Torque expression of a customized lingual appliance according to different elastomeric ligatures over time: an *in vitro* study

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Summary

***Aim*: Torque control in lingual orthodontics is essential to obtain optimal aesthetic results, nevertheless three dimensional control of anterior teeth depends on many factors and the role of ligatures in establishing the engagement of the wire into the slot is considered as a key point. The aim of this *in vitro* experimental study was to evaluate how different ligatures exposed to usage degradation perform in maintaining torque control in a customized lingual bracket appliance using two differently sized wires.**
***Materials and methods*: A typodont with eight extracted human teeth was created and a set of customized lingual brackets was obtained. Lingual ligatures and ordinary ligatures were tested on the 0.016x0.022 NiTi and the 0.016x0.024 SS wires using a compression/traction machine to calculate the efficiency in torque control. For each wire and type of ligature, the typodont was stored in physiological saline Sodium- Chloride 0.9%, pH 5.5 to simulate the oral environment for one month and then the mechanical test was repeated. A statistical analysis was performed.**
***Results*: No significant differences were found in angle values between ligatures or timepoints when the complete set of data was tested (p>0.01).**
***Conclusions*: The ligature type and stretching by use did not affect torque efficiency during the first month.**

Key words: orthodontics, torque, efficiency.

Introduction

The demand for an aesthetic orthodontic treatment has increased and more attention has been payed to “invisible” orthodontic techniques, such as clear aligners and lingual orthodontics. Lingual orthodontics is a reliable option for clinicians who want to fully accomplish therapeutic targets, because of the possibility of treating every malocclusion the same as the labial approach, from extraction cases to orthognathic patients, and other nonextraction treatments (1, 2).
The functionality and the aesthetics of the outcome are achieved by three-dimensional control of teeth during all the phases of the therapy; this control is particularly important for upper anterior teeth and it is obtained by using biomechanics that are different from the labial technique. In fact, in lingual orthodontics biomechanical changes are due to a different application point of the force, which affects the vertical position of teeth. Particularly, in all extraction cases, the space closure can determine considerable problems in incisors inclination.
Torque expression is affected by many factors, including the bracket position, the size of the wire, the alloy of the wire, the friction between the wire and the brackets, the tensile properties of + different elastomeric ligatures and the procedures adopted to manage third order movements (3-6). The effect of force decay on elastomeric ligatures is important as well, because the engagement of the wire into the slot determines the force which is transmitted to the tooth and the degradation of ligatures could make this engagement sub-optimal at some stage.
Force decay of elastics and ligatures is not an unknown effect in orthodontic practice: patients are recommended to daily change orthodontic elastics and doctors are invited to establish an initial force with about 8 to 14% of compensation above the force for the desired movement, because of the significant force degradation presented during the first twelve hours by most products (7). The force delivered by

elastomeric chains decays rapidly over time as well, with consequences on their mechanical properties and clinical efficacy (8-10).
However, a limitation of many *in vitro* studies on this subject is that they are based on measurements of the force and of the extension of ligatures which are stretched until rupture (11, 12), whereas a better clinical simulation may be obtained by focusing on how the ligature influences the behavior of the entire slot-wire system. The measure of torque moment is a feasible laboratory observation and represents an outcome which is strongly related to the appliance performance.
The aim of the present study was to evaluate how different ligatures exposed to usage degradation perform in maintaining torque control in a customized lingual bracket appliance, using two different wire sizes.

Methods

Typodont

Eight extracted human teeth were collected: a central upper right incisor, two upper lateral incisors (right and left), two upper canines (right and left), two upper first bicuspids (right and left) and one upper second bicuspid (left). All teeth were carefully cleaned with ultrasonic and manual instruments, disinfected with hydrogen peroxide and stored in physiological saline Sodium-Chloride 0.9%, pH 5.5 in order to avoid dehydration, elasticity loss, and to prevent the risk of fractures.
Transparent metil-metacrylate components (Orthojet, Lang. Wheeling, IL 60090 USA) were carefully mixed not to produce air bubbles and then poured into a 100 mm X 35 mm X 25 wax box (Tenatex Red, Kemdent. Purton, Swindon Wiltshire, UK) to create a resin base where the teeth could be accommodated. The resin was cured in a curing water machine (30°C, 6 atm).
Then the lateral surface of the resin block was dug over with a denture bur in a straight handpiece, and once enough space had been created, the teeth roots were put along a straight line in the pit and encased in fluid transparent resin (metil-metacrylate). The teeth were not positioned along the natural shape of the arch, but in a straight line, in order to study the mechanical properties of the system. The crowns emerged from the resin and presented a contact point with each adjacent tooth; one empty space was left for the missing tooth (upper left incisor). The block was cured again to obtain teeth stability.
A silicone biphasic impression of the obtained typodont was taken (Hydrorise, Zhermack. Badia Polesine (RO), Italy) and sent to the Incognito® lab. A set of customized brackets, an indirect bonding tray and straight sectional wires of different materials and dimensions were obtained.
All teeth were sanded with aluminium oxyde (50μ), then they were etched for 30 seconds with 32% orthophosphoric acid (Scotchbond™, 3M Unitek, Monrovia, Calif), rinsed with water for 30 seconds and dried for 20 seconds. Customized lingual 0.022 x 0.022 brackets (Incognito®,3M Unitek, Monrovia, Calif) in their indirect bonding tray were then bonded with an orthodontic composite (RelyX™ Unicem 2 Automix; 3M Unitek, Monrovia, Calif). After the composite was cured, all samples were extracted from the resin block and tied to a 0.018x0.025 SS archwire (Incognito®, 3M Unitek, Monrovia, Calif) one by one. Then the teeth crowns were included in a block of soft wax to stay integral with each other. Once more, the lateral surface of the resin block was dug over with a denture bur in a straight handpiece, and the teeth roots were put along a straight line in the pit and encased in fluid transparent resin (metil-metacrylate). The resin was cured and the wax was removed from the crowns. The obtained teeth position in the typodont allowed slots to be passively engaged by the archwire (Fig. 1).

Wires

The tested archwires were: 0.016x0.022 NiTi, and 0.016x0.024 SS. (Incognito®, 3M Unitek, Monrovia, Calif). Both wires were first measured with a digital caliper to verify if the nominal dimension corresponded to the real one.

Ligatures

Easy-to-tie (L1) and lingual ligatures (L2) were tested (Alastik, 3M Unitek, Monrovia, Calif).

Testing machine

The bracket matching the missing incisor was tied to the wire as the “testing” bracket on which the measurements were performed. An extension was laser-welded to the bracket in order to apply the necessary force to study it. The extension was a round steel wire large 1.5 mm in diameter. At the distance of 10 mm a bottleneck was created on the wire, to recognize and keep the same force application point trough all tests. The extension was laser welded to the back of the bracket.
The Zwick/Roell Z0.5 machine (sensibility: <1%, displacement sensibility 1µm, full scale range 500N) was used to apply forces to the system, using forces from 0N to 0.6N. The typodont was fixed to the ZwickLine® machine by bolts and screws that engaged with the grooves on the plate, so that the model was solidly fixed to the machine, in order to create a system suitable to the application of forces.
The model was positioned by placing the side with the largest area on the plate, so that the lingual side of the teeth was above, the vestibular side below, the coronal portion of the teeth on the right and the roots housed in the resin on the left.
The traction system was hooked to the bottleneck extension of the testing bracket via a rigid metallic perforated screw. The extension of the testing bracket was placed in the drilling of the screw (Fig. 1).
A connection -like an enarthrosis joint- was used between the screw and the machine to prevent the decomposition of the force in the horizontal components and to maintain a constant vertical

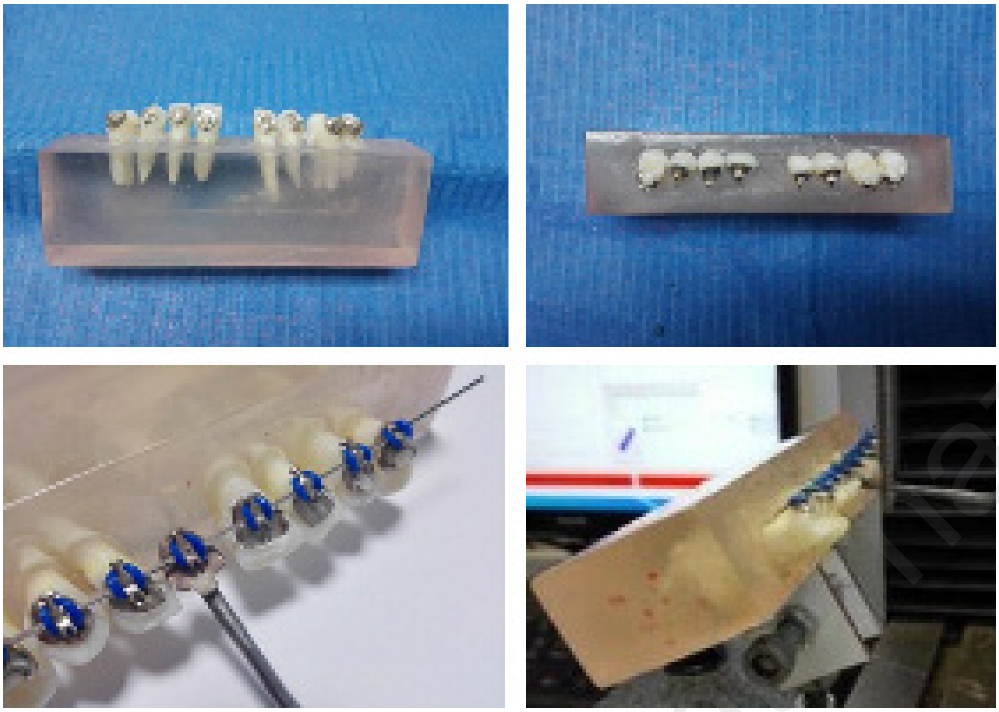

Figure 1. Experimental setting (the homemade typodont and the testing machine).

traction. The torque moment [Nmm] was calculated by multiplying the applied force through the arm, that is the distance between the axis of rotation and the point of application of the force which was fixed to 10 mm through the whole experiment. The torque angle [°] was algebraically calculated: the ZwickLine® machine is able to measure also the displacement performed by the extension, thus knowing the displacement (δ) and the arm (b) we can derive the sine of:

$$\sin \theta = \delta / b$$

The value of the torque angle (θ) was then derived by the arcsine function. When the angle between the extension and the machine changes, the arm of the force changes as well, thus the error was corrected after data collection.
The mechanical testing was repeated for each wire and for each type of ligature. For each wire and type of ligature, the typodont was stored in physiological saline Sodium- Chloride 0.9%, pH 5.5 to simulate the oral environment for one month and then the mechanical test was repeated.

Software
The TestXpert® II Zwick-Roell software was used to collect data and to represent the torque moment -on the ordinate-, with the torque angle -on the abscissa- in a Cartesian graph.

Statistical analysis
Descriptive statistics are expressed as median and interquartile ranges. Data were tested for normality using the Shapiro-Wilk test.
To evaluate differences between ligatures for time-points, a non-parametric analysis of variance was performed. Differences with a p-value less than 0.01 were selected as significant and data were acquired and analysed using R v3.4.4 software environment (13).

Results

Descriptive statistics are reported in Table 1 and Figure 2. Continuous variables are given as median with range, whereas categorical variables as numbers. The non-parametric analysis is reported in Table 2.
No significant differences were found in angle values between ligatures or timepoints when the complete set of data was tested (*p*-value=0.7090 and *p*-value= 0.6832).

Discussion

Experimental setting
Since the introduction of lingual customized appliances the problem of torque control in the anterior area has been a very important issue, addressed by different Authors (14-17).
Previous studies on torque control with buccal brackets had focused mostly on the play between wire size and slot dimensions. In a study comparing the torque play (degrees) of several lingual brackets with wires

Table 1. Descriptive statistics. Medians and interquartile ranges of angle values in each wire reading group for all types of ligatures and timepoints. Ligatures: L1: AlastiK™ Easy-to-tie, L2: AlastiK™ lingual ligature.

		Wires	
		016x022 NiTi	**016x024 ss**
L1	**T0**	9.74 [3.84, 13.21]	2.44 [1.39, 3.88]
	T1	10.01 [4.37, 13.34]	2.66 [1.20, 4.24]
L2	**T0**	8.44 [3.36, 12.71]	2.66 [1.56, 4.07]
	T1	8.77 [3.47, 12.71]	2.60 [1.51, 4.44]

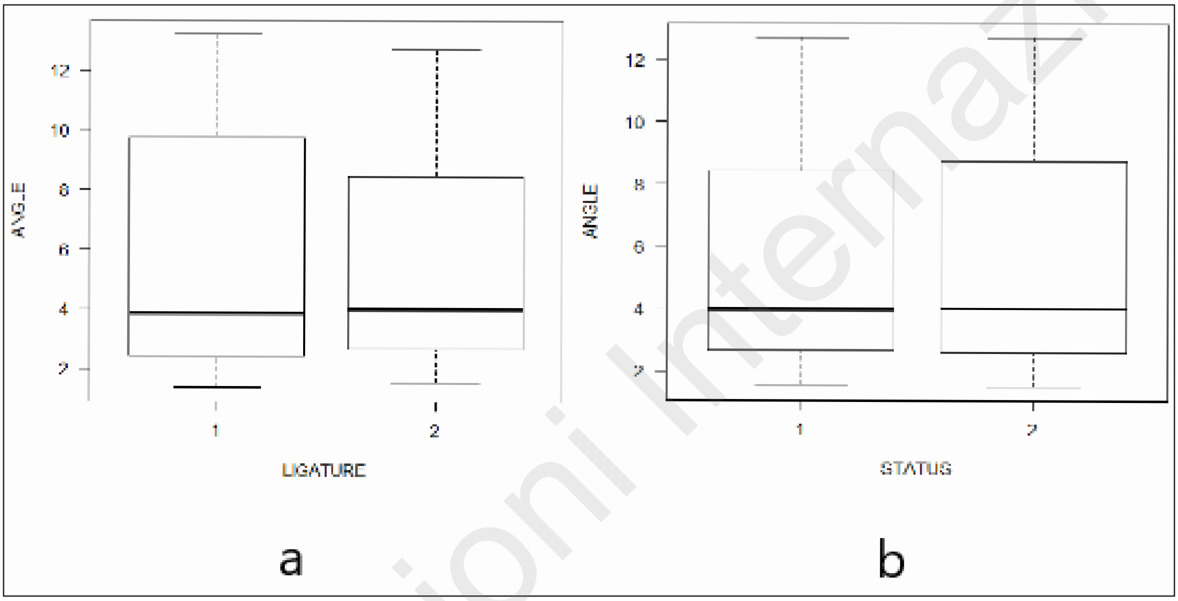

Figure 2. Medians and interquartile ranges graph of angle values: a) according to the type of ligatures: Ligature 1, AlastiK™ Easy-to-tie; Ligature 2, AlastiK™ Lingual ligatures; b) according to the status: status 1=fresh ligatures, status 2=stretched ligatures.

Table 2. Summary of non-parametric analysis. Results are expressed as coefficient of regression (Coeff.) with 95% confidence interval (95%).

Variable	**Coeff.**	**95% CI**
(Intercept)	100.23	64.89; 135.57
Status		
1	0	-
2	3.36	-12.85; 19.58
Ligature		
L1	0	-
L2	-3.18	-22.14; 15.78

of various sizes it was found that customized brackets were the most precise system (17). In fact, in lingual orthodontics with customized brackets the final arch wire is fully engaged into the slot, with less space for movements or rotation of the wire into the slot. Hence, in these systems the effect of the ligature type on three dimensional control of anterior teeth becomes essential, and from a clinical point of view, emphasis is given to particular ligature methods to obtain a better control.

Sifakakis et al. compared different lingual brackets using a traditional o-ring configuration to compare the torque variation (18). They concluded that customized brackets produced the highest moments, but they assumed that the moment is dependent by the ligation mode.

The present study was focused on two ligatures: a traditional one (AlastiK™ Easy-to-tie) and a type of ligature (AlastiK™ Lingual ligature) specifically developed to sit better the wire into the slot for a better tip and torque control in lingual brackets. The experimental setup was inspired by the lingual torque analysis performed by Lossdörfer et al. (19) who used a customized lingual appliance bonded on a typodont. Data collection was improved in the present study by a continuous data acquisition, which was obtained through a mathematical elaboration of the

movement analysis. The typodont was made of extracted human teeth, so that the bonding procedure was the one which is ordinarily applied in the clinical practice. Moreover, it was decided to put the teeth on a straight line, and to use wires in a straight shape, in order to eliminate any kind of distortion due to the wire configuration and to avoid any kind of interference on the wire-bracket-ligature system.
The simulation was completed by applying forces in a range between 0N and 0.6N: by multiplying the applied force through the 10 mm long arm, we obtained torque values beyond the 6 Nmm threshold. This was in accordance with the literature, which indicates values between 5 and 20 Nmm as ideal for torque control (18). Even though there is no general consensus on the optimal torque value, it is widely accepted that the minimum value to obtain a torque movement of an upper incisor would be 5 Nmm (20, 21). This value may differ for each tooth and for each patient, however optimal values are as near to the minimum to obtain a movement without inducing the risk of root resorption (3, 22).
In our study the AlastiK™ lingual ligature registered lower angle values at baseline and over time, which indicate a better torque expression, even if it did not give any statistically significant difference.
Other studies in the literature suggest that changes of ligature performance happen under a permanent deformation and that this is directly proportional to the degree of stretching. For example, a permanent deformation of 20% (21.3%) was found when stretched by 40 and 56.6% permanent deformation was reached when ligatures were stretched 100% of their original length. Finally, the highest percentage of permanent deformation occurred during the first week and was not statistically significant after this period (10). The ligatures in our study underwent the deformation of a standard clinical configuration and may not have achieved the cited levels of stretching.

Limits

The results of this study have to be prudently used when reported to clinical practice: other factors could play a role in an *in vivo* situation, even though this set up has been appositely studied to evaluate the ligation efficiency in a customized lingual bracket. The decision to use a straight wire instead of an archwire could also affect the results, considering that this appliance has a different wire insertion mode in the posterior area (horizontal, while it is vertical in the anterior), but the overall effects should be limited and are typical of this experimental configuration. Other limits of this study may depend on the ligature types: it may be possible that other ligatures from other companies can perform differently.
Finally, it could be useful to repeat the experiment at 60 and 90 days with a more accurate model of the human saliva composition.

Conclusions

In this *in vitro* study a torque expression record using two different ligatures and two wires was obtained for a customized lingual appliance at two different time-points:

- the ligature type did not affect the torque efficiency
- there were no differences in torque performance between fresh and stretched ligatures.

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