the production process, the model's precision, and the position of the aligner's margin all have an effect on the final performance of the appliance [12–15]; therefore, different results can be expected from different clear aligner systems [16]. Recently, Lombardo et al. [16], comparing planned and achieved tipping and rotation tooth movements in patients using another clear aligners system, found that orthodontic aligners are unable to achieve programmed movement with 100% predictability. In particular, although tipping movements were efficaciously achieved, especially at the molars and premolars, rotation of the lower canines was an unpredictable movement.

To the best of our knowledge, there is a lack of reliable literature on this subject, especially on the effective clinical predictability of torque movement of the anterior teeth using different clear aligners. Therefore, the aim of the present study was to evaluate the efficiency of a clear aligner system (Nuvola®, GEO S.r.l., Rome, Italy) [17] in controlling the torque movement of upper and lower anterior teeth. The null hypothesis was that no difference exists between planned and achieved torque movements.

Methods

The records of patients referred to the Dental Clinic of the Department of Biotechnological and Applied Clinical Sciences, University of L'Aquila, from September 2013 to September 2017 for orthodontic treatment with clear aligners, were screened for the following inclusion criteria:

- Caucasian adult patients (> 18 years) with full permanent dentition;
- Up to 6 mm of crowding in the anterior segment of the arch (from the distal right canine to distal left canine) evaluated on dental casts according to Lundstrom [18]
- Non-extractive orthodontic treatment with Nuvola® aligners;
- Presence of retention attachments for the buccal surfaces of the first and second premolars;
- Treatment plan that required interproximal reduction (IPR);
- Absence of local and systemic conditions that can alter bone metabolism.

Sample size calculation (G*Power version 3.1.9.2, Universitat Dusseldorf, Germany) [19], according to data on torque measurements retrieved from a previous study on the Invisalign® system [7], revealed that having a difference in the response of matched pairs of 0.26 and a standard deviation of the difference of 0.49; fifty-eight pairs would be needed to be able to reject the null hypothesis with a power of 0.90 and a type I error of 0.008.

Thirty-nine patients (14 males, 25 females) with a mean age of 30.7 years were retrospectively enrolled in the study group (Table 1), for a total of 63 treated dental arches (36 upper and 27 lower dental arches). Informed consent was obtained from every patient before inclusion.

Orthodontic treatment protocol

All subjects underwent a non-extractive orthodontic treatment with Nuvola® aligners. The Nuvola® system is designed to proceed through consecutive steps of a maximum of 12 aligners. After each step, new impressions should be acquired to design a new setup and to move forward to the next treatment phase.

The treatment plan required the presence of retention attachments for the buccal surfaces of the first and second premolars and the IPR of anterior teeth in order to achieve the correct dental alignment. Patients were instructed to wear their aligners for 22 h per day, except during meal times and oral hygiene procedures. Aligners were replaced every 14 days.

Measurement of digital models

For each treated dental arch, pre-treatment (T0), real post-treatment (T1: at the end of the first phase of treatment after 12 aligners), and ideal post-treatment according to setup (TS) digital casts were available. Pre-treatment and post-treatment models were acquired using a 3Shape E1 scanner (3Shape, Copenhagen, Denmark), and setups were constructed using Maestro 3D Ortho Studio software (AGE Solutions S.r.l., Pisa, Italy). The digital models of upper and lower arches at T0, T1, and TS were acquired as .STL files [20] and analysed by a single operator (M.T.) using VAM software (Vectra, Canfield Scientific, Fairfield, NJ, USA).

Fifteen landmarks were localised by the same well-trained operator on each digital model: the gingival limit of the lingual facial axis of clinical crown (FACC) of the right and left first molars, the incisal spot/the papilla between the central incisors (for upper and lower arch, respectively), and the gingival and occlusal limit of the buccal FACC of the central incisors, lateral incisors, and canines (Fig. 1). The landmarks' coordinates were exported as a .txt file and then imported into an Excel spreadsheet (Microsoft Excel, Microsoft, Redmond, WA, USA). The gingival points of the right and left molars and the point on the incisal spot/the papilla between the central incisors were used to define a reference plane. Then, the coordinates of the gingival and occlusal points of the buccal FACC of each tooth were transformed

Table 1 Demographic composition of the study sample

	Males ($n = 14$)	Females ($n = 25$)	Total ($n = 39$)
Age (mean ± SD)	30.7 ± 8.5	30.7 ± 10.8	30.7 ± 9.3

Age is expressed in years