes from T0 to T1 depending on the technique

The average difference between T0/T1 was estimated as main result in patient torque variation through the treatment. Success in treatment was defined as achieving a close value to 0º torque or achieving a 0º torque value. Maintaining a stable torque from T0 to T1, invariable, was also considered for measuring the success rate.

Depending on the initial torque values at T0, the classification of the improvement in torque variation would be achieved as follows:

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- Achieving a negative torque value close to 0, when higher negative values were measured at T0 (e.g. from-5º (T0) to-2º (T1)).
- Achieving a positive torque value close to 0, when higher positive values were measured at T0 (e.g. from 5º (T0) to 2º (T1)).
- Depending on the initial torque values at T0, the classification of the worsening in torque variation would be achieved as follows:
- Achieving a negative torque value away to 0, when lower negative values, closer to 0, were measured at T0 (e.g. from-2º (T0) to-5º (T1)).
- Achieving a positive torque value away to 0, when lower positive values, closer to 0, were measured at T0 (e.g. from 5º (T0) to 2º (T1)).

Results can be observed in Figure 3.

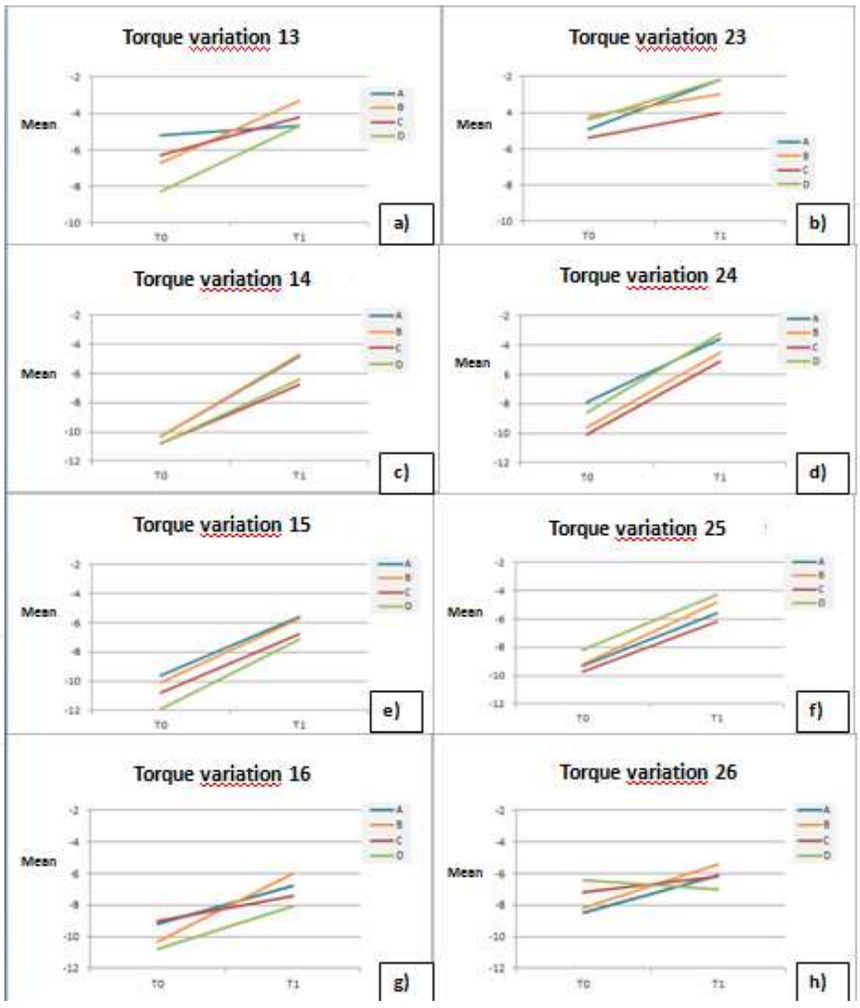


Figure 3. Maxillary torque changes between T0 and T1 depending on the technique. a) and b) left and right canine torque variation; c) and d) left and right 1st premolar torque variation; e) an f) left and right 2nd premolar torque variation; g) and h) lenf and right 1st molar torque variation.

5.3. Dentoalveolar maxillary width changes between T0 and T1 depending on the technique

Figure 4 shows the variation in width changes of the different posterior tooth analyzed (canines, 1st premolars, 2nd premolars, 1st molars) according to the technique used.

In the region of canines with techniques C and D there were no changes from T0 to T1 ($p > 0.05$); we found, though, changes in techniques A and B.

The increase in width at first premolars was significant from T0 to T1 ($p < 0.001$), but not of the same magnitude in all techniques ($p < 0.001$). In technique D the change was of low magnitude. In the region of second premolars, there was an increase in the width ($p < 0.05$) with all techniques. Finally, with respect to the width of the first molars, differences between T0 and T1 ($p < 0.0019$) in all techniques except technique D ($p = 0.149$, Bonferroni) were observed.

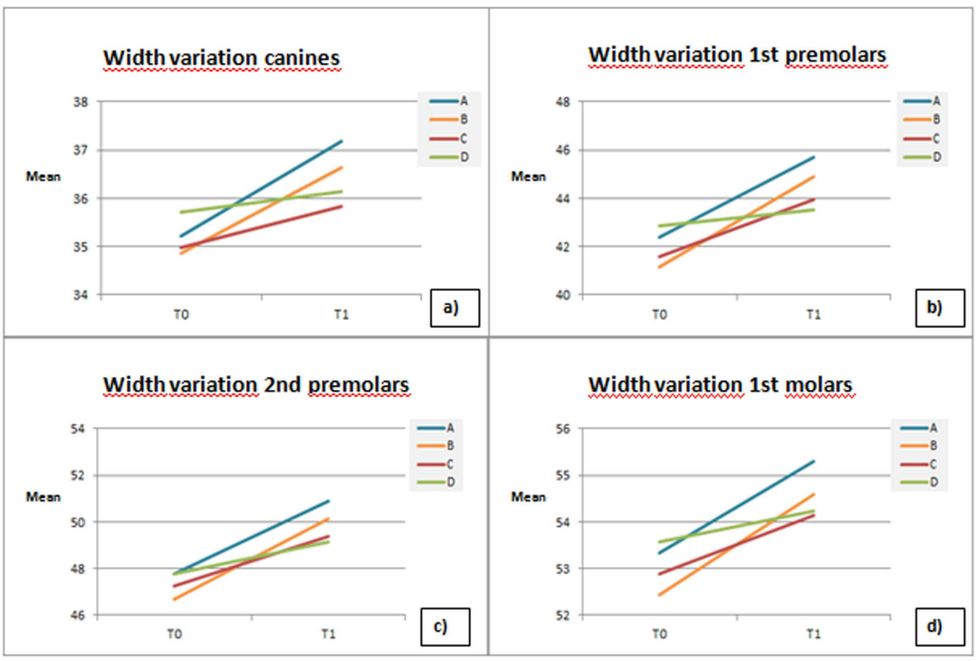


Figure 4. Dentoalveolar maxillary width changes between T0 and T1 depending on the technique. a) Canine width variation; b) 1st premolar width variation; c) 2nd premolar width variation; d) 1st molar width variation.

5.4. Relationship between torque and width variations between T0 and T1 depending on the technique

Table 4 shows the relationship between torque variation and the different interdental widths.

Correlation between torque changes and widths can also be observed in Figure 5 (a,b,c,d).

It also was determined whether these correlations are maintained within each of the techniques. When calculating correlations in small samples (n=19) is preferable to use the nonlinear coefficient of Spearman (table 5)

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	Width variation 1st premolars	Width variation 2nd premolars	Width variation 1st molars	Width variation canines
Torque variation canines	n.s.	n.s.		<0,001 (r=0,436)
Torque variation 1st premolars	<0,001 (r=0,392)	0,002 (r=0,352)	0,001 (r=0,363)	0,049 (r=0,226)
Torque variation 2nd premolars	0,023 (r=0,261)	<0,001 (r=0,399)	0,004 (r=0,330)	0,350 (r=0,109)
Torque variation 1st molars	0,008 (r=0,304)	0,048 (r=0,227)	0,011 (r=0,290)	n.s.

n.s. non significant

Table 4. Lineal correlation between torque and width variation (r Pearson's coefficient)

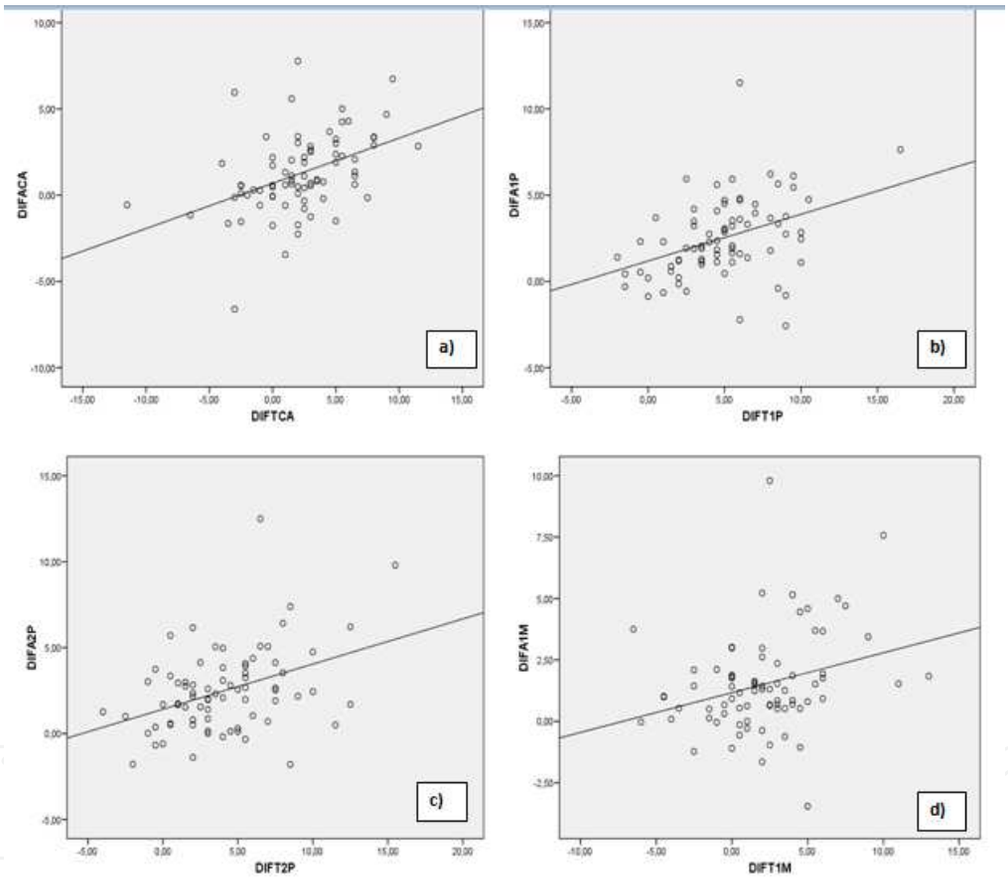


Figure 5. Relationships between changes in a) intercanine widths (DIFWCA) and torques in canines (DIFTCA), b) 1st interpremolar widths (DIFW1P) and torques in 1st premolars (DIFT1P), c) 2nd interpremolar widths (DIFW2P) and torques in 2nd premolars (DIFT2P) and d) 1st intermolar widths (DIFW1M) and torques in 1st molars (DIFT1M), respectively.

Correlations between torque and witdh variation were found to be frequent for A and B techniques, lower for C and almost insignificant for D technique. The strongest correlation between torque variation and width was found in the canine area, with the C prescription technique. Correlations were also detected at first premolar and canine areas for subjects treated with B technique.

TECHNIQUE		Width variation 1st premolars	Width variation 2nd premolars	Width variation 1st molars	Width variation canines
A	**Torque variation 1st premolars**	0,043 (r=0,468)	n.s.	0,036 (r=0,484)	0,006 (r=0,605)
	Torque variation 2nd premolars	n.s.	n.s.	0,015 (r=0,551)	n.s.
	Torque variation 1st molars	0,043 (r=0,469)	n.s.	0,019 (r=0,531)	n.s.
	Torque variation canines	n.s.	n.s.	n.s.	n.s.
B	**Torque variation 1st premolars**	**0,001 (r=0,676)**	**0,002 (r=0,673)**	n.s.	n.s.
	Torque variation 2nd premolars	0,035 (r=0,485)	0,005 (r=0,614)	n.s.	n.s.
	Torque variation 1st molars	n.s.	n.s.	n.s.	n.s.
	Torque variation canines	**0,003 (r=0,643)**	0,049 (r=0,456)	n.s.	0,034 (r=0,488)
C	**Torque variation 1st premolars**	n.s.	0,039 (r=0,478)	0,005 (r=0,613)	n.s.
	Torque variation 2nd premolars	n.s.	n.s.	n.s.	n.s.
	Torque variation 1st molars	n.s.	n.s.	n.s.	n.s.
	Torque variation canines	n.s.	n.s.	n.s.	**<0,001 (r=0,792)**
D	**Torque variation 1st premolars**	n.s.	n.s.	n.s.	n.s.
	Torque variation 2nd premolars	n.s.	n.s.	n.s.	n.s.
	Torque variation 1st molars	n.s.	n.s.	n.s.	n.s.
	Torque variation canines	0,043 (r=0,469)	n.s.	n.s.	n.s.

n.s. non significant

Table 5. No lineal correlation between torque and width variation. (Spearman´s Rho Coefficient)

6. Further research

It has been shown that proper torque should be extended to the last visible tooth when smiling [5, 6], reason why in this research the torque from the canine to the first molar has been studied.

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In this work, no cases previously treated with extractions in the maxillary arch were included, due to the controversy of the impact of dental extractions and their possible effect on the final aesthetic result [6, 19-22]. Therefore, a possible bias was eliminated.

The initial torque before and after treatment in different orthodontic techniques was measured. We chose to use pictures because it was intended to measure the coronal torque or 'apparent' torque that is seen when the patient smiles and not the 'real' torque, which corresponds to the angle between the long axis of root with a horizontal reference axis. Coronary torques were measured with the aim of observing whether these tend to approach a neutral value (close to 0 degrees) or, conversely, if the torques were kept still negative values after treatment in any of the techniques.

All measurements were taken from photographs of plaster models carried out before and after the orthodontic treatment. All the images were taken with the same camera, parallel to the same horizontal plane, with the same light conditions, and with the plaster models correctly positioned. However, intra and interexaminer errors have been detected, especially in torque measurements. This could be due to the lack, in frontal photographs, of clear reference points marking the line of the dental crown buccolingual axis.

Intraexaminer analysis determined that values were higher in the second round of measurements, both in torque and width. Variability in measurement differences was higher in torques than in widths.

In interexaminer analysis, no observer measured systematically more than the other. The measurement error (d Dahlberg) ranged from 0.8 mm to 2.0 mm approximately in width measurements, increasing to ranges of 2.0º-4.0º for torques. Again, variability in measurement differences was higher in torques than in widths.

6.1. Analysis of T0 to T1 changes in torque according to the technique

The differences between T0 and T1 as a result of variation of torque of the subjects during treatment were calculated. Treatment success was defined as the approximation of zero torque values without being positive.

Changes in torque were assessed as favorable when they went from a negative value to a less negative value or ideally zero. Not sought to find positive values, but close to zero or neutral. For example, the difference in degrees of a tooth torque when going from-5º to-1 º is 4º, the same as a tooth that go from-2° to+2º, or from 0º to+4º. However, not all situations are reflecting the same degree of success.

Three possible scenarios regarding the evolution of torque were defined: Favorable, unfavorable or stable. The favorable situation was the one in which the torque went to values close to zero, either from a situation with negative torque or (less often) positive torque. The stable situation was the one in which the torque did not varied, and the unfavorable was that in which the torque went away from zero, either from negative values or from positive values.

In the results, rarely the torques of the posterior teeth were 0º absolute value, but a remarkable tendency to obtain torque of 0 ° was observed in all teeth, especially the premolars (78-85% for

premolars, 60-70% for canines and between 63 and 73% for molars), which according to Zachrisson [5] is favorable for obtaining an aesthetic and functional smile [5,6]. Despite this overall improvement, there was significant variation in the final torque values when analyzed between techniques and within each of them, which is consistent with that observed by authors like Streva et al. [10] or Brauchli et al. [11].

Watching the torque of canines, most experienced a favorable outcome, they tended to evolve after treatment at values closer to 0 ° Specifically, techniques C and D showed a higher percentage of improvement, and techniques A and B the least. However, the technique B obtained the average torque values closest to 0 degrees. For cases that evolved unfavorably, the technique that showed fewer incidences was the technique B. With technique A no improvement in torque in this tooth was detected. After assessing the evolution of the torques of the canines in the four techniques, we can add that there is no statistically significant difference between the four techniques. However, we can see that there is no symmetry between the two sides in the case of canines.

At first premolars, in more than 80% of cases the torque from both sides improved. In these teeth a more homogeneous relationship between sides was observed, and all techniques improved significantly their torque. However, these differences were not statistically significant, although that it could impact clinically. The technique B obtained average values closer to 0 ° torque at end of treatment, and it was obtained more positive values of torque. Observing the evolution of the torque in the four techniques, techniques A and B showed higher percentages of improvement. Statistically, it was observed that all the techniques worked well with the torque of the premolars. The homogeneity in the results was significantly higher than for canines.

In the case of the second premolars, in about 80% of cases the techniques favorably modify the torque getting very obvious way. Again, not statistically significant differences between techniques regarding the improvement of the torque were found, and the situation is similar to that shown above. Although not statistically significant, a difference in the average torque at end of treatment was proven, and technique C presented the more negative torques.

In the case of the first molars, around 63% and 73% of patients showed improvement of torque in these teeth in the left and right side, respectively. As with the other teeth, the torque variation was significant during treatment. In general, we observed that the four techniques managed to improve the torque of the first molars but no statistically significant differences between techniques were found. However, in this case, differences which could have clinical significance were also observed. The technique B was the one that showed less negative torques at the end of treatment in these teeth, despite having very negative torques prior to treatment. Technique D presented the lowest percentage of improvement (50-57%).

It was also studied if the variation value of torque experienced by a particular tooth was similar to that of the contralateral. It was observed that the buccolingual inclination of the crowns were not symmetrical in most cases, however, the statistical results obtained allowed to conclude that the average change in torque on either side could be considered similar. The largest discrepancy occurred in the molars, but without being statistically significant. Despite not

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showing statistical significance, these differences between the two sides could itself have clinical significance, because they may affect the final aesthetic smile of the subjects. As suggested by Zachrisson et al. [5, 6] for optimal smile aesthetics, a normal canine of the maxillary arch should have a slight symmetrical lingual inclination and the first and second premolars should be straight and show also symmetrical torques [5,6]. Authors like Hulsey et al. [23] showed that attention must be paid to asymmetric variables, since alterations in symmetry negatively affect the aesthetics of the smile [23]. As has been explained above, the torque values of both sides were not uniform in many cases, indicating that preadjusted brackets systems do not meet the purpose of symmetry in many cases, although the same information on both sides is contained.

This diversity of results in torques could be explained by the presence of multiple factors that have influenced this research and are difficult to control in a clinical context. It should be remembered that this is a retrospective study, so there are treatment variables that could not be controlled. As Zachrisson [6] said, torque control is one of the weaknesses of the preadjusted bracket systems [6]. And, as many authors have suggested, the expression of torque is the result of interaction of many factors [9, 11, 24]. In this research, variables, such as individual biological variation, the deformation of the slot of the bracket during treatment, the amount of resin between the bracket base and the tooth, possible defects in wires and brackets or the starting torque of the posterior teeth, could not be controlled.

It is known that expression of the torque is achieved by filling the slot of the bracket and progressively increasing the size of the wires during treatment (wires sequence) [9]. In this study, all cases were applied a progressive increase in the sequence of archwires used during treatment. Initially, Nickel-Titanium wires of small-caliber were used, followed by intermediate wires of medium caliber and finishing with stainless-steel wires that filled completely the slot of the bracket. However, in this study the amount of time these arches remained in the mouth of the patient was variable and indefinite. According to authors like Brauchli et al,[11] the amount of time of treatment with high diameter arches as well as the materials used could influence the amount of expressed torque in teeth [11]. In all cases of the present study, the material of the bracket and the wires were the same.

Although the brackets in technique C contain the same torque information that in technique A, different results were obtained with both techniques. The observed differences could be due to the bracket ligation. While technique A uses is a conventional bracket ligation method (Victory®) technique C uses a passive self-ligating bracket (Smart Clip®). This confirms what suggested Morina et al. [12] or other authors as Huang et al. [25] about the different expression of torque depending on the way of the bracket ligation method.

Some authors like Badawi et al [9] observed that passive self-ligating brackets (such as technique C) got a lower expression of torque than their counterparts: active self-ligating brackets [9]. Other authors have demonstrated the absence of such relationship, stating that the basic system of self-ligation did not influence clinically the expression of torque [11]. Therefore, one might assume that if active self-ligating brackets were been used, the final torque would have been similar to that obtained with brackets of technique A (conventional ligatures). However, we do not have enough data to support this claim.

Observing the results, and coinciding with authors like Archambault et al. [7], one could assume that it is difficult to predict the final torque to be obtained at the end of treatment only from a certain system of brackets.

6.2. Analysis of T0 to T1 changes in twidth according to the technique

At this point, the differences obtained in the width between the two times T0 and T1 and the dependence of the technique used were analyzed. Techniques A and B showed significant changes from T0 to T1 in the interdental width of posterior teeth analyzed, B being the most, while technique D showed no significant changes in intermolar or interpremolar widths. This coincides with the different archforms used. In technique B, the archwire was the widest of the four techniques. Instead, in technique D the archwire was the one that least width presented.

6.3. Correlation between torque changes and widths

A general correlation between torque variations and widths was found. These relationships were direct, with a higher torque variation meaning a higher width variation.

Correlations were found to be frequent, especially for techniques A and B, lower for technique C and almost disappeared for technique D. Therefore, in this last technique (D), torque variation was completely independent from width variation, whereas with techniques A and B, torque variation could be considered dependent on width variation. With technique B, the achieved width in premolars and canines allowed a good prediction of torque variation in these teeth.

At the end of the treatment, a general direct relationship between width change and torque change was detected. This implies that higher expected width changes will mean a higher change in posterior torques into close to neutral values. No literature supporting this observation has been found, but it could open new research lines.

A direct relationship between the level of performed dentoalveolar expansion and the achieved negative torque reduction has been shown. This was specially visible at premolar level where, according to Zachrisson[5,6], the torque must be closer to 0º. It could be inferred from these results that a way of changing the initial negative torque would be by incrementing the interpremolar width dentoalveolarly. However, there is not scientific literature to date relating maxillary width variation with final torque value.

The tipping movement described for quick expansion or disjunction [17,11] implies that dental crowns in posterior sectors present a higher buccal inclination at the end of treatment than at the beginning of the treatment. This could be one of the causes explaining the previously described relationship. Therefore, it can be concluded that the use of wires to achieve a dentoalveolar expansion in posterior sectors would help in getting a neutral torque in these sectors. Specifically, with technique B, at the end of treatment, the relationship between width gain and torque change close to 0º was higher than with the other techniques, especially in the premolar area, where a higher trend to neutral torque and a higher expansion could be

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observed. In accordance with authors such as Fleming et al.[18,12] and the findings in this study, in cases with a higher dentoalveolar compression, the gain of close to 0º torque could also be higher.

As described by Sarver et al.[4], treatment with ovoid or expanded arches should increase maxillary width and promote neutral torques in posterior sectors, and thus cause an aesthetic improvement. However, it has to be noted, that works of authors such as Mutinelli et al.[25,17] showed that the original width should be kept in order to achieve a long term stability of the orthodontic treatment. Accordingly to these authors, an arch shapes assessment prior to the orthodontics treatment is essential to choose the most appropriate arch shapes[25,17].

In our study, in cases treated with technique D, torque changes were found to be completely independent of width changes. Through the results, it can be observed that with this technique the change in final width was low, especially in the molar area. From these results, it can be inferred that the torque achieved at the treatment end was mainly related with the torsion forces applied individually to the wire in each posterior tooth, and not with the expansion. In such cases torque could be individualized by bending the wires, and an appropriate torque was achieved for each individual.

Thus, it can be concluded that the highest torque change is not only caused by the fact of filling the slot completely, as stated by Brauchli et al.[11,18], but also by the use of a strong and rigid wire that can generate a greatest dentoalveolar expansion. Therefore, with a tipping movement a negative torque becomes closer to 0º simply by changing the dentoalveolar width.

Considering the great variety in torque level of expression in posterior maxillary sectors found in literature and in the present study, it could be inferred that torque present in the different bracket system is irrelevant, and that the individualization of cases in order to achieve an appropriate torque close to 0º in posterior sectors would be more recommendable. Securing an ideal arch shape applying the appropriate torsion in each case would help in the achievement of neutral torques at the end of treatment.

7. Conclusions

Conclusions derived from our study are:

1. The four orthodontic techniques (A, B, C and D) showed a reduction on posterior dental torque with the orthodontic treatment, although this reduction is not related to the prescription used.

2. Between 70 and 90% of the subjects achieved an improvement in the value of torque in first and second premolars. These ratios decrease for canines and first molars.

3. The results in reducing the torque are not significantly different according to the technique used. The type of treatment hardly influenced the quality of the correction.

4. Increases occurred in the widths of the maxillary arches after treatment were related to improvements to neutral torques (to values closer to 0º), especially in subjects treated with the A and B techniques. In technique D no such relationship was observed.

Author details

Gaastra Carolin, Zamora Natalia*, Paredes Vanessa, Tarazona Beatriz and Jose Luis Gandía

*Address all correspondence to: natalia.zamora@uv.es

Department of Orthodontics, Faculty of Medicine and Dentistry, University of Valencia, Valencia, Spain

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