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Preadolescents' Smile Outcomes after Two Different Orthodontic Treatments: Traditional Interceptive Therapy with Rapid Maxillary Expansion (RME)/Schwarz Plate and Clear Aligners

Matteo Rozzi [1], Manuela Mucedero [1], Silvia Fanelli [1,*], Patrizio Bollero [1] and Paola Cozza [2]

[1] Department of System Medicine, University of Rome "Tor Vergata", 00133 Rome, Italy; matteini.r@gmail.com (M.R.); mmucede@tin.it (M.M.); patrizio.bollero@ptvonline.it (P.B.)
[2] Department of Health Sciences, «UniCamillus-Saint Camillus» International Medical University in Rome, 00131 Rome, Italy; profpaolacozza@gmail.com
* Correspondence: silviafanelli7@gmail.com

Abstract: To compare preadolescents' smile outcomes after two different orthodontic treatments: RME/Schwarz plate (RS) and clear aligners (CAs). A sample of 31 patients (13 M, 18 F, mean age 8.3 ± 1.2 y.m) treated with RS and a sample of 28 patients (12 M, 16 F, mean age 7.9 ± 1.1 y.m) treated with CAS were included. Pre-treatment and post-treatment records were taken before the treatment (T1) and at the end of treatment (T2). Seventeen variables were evaluated. Both therapies were effective in smile width increase (RS = $p < 0.02$; CAs = $p < 0.04$) and buccal corridor reduction (RS = $p < 0.02$; CAs = $p < 0.04$). The intragroup analysis showed in the RS group an increase of incisor gingival display ($p < 0.02$), overbite (OVB) ($p < 0.04$) alongside a reduction of overjet (OVJ) ($p < 0.01$). Conversely, the CAs group evidenced a reduction in incisor gingival display ($p < 0.04$) and OVB ($p < 0.01$) with an increase in C angulation ($p < 0.02$) and maxillary incisor inclination ($p < 0.04$). An intergroup comparison evidenced a greater improvement in smile width, smile index and buccal corridor in the RS group with respect to the CAs group ($p < 0.02$; $p < 0.02$; $p < 0.03$). CAs were more effective in the management of gingival display, incisor position, midline correction (incisor gingival display $p < 0.01$; maxillary incisor position $p < 0.04$; maxillary dental midline $p < 0.02$), with a better control of OVJ ($p < 0.01$) and OVB ($p < 0.02$). The RS approach resulted in a greater smile width and a reduction in buccal corridor with respect to the CAs. The CAs provided a better management of both gingival display and smile aesthetics.

Keywords: Invisalign®; Invisalign® First system; clear aligners; smile outcome; interceptive therapy

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1. Introduction

The smile is one of the most important criteria in the judgement of facial attractiveness, and a well-balanced smile is particularly important for self-esteem and social integration [1,2]. In orthodontics, the smile is extensively studied, with the assumption that soft tissue form largely defines facial aesthetics [3,4]. The anterior aesthetic zone is framed by three components: dental, gingival and soft tissue components [5]. The idea of a perfect smile remains not determined. A smile can be considered "attractive" when a "balanced" and harmonious inter-relationship exists between the teeth, gingiva and lips, interplaying within the dynamic display zone of the face [5,6]. Moreover, upper incisal edges and canine tips that are set in harmony with the lower lip incurvation, as well as correspondence of the upper central incisors to the facial midline, are supposedly desirable features in an attractive smile. Lastly, the position and inclination of the upper incisor provide support to the upper lip, influencing smile appeal as well as the amount of upper gingival show; up to 3 mm upon smiling was found to be the accepted norm for an attractive smile [7]. The soft tissue component of a smile comprises the lips at rest and at the time of smiling, thus representing the frame of each exclusive smile [7].

Maxillary constriction is very common in orthodontic patients during the mixed dentition stage and can affect occlusion, facial development and smile aesthetics. A constricted maxilla is becoming more frequent nowadays and it is also proven that environmental factors—like diet consistency and/or mastication—could play a significant role in the growth of the maxilla and the mandible [8–11].

However, maxillary expansion is required not only to correct transverse deficiencies but also to expand the perimeter of the arch [12], and it can be performed as Slow Maxillary Expansion (SME) or Rapid Maxillary Expansion (RME). The differences between these two treatments concern the intensity and time of application of forces [13]. Substantial differences are also highlighted in the dental and skeletal structures involved in the two different approaches. In fact, different studies have evidenced changes in facial soft tissues consequent to skeletal modification with RME [14,15]. Furthermore, as reported by McNamara L. et al. [15] and Maulik C. and Nanda R. in 2007 [16], an improvement in smile aesthetics was registered after RME, with an evident decrease in the buccal corridors [15–17]; additionally, Cobra de Carvalho et al. [18] underlined that RME was beneficial for smile aesthetics through increases in the transverse smile dimension and exposures of maxillary central and lateral incisors [17–19]. Moreover, a constricted maxilla can be associated with several problems that include occlusal or functional difficulties such as narrowing of the pharyngeal airway, increased nasal resistance and alterations in tongue posture that results in a retroglossal airway narrowing and mouth breathing. Therefore, early treatment of this malocclusion through palatal expansion is intensely recommended [20].

On the other hand, CAs is a viable alternative system to conventional orthodontic therapy in the correction of mild-to-moderate malocclusions [21–25]. The introduction of CAs in young patients provides an answer to the ever-growing demand for aesthetic and comfortable treatments, even in children. This device can be used to perform phase 1 orthodontic treatments, including the correction of a narrow maxillary arch [26,27].

Numerous authors [27,28] have recently analyzed the effectiveness of CAs in maxillary arch expansion. These studies reported encouraging results comparable to those obtained with RME therapy, with a consistent amount of bodily expansion for canines, deciduous molars and permanent first molars [24,27,28]. Other authors have also investigated the effect of these two expansion techniques on the craniofacial region and on the airway. Foutoulaki G et al., in 2022, observed that RME can significantly increase the volume and minimal cross-sectional area of the nasal passage airway, with benefits on respiratory disorders treatment [29,30]. Conversely, also clear aligners allow changes in upper airway volume, with a statistically significant increase in volume (+2.92 cm^3) during therapy, and changes in the tongue position and in its relationship to the incisors and palate [31].

In cases of mild crowding or limited transverse deficiency, clear aligners can be a great alternative to dentoalveolar expander, simultaneously allowing for arch expansion, crowding resolution, management of the arch perimeter and achievement of an aesthetic smile. In addition to these advantages, clear aligners deliver better aesthetics, less discomfort and improved oral hygiene during the treatment [32].

In recent years, many patients have pursued CAs treatment. Therefore, an outcome comparison between fixed appliances and this alternative treatment modality is necessitated. Different studies have analyzed the effect of CAs on arch development [24,26,28,33–35], but no study has investigated changes in the smile of patients during early mixed dentition after maxillary expansion with CAs treatment.

Understanding the effects of orthodontic treatments on the smile is critical, and smile improvement is an important motivation for those seeking orthodontic treatment [36]. Therefore, it is important to understand how treatment types affect smile outcomes. It would be interesting to reveal if there are therapeutic alternatives that guarantee not only an adequate arch development but also an improvement in smile aesthetics during phase 1 treatment.

The aim of this study was to compare smile balance reached in two different groups of growing subjects with narrow arches treated with traditional interceptive therapy RS and CAs.

2. Materials and Methods

2.1. Subjects

All patients signed informed consent to participate in this study, which was approved by the ethics committee on human research at the University of Rome "Tor Vergata". A sample of 387 subjects scheduled for interceptive orthodontic treatment were retrospectively collected from the archives of the Department of Orthodontics of the University of Rome "Tor Vergata". A total of 146 CAs and 241 RS patients were retrieved from the archive. After applying the inclusion and exclusion criteria (Table 1), numerous subjects were excluded for absence of inclusion criteria (136), incomplete or poor-quality records (72), missing teeth or caries (39), presence of sagittal discrepancy (57) or tooth anomaly (24). A total of 59 patients were identified and divided in two groups: a sample of 28 patients (12 males, 16 females, mean age 7 years. 9 months) treated with CAs (mean treatment time: 1 years. 2 months) and a sample of 31 patients (13 males, 18 females, mean age 8 y. 3 m) treated with RS (mean treatment time: 1 years. 1 months). Pre-treatment and post-treatment records (extraoral photographs and lateral cephalograms) were available before the treatment (T1) and at the end of the active treatment (T2). Pre-treatment dental casts were used to match the subjects for dental crowding (little index).

Table 1. Inclusion and exclusion criteria applied to the sample.

Inclusion Criteria	Exclusion Criteria
- Mixed dentition: intertransitional period (presence of permanent lateral and central incisors and first permanent molars); - Class 1 molar classification or mild class 2 molar classification; - Nonextraction treatment; - Minor crowing (1–4 mm) in each dental arch evaluated with little index; - Absence of crossbite; - maxillary contraction; - Pre-treatment and post-treatment records available (lateral cephalograms and intraoral and extraoral photographs).	- Craniofacial discrepancies, syndromes or skeletal asymmetries; - Previous orthodontic treatment; - Previous traumas involving oral soft and hard tissue; - Missed tooth (traumas, caries, agenesis); - Absence of dental anomalies (macrodontics or microdontics teeth); - Incomplete or poor quality of records; - Unnatural posed smiles (a smile that is not reproducible, and therefore cannot be used as a reference for further measurements).

2.2. Methods

Frontal smiling photographs were taken of each patient using a Canon T3 digital camera (Canon Inc., Tokyo, Japan) assembled with a Canon 100 mm macro lens and circular macro flash (Canon Inc., Tokyo, Japan). Photographs of a posed smile were taken as part of each patient's routine orthodontic data base. Although orthodontic assistants followed a protocol, the photographs were not standardized; they were not taken at a precise fixed distance, and patients' heads were not placed in a head holder. The posed smile is voluntary and not elicited by an emotion, and it can be a learned greeting or a signal of appeasement; it can be sustained and is reliably repeatable. It is not spontaneous and is unstrained and posed. Patients were trained before the photographs [37,38]. Each patient in this study had at least four photographs taken, which were reviewed to determine their acceptability and the authenticity of the unstrained posed smile. Each frame was opened in Adobe Photoshop 2020 Version (Adobe Inc., San Jose, CA, USA) and adjusted using the millimeter ruler in the frame; the calibration of all images in the software was performed according to Bray et al. [39]. All measurements were performed using the interpupillary line as a horizontal reference axis and its perpendicular (true vertical line) as a vertical reference (Figure 1).

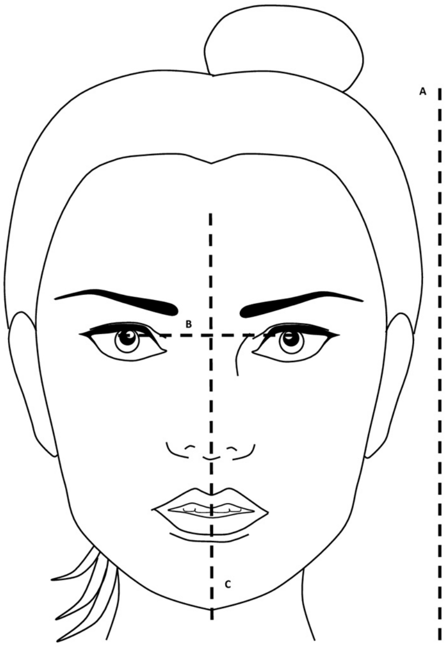

Figure 1. Reference lines for photograph misurations. A, Interpupillary line: line from the center of right pupil to the center of the left pupil; B, true vertical line: perpendicular to interpupillary line; C, midline of the face: midpoint of the interpupillary line parallel to true vertical line.

The appliances used for the CAs group were fabricated using the Invisalign® First protocol [40] (Align Technology Inc., Tempe, AZ, USA), and 22 to 40 aligners were used for each arch. Only one revision set of aligners was used. There were no restrictions on the number of attachments that could be placed; no auxiliaries other than Invisalign® attachments were used. Tooth movement started from the first aligner. All subjects were instructed to wear each aligner full time, excluding during meals and tooth brushing. The programmed dental movements were expansion of the first molars and simultaneous mesial, out of 1.6 and 2.6, with an addition of radiculo–buccal torque, expansion of the middle sectors of the arch; sequential radiculo–buccal torque (to follow the coronal expansion movement), alignment of the frontal group—leaving 1 mm of mesiodistal space to the deciduous canines—and adjustment of the coronal–buccal torque (to avoid making the crowns lingual). Expansion was considered adequate when an overcorrection of 2 mm per side was achieved in the posterior and middle sectors. Each aligner was changed every 7 days. Every four stages, the clinician checked for good aligner fit and the position of the attachments. The mean treatment time for the CAs group was 12 m $\pm$ 3 m (months).

The treatment protocol for all patients in the RS group included the application of RME (Leone spa., Sesto Fiorentino, FI, Italy) soldered to bands on the first permanent molars and a removable mandibular Schwarz plate in the lower arch. Each patient underwent a standardized treatment protocol with RME. Once RME was started in the patients, in situ screw activation was used. The expansion screw was activated once a day until overcorrection was achieved in each group (i.e., the palatal cusps of the maxillary posterior teeth approximated the buccal cusps of the mandibular posterior teeth). RME was maintained for at least 8 months as a passive retainer, stabilizing the expansion reached during screw activation. No removable appliance was applied after RME removal.

In the RS group, a removable appliance was constructed in the form of a Schwarz plate with a central screw (Leone spa., Sesto Fiorentino, FI, Italy) for the lower arch. The Schwarz plate was prescribed for 8 months to control the arch dimension. The patients were instructed to wear the Schwarz plate 24 h a day, excluding during meals and tooth brushing.

As in studies involving any removable device, compliance varied among patients. The removable appliance was activated by rotating its screws once a week (90° for 0.175 mm). The mean treatment time for the RS group was 10 m ± 6 m (months). Demographic data of the examined samples are reported in Table 2.

Table 2. Demographics of the treated groups.

	Age at T1		Age at T2	
	Mean	**SD**	**Mean**	**SD**
IF Group (12 males, 16 females)	7.9 y.m	1.1 y.m	9.1 y.m	1.2 y.m
RS Group (13 males, 18 females)	8.3 y.m	1.2 y.m	9.4 y.m	1.4 y.m

SD = standard deviation; y = years, m = months.

Seventeen variables, twelve on photographs for smile evaluation and five on cephalograms for incisor position and angulation, were evaluated to assess the smile outcomes [33]. A description of the analyzed variables is reported in Table 3, Figures 2a–c and 3. All seventeen variables were measured at T1 and T2 for all subjects.

Table 3. Definition of variables.

Variable	Definition
Smile width (mm)	Linear distance between the most distal point of the last visible posterior tooth on the right and the most distal point of the last posterior tooth on the left, perpendicular to the midline of the face
Lip symmetry (ratio)	The sum of the upper and lower left lip length divided by the upper and lower right lip length
Smile index (ratio)	Smile width to interlabial gap ratio
Smile cant (°)	The angle between the interpupillary line and a line from the right to the left corner of the mouth
Buccal corridor (ratio)	The ratio of the intercommissure width divided by the distance from first premolar on right side to first premolar on left side
Buccal corridor (mm)	Dark space visible during smile formation between the corners of the mouth and the buccal surfaces of the maxillary teeth, perpendicular to the midline of the face
Upper lip thickness (mm)	The vertical distance from the most superior peak of the lip to the most inferior portion of the tubercle of the upper lip, parallel to the midline of the face
Lower lip thickness (mm)	The vertical distance from the deepest midline point of the superior margin of the lower lip to the most inferior portion of the lower lip, parallel to the midline of the face
Gingival display (mm)	Mm of maxillary gingival exposure between the inferior border of the upper lip and the marginal gingiva of the maxillary central incisor on the right side, parallel to the midline of the face
Maxillary dental midline (mm)	Perpendicular distance between the vertical contact interface of maxillary centrals and midline of the face
Canine display (mm)	Mm of maxillary gingival exposure between the inferior border of the upper lip and the marginal gingiva of the maxillary canine on the right side, parallel to the midline of the face
C angulation (°)	The angle between the line tangent to the buccal surface of the maxillary canine and the line perpendicular to the midline of the face
Maxillary incisor position (mm)	Distance from upper incisor incisal point to N-A line
Maxillary incisor inclination (°)	The angle between U1 Axis and S-N line
IMPA (°)	The mandibular incisor angle is the inner angle formed between L1 Axis and the Mandibular Plane
Overjet (OVJ) (mm)	Measure of the overlap of the incisors horizontally
Overbite (OVB) (mm)	Measure of the overlap of the incisors vertically

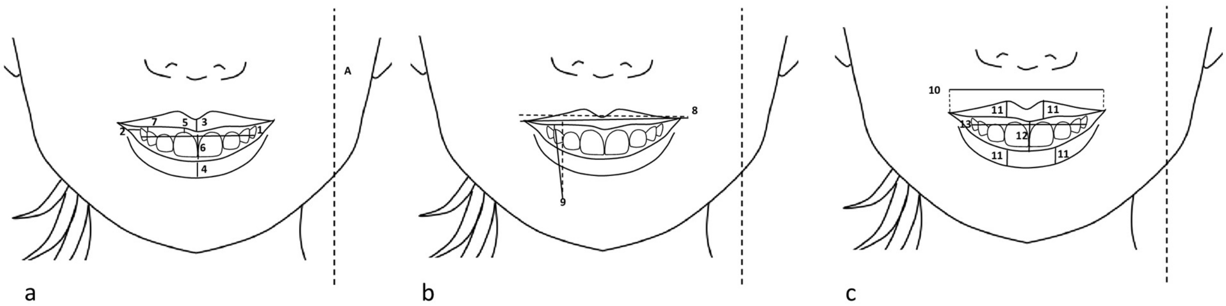

Figure 2. (**a**) Linear measurements of the smile: (1) smile width, (2) buccal corridor, (3) upper lip thickness, (4) lower lip thickness, (5) gingival display, (6) maxillary dental midline, (7) canine display. (**b**) Angular measurements of the smile: (8) smile cant, (9) C angulation. (**c**) Distance of reference for percentage measurements: (10) intercommissural width, (11) upper and lower lip, (12) interlabial gap, (13) interpremolar distance. Refer to Table 3 for variables description.

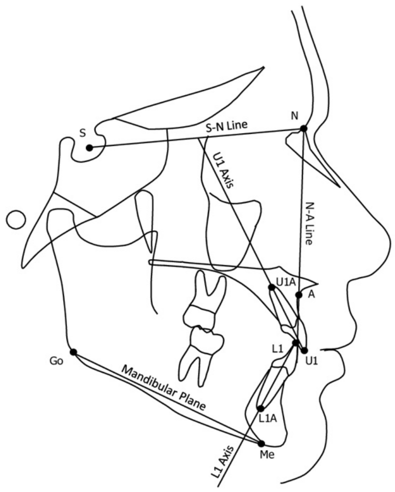

Figure 3. Reference point and axis for angular and linear variables on lateral cephalograms. S, Sella; N, Nasion; A, A point; Go, Gonion; Me, Menton; U1A, root apex of maxillary central incisor; U1, most proclined incisal edge of maxillary central incisor; L1, most proclined incisal edge of mandibular central incisor; L1A, root apex of mandibular central incisor; S-N Line, line from S to N; N-A Line, line from N to A; U1 Axis, line from U1 to U1A; L1 Axis, line from L1 to L1A; Mandibular Plane, line from Go to Me.

2.3. Statistical Analysis

The sample size for the treated groups was calculated considering a clinically significant difference for the buccal corridor (1 mm) and incisor gingival display (1 mm) with a power of 0.85 and $\alpha = 5\%$. The calculated sample size for the statistical analysis test was at least 25 subjects in each group. Intra-examiner reproducibility was assessed by repeating the gingival and canine display measurements, 4 weeks after the original measurements, on 15 randomly selected radiographs and photographs. Reliability was calculated using a paired *t*-test. The difference was found to be not significant. Subsequent statistical analyses were performed with Statistical Package for the Social Sciences software (version 24; IBM, Armonk, NY, USA) and were run using the Mann–Whitney U test to determine if pre-treatment and post-treatment outcome measurements significantly differed in patients between the two conditions (CAs group vs. RS group). The Wilcoxon *t*-test was used to reveal whether significant differences existed in the pre-treatment and post-treatment variables within each group.

3. Results

The analysis of starting forms showed no significant differences between the two groups RS and CAs at T1 (Table 4). A visual comparison of pre- and post-treatment smile outcomes is reported in Figure 4.

Table 4. Descriptive statistics and statistical comparison on the starting forms (valuated at T1).

	RS Group		**IF Group**		
Variable	**Median**	**Mean (SD)**	**Median**	**Mean (SD)**	***p* Value**
Smile width (mm)	44.12	43.75 (4.33)	44.15	44.2 (4.67)	0.62
Lip symmetry (ratio)	1.05	1.07 (0.02)	1.09	1.07 (0.09)	1.00
Smile index (ratio)	5.98	5.71 (1.33)	5.96	5.56 (1.61)	0.39
Smile cant (°)	0.99	1.18 (0.27)	1.03	1.12 (0.13)	0.46
Buccal corridor (ratio)	23.45	23.32 (4.22)	23.07	22.86 (4.67)	0.07
Buccal corridor (mm)	8.21	8.11 (0.56)	8.56	8.48 (0.39)	0.61
Upper lip thickness (mm)	6.77	6.02 (1.22)	6.43	6.07 (1.94)	0.73
Lower lip thickness (mm)	8.93	8.12 (1.03)	8.65	8.39 (1.18)	0.75
Incisor gingival display (mm)	2.02	2.82 (1.0)	2.89	2.67 (0.87)	0.62
Maxillary dental midline (mm)	0.85	0.94 (0.02)	0.79	0.98 (0.19)	0.89
Canine gengival display (mm)	1.72	1.52 (0.85)	1.63	1.34 (0.66)	0.34
C angulation (°)	77.01	76.32 (7.55)	77.32	77.43 (8.97)	0.47
Maxillary incisor position (mm)	5.54	4.62 (2.01)	5.76	4.73 (2.33)	0.54
Maxillary incisor inclination (°)	106.91	106.23 (8.54)	106.06	105.62 (7.53)	0.69
IMPA (°)	88.09	88 (5.45)	88.01	87.23 (4.73)	0.72

SD = standard deviation.

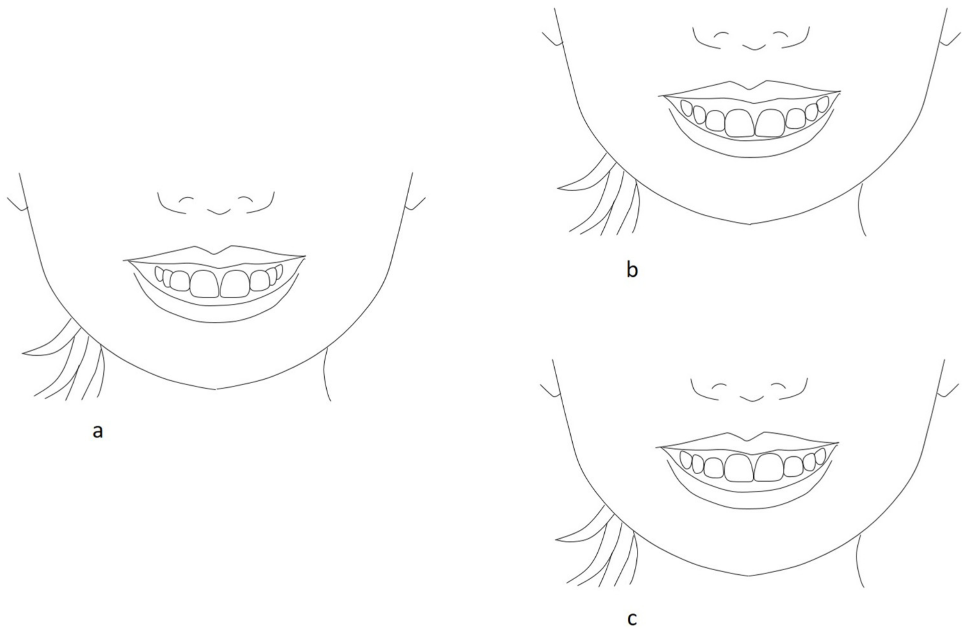

Figure 4. (**a**) Pre-treatment; (**b**) post-treatment smile outcomes after RME treatment; (**c**) post-treatment smile outcomes after clear aligners treatment.

3.1. Intragroup Comparisons

After treatment, the RS group showed an improvement in arch width, which was supported by statistical increases in smile width (5.23 mm) and smile index (0.80 ratio), and a significant decrease in buccal corridor (−6.35 ratio, −3.53 mm). After RME therapy, the RS group subjects also evidenced an extrusion and lingualization of the maxillary incisors, which was supported by statistically significant increases in incisor gingival display (0.80 mm) and OVB (0.51 mm), and significant reductions in maxillary incisor inclination (−3.33°) and OVJ (−1.55 mm) values. In addition to these movements, a worsening in maxillary dental midline (0.21 mm) was also evident after RME treatment.

No statistical differences in canine gingival display or C angulation parameters were reported at T2.

In the same intragroup comparisons, at the end of treatment (T2), the CAs group evidenced an effective improvement in arch width, as shown by increases in smile width (3.42 mm) and smile index (0.53 ratio) and a reduction in buccal corridor (3.02 mm, 1.48 ratio). Furthermore, differently to the RS group, after therapy, the CAs subjects evidenced incisor intrusion movement, supported by reductions in incisor gingival display (−0.45°), overbite (−1.54 mm) and canine gingival display (−0.41 mm) values. At the same time, significant improvements in incisor and canine inclination were achieved, as demonstrated by increases in maxillary incisor inclination (3.70°) and C angulation (3.57°) values. A statistical improvement in maxillary dental midline (−0.62°) was also evidenced in the CAs group.

The results for intragroup comparisons are reported in Table 5.

Table 5. Intragroup and intergroup comparison for the two analyzed groups.

	RS Intragroup Comparison				**CA Intragroup Comparison**				**Intergroup Comparison**	
Variable	**T1 Mean (SD)**	**T2 Mean (SD)**	**Mean Difference**	***p* Value**	**T1 Mean (SD)**	**T2 Mean (SD)**	**Mean Difference**	***p* Value**	**Mean Difference**	***p* Value**
Smile width (mm)	43.75 (4.33)	48.98 (3.78)	5.23	0.02 *	44.2 (4.67)	47.62 (3.03)	3.42	0.04 *	1.36	0.02 *
Lip symmetry (ratio)	1.07 (0.02)	1.15 (0.21)	0.08	0.84	1.07 (0.09)	1.16 (0.27)	0.09	0.85	−0.01	0.82
Smile index (ratio)	5.09 (0.87)	5.89 (1.33)	0.80	0.03 *	5.56 (0.76)	5.03 (1.60)	0.53	0.04 *	0.86	0.02 *
Smile cant (°)	1.18 (0.27)	1.12 (0.11)	−0.06	0.91	1.12 (0.13)	0.51 (0.18)	−0.61	0.01 *	0.61	0.01 *
Buccal corridor (ratio)	23.32 (4.22)	16.97 (5.01)	−6.35	0.02 *	22.86 (4.67)	19.84 (4.92)	−3.02	0.04 *	−2.87	0.03 *
Buccal corridor (mm)	8.11 (0.56)	4.58 (0.63)	−3.53	0.02 *	8.48 (0.39)	7.00 (0.88)	−1.48	0.04 *	−2.42	0.03 *
Upper lip thickness (mm)	6.02 (1.22)	5.66 (1.55)	−0.36	0.40	6.07 (1.94)	5.79 (1.57)	−0.28	0.52	−0.13	0.53
Lower lip thickness (mm)	8.12 (1.03)	8.37 (1.32)	0.25	0.64	8.39 (1.18)	8.67 (1.39)	0.28	0.68	−0.30	0.38
Incisor gingival display (mm)	2.82 (1.0)	3.62 (0.89)	0.80	0.02 *	2.67 (0.87)	2.22 (0.26)	−0.45	0.04 *	1.40	0.01 *
Maxillary dental midline (mm)	0.94 (0.02)	1.15 (0.05)	0.21	0.05 *	0.98 (0.19)	0.36 (0.09)	−0.62	0.02 *	0.79	0.02 *
Canine gingival display (mm)	1.52 (0.85)	1.79 (1.47)	0.27	0.06	1.34 (0.66)	0.93 (1.32)	−0.41	0.04 *	0.86	0.02 *
C angulation (°)	76.32 (7.55)	74.8 (6.98)	−1.52	0.09	77.43 (8.97)	81 (6.08)	3.57	0.02 *	−6.20	0.03 *
Maxillary incisor position (mm)	4.62 (2.01)	3.11 (3.89)	−1.51	0.03 *	4.73 (2.33)	4.98 (3.81)	0.25	0.09	−1.87	0.04 *
Maxillary incisor inclination (°)	106.23 (8.54)	102.9 (8.00)	−3.33	0.05 *	105.62 (7.53)	109.32 (8.45)	3.70	0.04 *	−6.42	0.04 *
IMPA (°)	88 (5.45)	86.68 (5.66)	−1.32	0.09	87.23 (4.73)	88.75 (5.78)	1.52	0.09	−2.07	0.07
OVJ (mm)	3.53 (2.25)	1.98 (2.48)	−1.55	0.01 *	3.67 (2.39)	3.14 (2.41)	−0.53	0.06	−1.16	0.01 *
OVB (mm)	2.98 (1.25)	3.49 (1.95)	0.51	0.04 *	3.05 (1.67)	1.51 (2.86)	−1.54	0.01 *	1.98	0.02 *

* $p = 0.05$; SD = standard deviation.

3.2. Intergroup Comparisons

In the intergroup comparisons, the RS group showed a larger arch width than the CAs subjects after therapy. This result was evidenced by statistically significant increases in smile width (1.36 mm) and smile index (0.86 ratio), and a reduction in buccal corridor (−2.87 ratio, −2.42 mm) in the RS group with respect to the CAs group.

The differences in incisor position after treatment, as already underlined in the intragroup comparisons, were statistically supported in the intergroup comparison. In this analysis, increases were evident in smile cant (0.61°), incisor gingival display (1.40 mm), maxillary dental midline (0.79 mm), canine gingival display (0.86 mm) and OVB (1.98 mm) values in the RS group compared to the CAs group. In the RS group, the absence of support to the anterior teeth allowed them to collapse into the space gained after orthopedic expansion, reflected in statistical reductions in C angulation (−6.20°), maxillary incisor position (−1.87 mm), maxillary incisor inclination (−6.42°) and OVJ (−1.16 mm) parameters compared to the CAs subjects.

Comparisons of the post-treatment (T2) intergroup measurements are reported in Table 5.

4. Discussion

The aim of this study was to compare preadolescents' smile outcomes after two different early orthodontic treatments: CAs and traditional interceptive therapy with RS [33]. These two orthodontic approaches are different to each other: RME produces skeletal effects in growing subjects [41,42], whereas CAs exclusively induce dentoalveolar changes [43]. Our aim was to compare the two approaches by focusing exclusively on the different smile outcomes.

The evaluation of the orthodontic treatments on smile aesthetics is an important area of study, as smile improvement is a crucial motivation for patients [36]. Therefore, it is important to understand how the types of treatment affect the smile.

Of the smile variables analyzed in this study, both groups showed an increase in smile width and a decrease in the buccal corridors. This suggests that both types of treatment induce improvements in smile aesthetics [14,17,18,44].

Previous reports have demonstrated that the transversal dimension of the smile showed a statistically significant increase following skeletal expansion compared to the baseline [18], with increases in intercanine and intermolar width observed after expansion [3]. These results are justified by the fact that RME had an impact on the median and surrounding sutures of the maxilla, increasing the bone tissue support of the dental arches [44,45].

At the same time, our results agree with previous studies that have reported dentoalveolar arch expansion with controlled movement of the teeth following the use of CAs [23,24,27,33,46]. These effects are comparable to those of an SME. In fact, CAs allow for digital planning of the upper arch expansion, using a combination of buccal dental tipping and bodily translation of the posterior teeth [24].

The post-treatment smile score comparisons showed an increase in smile width and a reduction in the buccal corridors, with statistically greater variation in the RS group than the CAs group.

Many studies have confirmed that skeletal expansion is greater and more stable than dentoalveolar expansion [47]. Several authors have underlined the effectiveness of RME in arch expansion by opening the mid-palatal suture in growing individuals [41,42] and also inducing a significant reduction in the buccal corridors [48]. Conversely, Houle et al. in 2017 [46] demonstrated that the efficiency of expansion movement with CAs can be reduced when moving posteriorly into the arch, finding a statistically significant difference between digital planning and final outcome, with predictions worsening toward the posterior region of the arch. Expansion across the first permanent molars is significantly less predictable, which may be due to a CA's limited ability to exert orthodontic forces on the terminal tooth, as recently reported by Kim et al. [34].

In support of this thesis, Cretella Lombardo et al. [28] reported a better expansion, using CAs treatment, at the levels of the first and second deciduous molars compared to the first permanent molars.

The forces generated with the CAs system led to an adaptation comparable to slow maxillary expanders [27]. Indeed, according to Phan X. and Ling P.H., greater success is obtained with CAs when not treating skeletally constricted arches [25].

The results of the dental variables analyzed in this study show differences between the two groups. In agreement with the previous literature, the RS group showed a decrease in OVJ as a consequence of increases in incisor lingualization and OVB.

RME was fixed on the first molars, without any control on the other teeth. Therefore, the movements of extrusion and lingualization were made possible. Cerruto et al. [19] reported that RME might guarantee more space for the upper central and lateral incisors, which are therefore free to align themselves and rotate mesially whilst also under the influence of the upper lip [49]. Cobra de Carvalho et al. [18] demonstrated that central and lateral incisors' crown exposures were statically greater after expansion completion, underling their extrusion and an increase in OVB. This is in accordance with Proffit W.R.'s theory of equilibrium [50], which might explain the spontaneous retraction and alignment of the upper incisors.

The CAs group showed significant increases in maxillary incisor inclination and OVJ values, while there was a reduction in OVB. Furthermore, if RME only acted on the first permanent molars, clear aligners were digitally set on the alignment of the arches and the proclination of the upper incisors, leaving an OVJ value at least 2 mm to allow for mandibular growth. Advantageously, this technology enables movements on the three space dimensions simultaneously, correcting different issues at the same time [37] by levelling the dental arch and determining a partial midline correction through a digital plan.

After treatment in the RS group, the primary canine stayed in the same position or underwent a slight lingual torque. As explained above, the creation of space in the anterior area after expansion likely provided the canines with more space and allowed them to lingualize, following the same movement of incisors. Ugolini et al. [49] have confirmed that 5.3 and 6.3 showed no statistically significant increase in angulation, proving that no dental tipping or dentoalveolar compensation were observed. The appliances used in the present study were not anchored to canines, which might have caused a smaller increase in the intercanine arch width [50].

Conversely, in the CAs group, the maxillary canine angulation was increased because the primary canines showed greater buccal tipping at the end of the treatment. According to the previous literature, one protocol recommended an overcorrection during dentoalveolar expansion and inclination of the anterior teeth for functional and aesthetic reasons [24]. Our results are in agreement with recent studies which reported that clear aligners are able to determine dentoalveolar expansion in the intercanine width, changing the arch-form in the anterior and lateral regions especially [34,51–55].

Evaluating the changes in gingival display after therapy, there were statistical differences between the two groups. The RS group evidenced an increase in the skeletal size of the anterior region of the maxilla, which allowed the incisors to move without any clinical control. Similar observations have been described in the literature, as Van Der Linden F.P.G.M evidenced the extrusion and lingual inclination of anterior teeth after RME [56]. Conversely, the CAs group evidenced better management of this clinical aspect, showing improved leveling of the upper arch with proper movements (anterior intrusion and posterior extrusion) and controlling the inclination of the anterior teeth at the same time, as demonstrated by a reduction in gingival display in the incisor and canine regions with the CAs. Therefore, this therapy encouraged correction of the excessive OVB values and guarantees adequate incisor inclination for future mandibular growth in children. These results confirm those reported by Lione et al. [57], who reported that a sequential expansion protocol with CAs which included a correction of anterior crowding induced significant modifications in gingival contour, resulting in a more harmonious smile. For these reasons, accurate management of the gingival display and smile aesthetics is possible even in early treatments utilizing this appliance [58].

The outcomes of our research highlight that both therapies guarantee adequate arch expansion in young subjects with moderate maxillary contraction. Clear aligners are a treatment option also suitable for performing phase 1 of orthodontic treatment. Phase 1 treatment in the presence of narrow maxillary arches is traditionally performed via RME and represents early interceptive orthodontics treatment for growing patients with mixed dentition. A correct management of orthodontic phase 1 allows an immediate improvement of malocclusions and simplifies the achievement of excellent results in the orthodontic phase 2. The results of this study, supported by evidence from previous literature, showed how during interceptive therapy the clear aligners allow the expansion of the maxillary arch and at the same time, movements on the three spaces dimensions. This allows you to correct several problems, including dental crowding, diastema, deep bite, open bite and increased overjet. Clear aligners represent a more aesthetic and comfortable alternative in respect to conventional fixed appliances accompanied by a reduction in the number of appointments or emergency visits and overall treatment time [59]. Additionally, the use of removable aligners minimizes the negative effects of fixed orthodontics on the periodontium and allows for better oral hygiene [60–62].

The limitations of the present study are to be found in the retrospective design of the study, in the use of photographic images for the esthetic analysis, in the sample size dimension and in the short-term evaluation. In future research, it would be interesting to integrate the data of smile photographs with CBCT files or digital models to obtain a complete analysis. Therefore, additional assessments are necessary to increase the sample size and to analyze the long-term stability of the results obtained.

5. Conclusions

Both therapies delivered an increase in smile width and decrease in buccal corridors in growing subjects with narrow arches.

Although the results of this study highlight how RME guarantees a wider smile after therapy, in cases of moderate contraction of the arches, the treatment with clear aligners guarantees better management of the aesthetics of the smile, allowing the simultaneous management of multiple aspects of the smile such as dental alignment, vertical positioning of the incisors and the management of dental inclinations.

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