

# Kinesiographic evaluation of patients under orthodontic treatment with or without tooth extraction

## Abstract

### Objective

In orthodontic practice, it is always required to decide whether to extract a tooth or to close the gap in the case of edentia. There are no scientific reports on changes to the temporomandibular joint and muscle system after orthodontic treatment including dentition size and shape reduction. The objective of this study was to improve diagnostic methods using computed diagnostic equipment.

### Materials and methods

After undergoing orthodontic treatment with dentition size and shape reduction, 127 patients aged between 16 and 32 were examined. Patients with physiological occlusion and without any functional problems were included in the control group. Morpho-functional investigation of mandibular movement was conducted via a kinesiograph.

### Results

All of the patients showed some functional problems on the frontal and lateral planes.

### Conclusion

Improvements were seen with the regain and restoration of the edentulous spaces.

### Keywords

Temporomandibular joint, TMJ, temporomandibular disorder, TMD, occlusal plane, muscular function.

Tatiana Klimova,<sup>a</sup> Nabi Nabiev,<sup>a</sup> Gianfranco Cesaretti<sup>b</sup> & Leonid Persin<sup>a</sup>

<sup>a</sup> Orthodontic department, Moscow State University of Medicine and Dentistry, Moscow, Russia

<sup>b</sup> ARDEC Academy, Rimini, Italy

### Corresponding author:

#### **Dr. Gianfranco Cesaretti**

Viale Pascoli 67  
47923 Rimini  
Italy

T +39 335 220 548

giancesa55@gmail.com

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**Figs. 1a–c**

The patient after orthodontic treatment (several years ago) with the second premolar extraction.

**Figs. 2a–c**

The patient after orthodontic treatment with space closure (primary edentia of tooth #22).

## Introduction

In order to determine a correct, comprehensive diagnosis of the maxillofacial system and the muscle chains, different methods of diagnosis are used, such as clinical examination, facial profile and photometry, anthropometric diagnostics of the dentition and occlusion, radiographic diagnostics (dental panoramic tomogram, lateral cephalogram, CT, MRI, etc.) and functional diagnosis (kinesiography, electromyography, myostimulation, posotonic state identification, etc.). All these methods have been extensively investigated and applied in the orthodontic department of the Moscow State University of Medicine and Dentistry, Moscow, Russia. Owing to these kinds of diagnostic equipment, a correlation between orthodontic treatment with dentition size and shape reduction (owing to tooth extraction [Figs. 1a–c] or partial primary or secondary tooth edentia [Figs. 2a–c]) and temporomandibular disorder (TMD) has been observed.

In orthodontic practice, it is required to decide between extracting a tooth and closing the gap in the case of edentia. It is necessary to state that these border cases arise rather rapidly. It was decided to assess this issue from the perspective of different orthodontic approaches. The study was based on several scientific articles.<sup>1–20</sup>

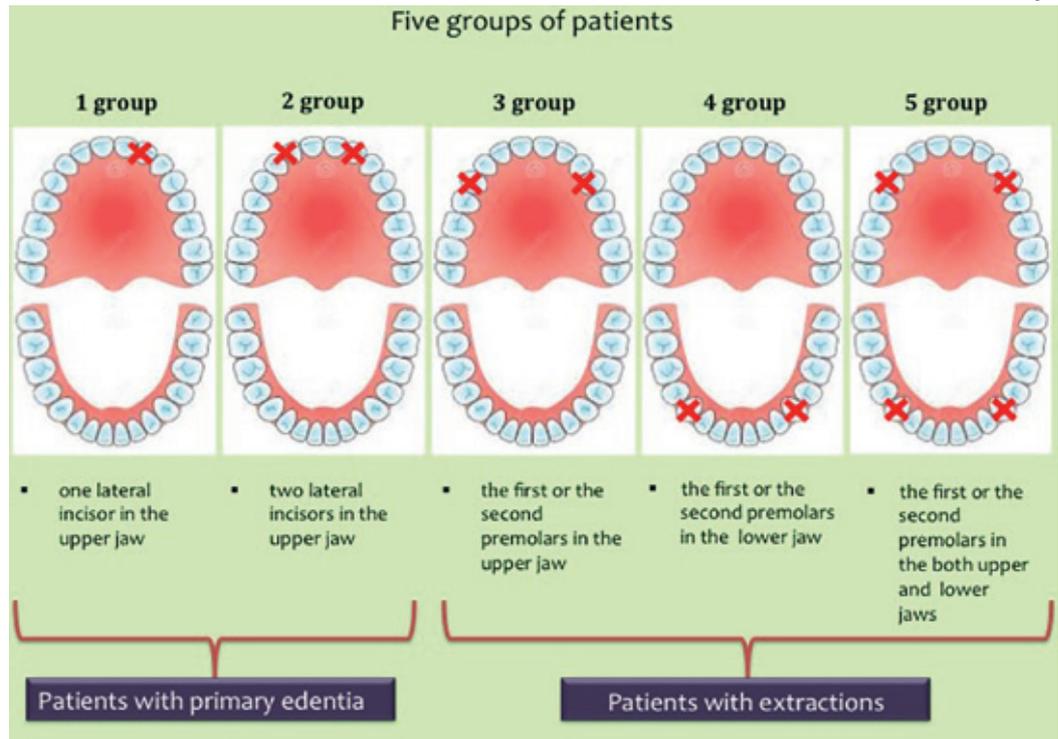
All of the structures of our body are phylogenetically connected. There is obvious continuity from vertebral column to cranium. All

cranial bones are generated from the first three vertebrae during the evolutionary process. There are also two subsystems that unite the entire body: the craniosacral and craniomandibular ones, joining together in the central nervous system. They are divided into musculoaponeurotic chains, starting from the cranial bones.<sup>21,22</sup> In light of this, it is necessary to know that all body systems are able to change during orthodontic treatment. Occlusal changes also influence the connection of cranial bones and as a result they can lead to TMD. By reorganizing the systems, we can improve stability and quality of treatment.

Therefore, while different authors' conclusions about extraction or nonextraction treatment are based on clinical, radiographic, CT or MRI examination, there are insufficient data on muscle adaptation to decide on the treatment in this case. There are no scientific reports on changes to the temporomandibular joint (TMJ) and muscle system after orthodontic treatment with dentition size and shape reduction (owing to tooth extraction or partial primary or secondary tooth edentia). This makes it difficult to evaluate the treatment choices properly in relation to the effect on the muscles and TMJ. These parameters are known as being essential for patients' health. Consequently, the aim of this study was to improve diagnostic methods after orthodontic treatment with dentition size and shape reduction using computed diagnostic equipment.

Fig. 3

**Fig. 3**  
Five groups of patients were selected according to the area of the absent teeth.



**Fig. 4**  
The BioKeyNet kinesiograph and the patient wearing the kinesiograph mask.

**Fig. 5**  
Kinesiographic interpretation in graphic and digital forms.



Fig. 4

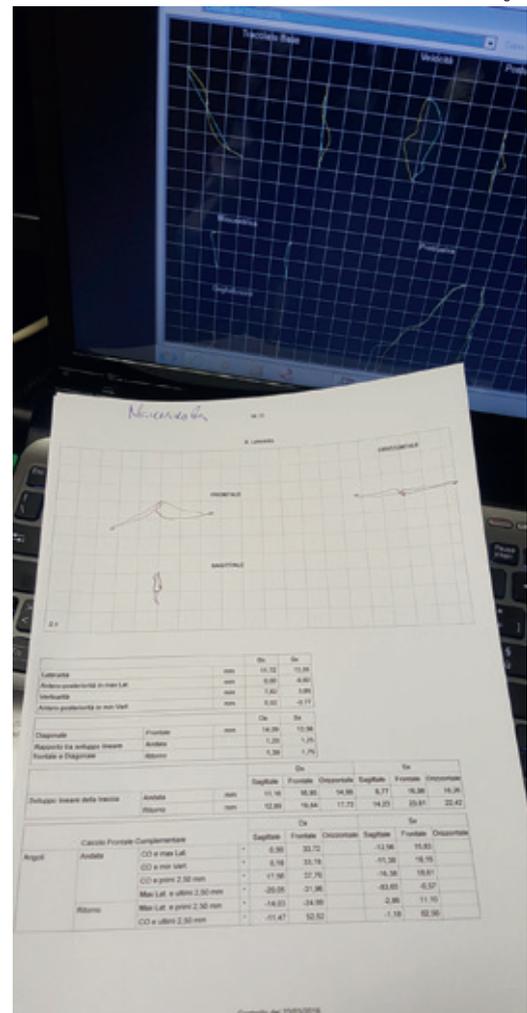


Fig. 5

## Materials and methods

This cross-sectional observational study included 127 patients aged between 16 and 32 during a period of two years. The patients were examined after orthodontic treatment that included dentition size and shape reduction for partial primary or secondary tooth edentia. Five groups of patients were selected according to the area of the absent teeth (**Fig. 3**):

- 1) absence of one lateral incisor in the upper jaw; composed of 21 patients;
- 2) absence of two lateral incisors in the upper jaw; composed of 16 patients;
- 3) absence of the first or the second premolar in the upper jaw; composed of 24 patients;
- 4) absence of the first or the second premolar in the lower jaw; composed of 19 patients; and
- 5) absence of the first or the second premolar in both the upper and lower jaws, composed of 22 patients.

Moreover, a control group was formed of 25 patients with physiological occlusion and without any functional problems. Morpho-functional investigation of mandibular movement was conducted using a kinesiograph (BioKeyNet, Bioket, San Benedetto del Tronto, Italy; **Fig. 4**). Kinesiography is the precise registration of the various movements of the mandible in three planes—sagittal, frontal and horizontal—including muscle contraction speed with complex performance in graphic and digital forms (**Fig. 5**).<sup>23, 24</sup>

In order to assess the current morpho-functional condition of the entire dentoalveolar system, the following functional tests and their further modification were set in various planes:

1. maximum mandibular lowering and lifting;
2. maximum mandibular lowering and lifting with regular and maximum movement speed;
3. maximum mandibular extension (a movement path was studied, including an individual angle of mandibular lowering and the trajectory of mandibular protrusion and its deviation);
4. maximum lateral mandibular movement (investigation was conducted on the trajectory of a mandibular movement and its individual angle, turning to the right and to the left);
5. mandibular movement from its regular physiological rest position to its common teeth joining myocentric index (an individual angle was tested to perform a mandibular anterior or posterior movement).<sup>24</sup>

## Results

The first group showed well-defined restrictions. While the mandible was lowered and lifted in the frontal plane, a simultaneous decrease in muscle contraction speed was seen in 80% of these patients, particularly in the vertical index (**Fig. 6**; **Table 1**). In the mandibular movement in the sagittal plane, a frontal block was observed. This block was also registered in all patients in the remaining groups (**Table 2**).

In the second group, the mandibular lowering and lifting led to its deviation and to the decreasing of the muscle contraction speed (**Fig. 7**; **Table 1**). This occurrence was even more marked compared with that seen in the first group, owing to the more distal position of the mandible (**Table 3**). The protrusive movement according to angle showed a significant frontal block and difficulty during mandibular movement (**Fig. 8**; **Table 2**). This group was also characterized by blocked mandible lateral movement to both the right and the left sides, with trajectories simultaneously shortening (**Tables 4 & 5**). TMD was seen in 60% of patients, while 40% of patients exhibited full blocking of lateral and protrusive movement.

The third group was divided into two subgroups according to the type of mandibular movement. The first subgroup (40% of the patients) was characterized by a severe decrease (flat angles) of lateral and protrusive angles (**Tables 2, 4 & 5**; **Figs. 8 & 9**). In contrast, the second subgroup (60% of the patients) showed an obvious increase (deep angles) of the lateral and protrusive angles (**Tables 2, 4 & 5**; **Figs. 8 & 9**). These outcomes showed an impairment of the essential lateral and frontal mandibular movements. Furthermore, the second subgroup was characterized by a distal position of the mandible (**Table 3**), restriction of movement during its lowering and lifting, and TMD (**Table 1**).

In the fourth group, all of the patients without exception (100%) showed considerable restriction of mandibular lowering with its deviation (**Fig. 10**), restriction of the muscle contraction speed (**Table 1**), and a decrease of the lateral and the protrusive angles (**Tables 2, 4 & 5**).

In the fifth group, restriction of mandibular lowering and lifting (36.85 mm) and its deviation during protrusion (2.62 mm) were observed (**Table 2**). The mandibular movement restriction to the left side (2.40 mm) showed values double that of the right side (1.56 mm; **Tables 4 & 5**;

**Table 1**  
Mandibular movement during the lowering–lifting test.

Index Group	Mandibular lowering–lifting in frontal plane (mm)		Working angle (individual mandibular movement angle) in sagittal plane (°)	Mandibular movement speed (mm/s)	
	Vertical	Mandibular deviation during lowering (mm): to right (+); to left (-)		Lowering	Lifting
1 <sup>st</sup> group	36.05	1.10	42.08	16.50	20.75
2 <sup>nd</sup> group	30.00	2.26	41.19	9.60	13.20
3 <sup>rd</sup> (1 <sup>st</sup> sub-group) group	38.12	-0.80	40.21	16.60	21.33
3 <sup>rd</sup> (2 <sup>nd</sup> sub-group) group	28.69	-1.31	38.46	17.80	32.60
4 <sup>th</sup> group	33.00	2.86	45.42	18.00	26.75
5 <sup>th</sup> group	36.85	1.72	40.78	16.57	33.00
Norm (N)	43.72 ± 1.30	1.84 ± 0.28	38.89 ± 1.10	19.78 ± 1.35	31.94 ± 3.73

Table 1

**Table 2**  
Mandibular movement during the protrusion test.

**Table 3**  
Mandibular movement during the myocentric test in the frontal and sagittal planes.

Index Group	Mandibular movement in vertical plane (mm)	Mandibular deviation during protrusion in vertical plane (mm): to right (+); to left (-)	Mandibular movement in sagittal plane (mm)	Centric occlusion angle (°)—maximum protrusion Only for 3 <sup>rd</sup> group	Angle (°) 2.5 mm from start of mandibular movement Only for 3 <sup>rd</sup> group	Diagonal (mm) Only for 3 <sup>rd</sup> group
1 <sup>st</sup> group	5.47	1.68	7.09			
2 <sup>nd</sup> group	3.00	-1.09	5.21			
3 <sup>rd</sup> (1 <sup>st</sup> sub-group) group	2.84	1.12	8.71	19.40	19.79	8.27
3 <sup>rd</sup> (2 <sup>nd</sup> sub-group) group	6.36	0.67	7.00	41.90	61.16	9.50
4 <sup>th</sup> group	3.75	1.21	8.60			
5 <sup>th</sup> group	5.00	2.62	8.99			
Norm (N)	3.62 ± 0.21	1.08 ± 0.19	9.28 ± 0.53	28.20 ± 2.68		9.77 ± 0.53

Table 2

Index Group	Myocentric, frontal plane (mm)	Individual angle, sagittal plane (°)
1 <sup>st</sup> group	0.10	36.42
2 <sup>nd</sup> group	0.19	31.86
3 <sup>rd</sup> (1 <sup>st</sup> sub-group) group	-0.08	28.79
3 <sup>rd</sup> (2 <sup>nd</sup> sub-group) group	-0.10	25.33
4 <sup>th</sup> group	0.09	33.58
5 <sup>th</sup> group	-0.12	33.11
Norm (N)	1.78 ± 0.17	26.89 ± 1.76

Table 3

Table 4

Index Group	Angle (°) 2.5 mm from start of mandibular Movement Only for 3 <sup>rd</sup> group		Mandibular movement (mm)		Centric occlusion angle (°) —maximum lateral movement Only for 3 <sup>rd</sup> group	
	Right	Left	Right	Left	Right	Left
1 <sup>st</sup> group			0.79	1.75		
2 <sup>nd</sup> group			1.40	1.05		
3 <sup>rd</sup> (1 <sup>st</sup> sub-group) group	29.13	-12.89	3.61	1.89	70.56	33.00
3 <sup>rd</sup> (2 <sup>nd</sup> sub-group) group	-11.85	-17.60	1.57	0.37	24.51	4.93
4 <sup>th</sup> group			2.66	1.63		
5 <sup>th</sup> group			2.45	1.56		
Norm (N)			13.34 ± 0.98	11.88 ± 0.95	33.81 ± 4.53	23.91 ± 6.20

Table 5

Index Group	Angle (°) 2.5 mm from start of mandibular movement Only for 3 <sup>rd</sup> group		Mandibular movement (mm)		Centric occlusion angle (°) —maximum lateral movement Only for 3 <sup>rd</sup> group	
	Right	Left	Right	Left	Right	Left
1 <sup>st</sup> group			10.44	10.64		
2 <sup>nd</sup> group			5.00	6.10		
3 <sup>rd</sup> (1 <sup>st</sup> sub-group) group	21.03	23.20	10.00	10.37	5.74	16.97
3 <sup>rd</sup> (2 <sup>nd</sup> sub-group) group	44.05	47.43	7.68	8.68	30.68	28.60
4 <sup>th</sup> group			8.23	9.22		
5 <sup>th</sup> group			9.61	9.00		
Norm (N)			9.14 ± 0.40	9.24 ± 0.44	22.12 ± 2.35	22.56 ± 2.13

**Fig. 11).** This group exhibited a distal position of the mandible (**Table 3**) and TMD.

Clinical case

A patient came to our clinic after a previous treatment performed in another private clinic. She complained of great discomfort in the TMJ area. The previous treatment had included the extraction of the second premolars of the lower jaw. The following diagnostic scheme was carried out in our clinic, according to the protocol for patients with TMD: 1) anthropometric studies of digital jaw models (3-D scanning); 2) radiographic diagnosis; and

3) morpho-functional diagnosis using a kinesiograph (**Figs. 12 & 13**), which showed a significant frontal block, a distal position of the mandible, TMD and a rotation of the occlusal plane.

During the one-year treatment in our department, the second premolar regions were regained and prepared for implant placement (**Figs. 14a–c**). After the treatment, the kinesiographic data showed significant improvements. The myocentric graph indicated a change of the mandibular movement direction, the laterotrusion graph revealed normalization of the occlusal plane and the protrusion graph showed elimination of the frontal block (**Fig. 13**).

**Table 4**  
Mandibular movement during the laterotrusion test in the sagittal plane.

**Table 5**  
Mandibular movement during the laterotrusion test in the frontal plane.

**Fig. 6**

Muscle contraction speed decreased during mandibular lowering and lifting in patients in the first and second groups.

**Fig. 7**

Protrusive movement with a significant frontal block and difficulty during mandibular movement in patients in the second group.

**Fig. 8**

Lateral mandibular movements in patients in the third group (the first and second subgroups).

**Fig. 9**

Protrusive mandibular movements in patients in the third group (the first and second subgroups).

Fig. 6

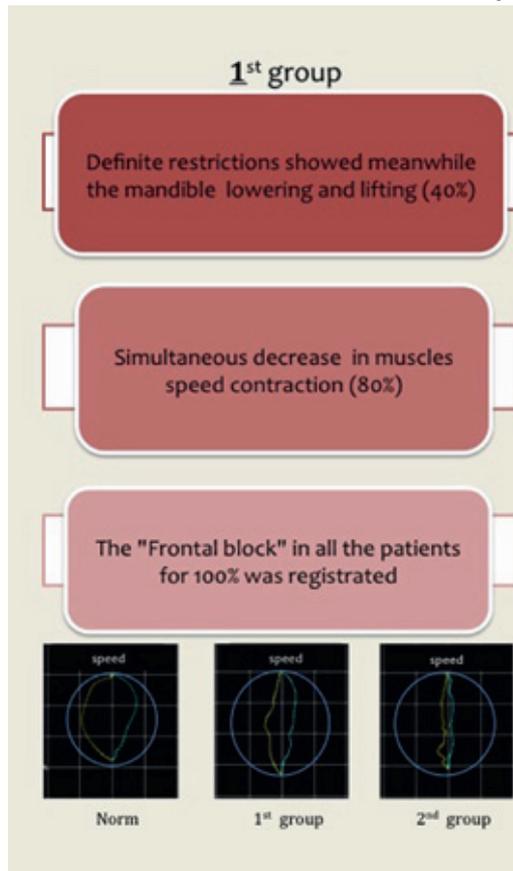


Fig. 7

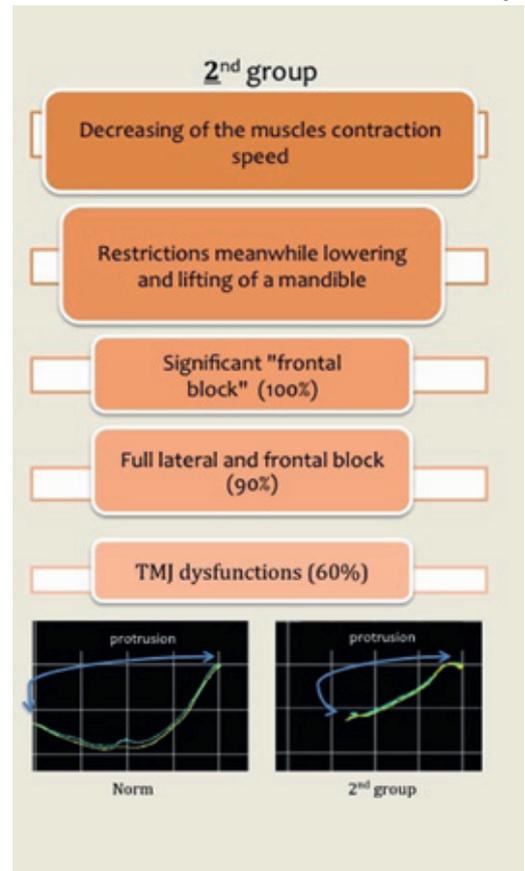


Fig. 8

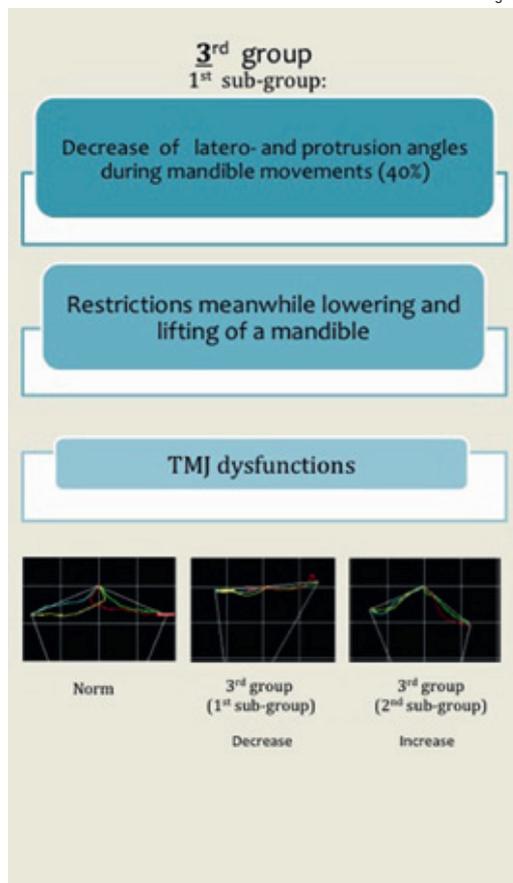
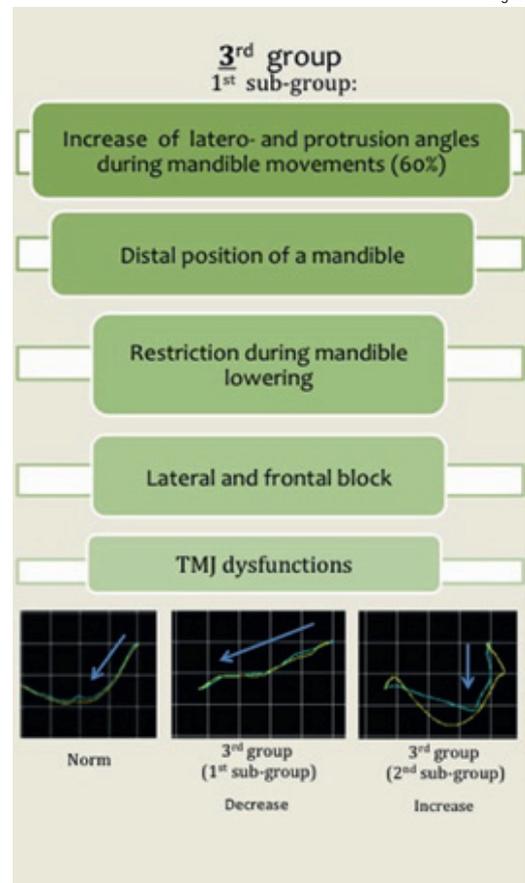


Fig. 9



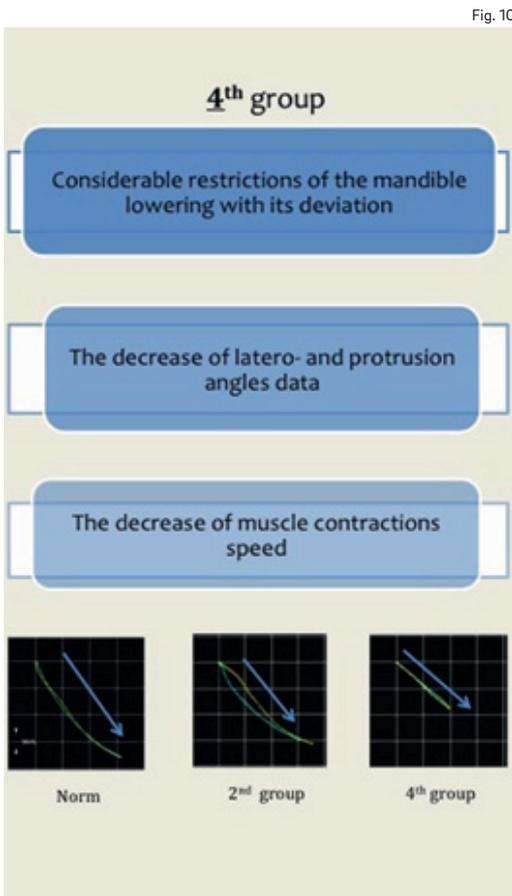


Fig. 10

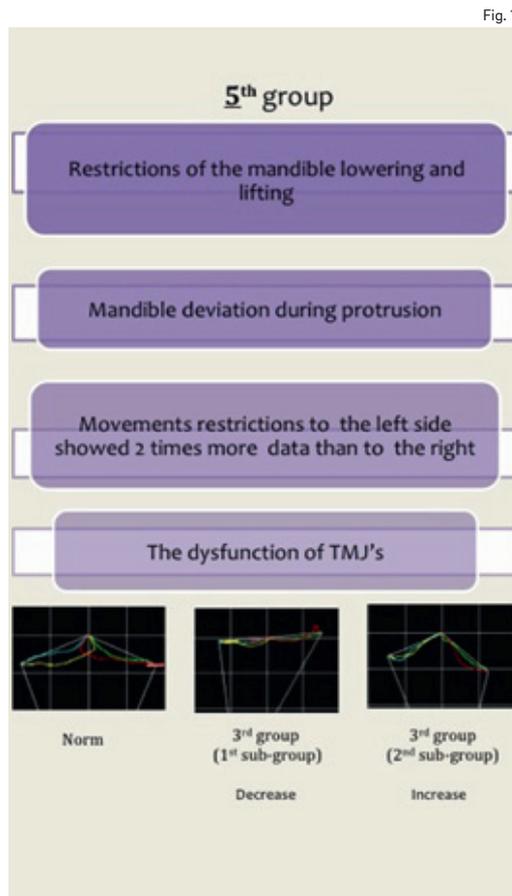


Fig. 11

**Fig. 10**

Restriction of mandibular lowering in patients in the fourth group.

**Fig. 11**

Lateral mandibular movements in patients in the third group (the first and second subgroups) and the fifth group.

**Fig. 12**

Morpho-functional diagnostics using kinesiography.



Fig. 12

## Discussion

A number of authors have carried out particular assessment in order to compare two approaches to patient treatment: extraction or nonextraction.<sup>25-27</sup> Various combinations of tooth extraction have been examined, and most of these cases were located in the area of the premolars

(from one to four teeth). The requisite data were gained from models and radiographs before, during and after the treatment. Also, authors compared changes in extraction versus nonextraction orthodontic treatment using pre- and post-treatment lateral cephalograms, comparing the skeletal, dental and soft-tissue profile changes, but no functional diagnostics or TMJ condition study was performed. For example, an investigation was carried out at the University of California, San Francisco Graduate Orthodontic Clinic on treatment for correction of a Class I or II malocclusion. There were 148 patients examined. With regard to the primary decision as to whether extraction or nonextraction treatment was to be preferred, agreement among clinicians was higher than had been anticipated, but how did the clinicians make their decision on whether to extract? Crowding was cited as the first reason in 49% of decisions to extract, followed by incisor protrusion (14%). Clinicians focused heavily on appearance-related factors that are qualitatively determinable by physical examination of the surface structures of the face and teeth, but no functional tests were conducted.<sup>28,29</sup>



Fig. 13a-c

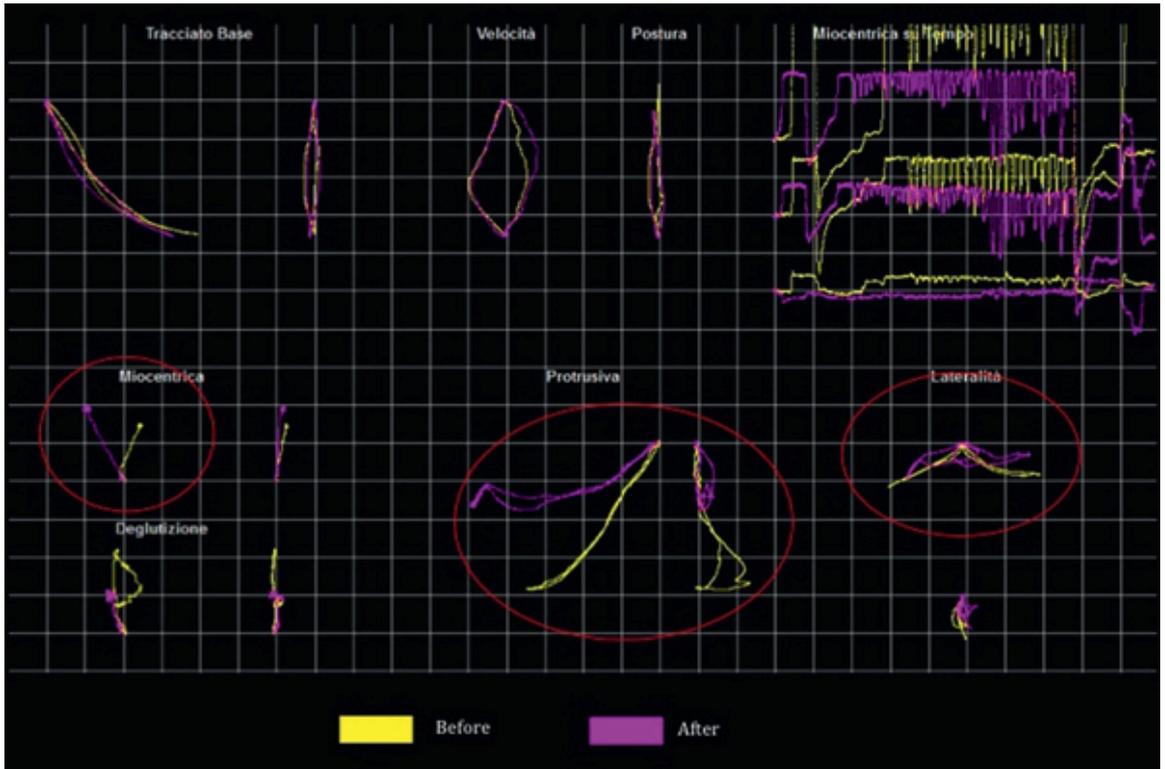


Fig. 14

**Figs. 13a-c**

The patient before and after treatment. Prepared spaces for the implants.

- (a) Before treatment.
- (b) Implant placement.
- (c) After treatment.

**Fig. 14**

Example of the kinesiogram before (yellow) and after (violet) the patient's treatment.

Nevertheless, there is no one common approach to the decision on whether it is necessary to extract teeth as long as such clinical situations continue to arise.<sup>4</sup> In most cases, authors insist that tooth extractions are significant only for surgical patients. Furthermore, it is known that it is better not to perform tooth extractions with border cases in order to avoid further complications.<sup>9</sup>

We highly agree with authors who suggest provision of nonextraction orthodontic treatment by using finishing wires of a particular material, size and arch form. The main determinants of final arch form and dimension appear to be the original muscular and occlusally related arch form and dimension and the amount of crowding to be relieved.<sup>30</sup> Evident changes in soft tissue and dentoalveolar characteristics appear with tooth extraction than is the case with dental arch

expansion and tooth movement. Also, several studies have been conducted to estimate the effect of dental arch length reduction (owing to dental extractions, dental agenesis and dental malpositions) during orthodontic treatment on the upper airway development.<sup>31</sup>

To our regret, there are no scientific reports on changes to the TMJ, muscle system and mandibular movements after orthodontic treatment with extraction. However, in our opinion, these indicators are more important than esthetic indicators. Esthetic indicators will be harmonious only when both morphological and functional indicators are taken into account.

All the methods for orthodontic research can be considered as a background for making a decision on further treatment and precise consequence assessment. The more initial scientific planning is carried out, the more effective the

treatment scheme formed and accomplished will be. Overall, orthodontic treatment planning, with or without extraction, is supposed to take into account not only morphological parameters but also parameters vital for function. Functional investigation of patients should be extensive and applied in current orthodontic practice.

## Conclusion

In all of the groups examined after orthodontic treatment that included dentition size and shape reduction for partial primary or secondary tooth

edentia, problems were registered during mandibular movements. These problems were mainly related to the restriction of mandibular movement during lowering and lifting, of lateral movement and of muscle contraction speed. Moreover, TMD was reported. Improvements were seen with the regain and restoration of the edentulous spaces.

## Competing interests

The present study was self-funded. All of the authors declare no conflict of interests.

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