Clear aligner orthodontic treatment: An international modified Delphi consensus study

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Ferrara, Genoa, Turin, Rome, La Spezia, Bologna, Trieste, Milan, Modena, Varese, and Naples, Italy, and Madrid and Ciuciad Real, Spain, and Gainesville, Fla, and Saar and Cologne, Germany, and Farmington, Conn, and San Francisco, Calif, and Athens, Greece, and Edmonton, Alberta, and Vancouver, British Columbia, Canada, and Nicosia, Cyprus, and Gandra, Portugal, and Tokyo, Japan, and Melbourne, Victoria, Australia, and Choisy le Roi, France

Introduction: This study aimed to establish a consensus, thanks to the participation of a large group of experts in the field of aligner therapy, on several of its clinical and extraclinical aspects, with particular reference to its potential and biomechanical limitations. **Methods:** A Delphi study was conducted in 3 rounds. On the basis of the most recent systematic reviews in the literature, the steering committee formulated 35 questions. A group of 36 international experts agreed to participate in the survey and were asked to respond to the questions, choosing their level of agreement on a scale of 1-5 in the first round, then from 1 to 3 in the second, and finally with a yes or no response in the third, progressively narrowing the field of research. The items for which consensus (≥70%) was obtained were accepted; the others were reformulated. **Results:** On the basis of the analysis of the experts' responses, 68 questions were reformulated for the second round and 28 for the third round. After 3 rounds, the study generated 47 consensus statements regarding biomechanical aspects and extraclinical factors. **Conclusions:** The study, based on the modified Delphi method, collected the opinion of

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experts, comparing it with the scientific literature to evaluate the potential and limitations of orthodontic aligners, obtaining 47 consensus statements related to biomechanics and extraclinical factors. (Am J Orthod Dentofacial Orthop 2025;168:620-38)

Although esthetic aligners have rapidly gained popularity and been the subject of significant research by universities and manufacturers alike, their effectiveness in various clinical settings remains a topic of discussion among professionals in the field.[1–3]

Since 2015, several systematic reviews have assessed the results of studies on the effectiveness of clear aligner treatment (CAT) in controlling orthodontic tooth movement.[3–10] Although the results that emerged from these reviews, published between 2015 and 2024, are fairly homogeneous, there is still a discrepancy between the claims of some opinion leaders who extol the advantages and benefits of aligners, maintaining that they can be used to treat all types of malocclusions and other research groups that instead underline their limitations and question the real biomechanical abilities and predictability of movement, in particular in moderate to complex malocclusion.[11] Exacerbating this situation, artificial intelligence platforms that provide particularly misleading information, supporting false myths such as the possibility of reducing the need for orthognathic surgery, extraction, or improving upper airway function, can be found on the internet.[12] These platforms are often consulted directly by patients, and this can become an additional factor that leads to confusion.

With a view to clarifying the issue, a Delphi method survey[13] in which a group of experts was asked to share their experience and opinions on various issues concerning aligners, was set up; various aspects of the treatment were analyzed, from the predictability of certain movements to the choice of staging, as well as its practical limitations and several extraclinical issues. The results are presented and discussed in detail, comparing them with evidence from the most recent scientific literature, including research articles and systematic reviews. The objective of this study was 2-fold: first, to try to reach a consensus on specific controversial issues concerning clear aligner treatment, and second, to verify whether the clinical experience of the experts coincided with the available scientific evidence.

MATERIAL AND METHODS

Methods

This Delphi study on aligners was conducted by a steering committee composed of a chair (N.A.) and a group of expert researchers from the University of Ferrara Postgraduate School of Orthodontics (L.L. and G.S.) and the Universities of Genoa (T.C.), Turin (F.G.), and Rome (A.G.).

To participate in the survey, potential panel members had to meet at least 1 of the following inclusion criteria: membership of the American Board of Orthodontics, European Board of Orthodontics, Italian Board of Orthodontics, Italian Board of Orthodontics Aligner or European Board of Aligner Orthodontics Boards, $\geq$5 publications on the topic of aligners in accredited journals or $>$15 years of internationally recognized expertise in the field of aligners. Thirty-six experts who met these criteria were selected and invited to participate by the chair (Table I). All potential panelists were sent an email to which a description of the project, outlining the aims and scope of the survey, which was attached. Of the experts who initially agreed to participate, 6 dropped out, so the survey ultimately collected responses from 30 participants, whose anonymity is protected.

The questions in the survey were formulated on the basis of the most recent systematic reviews, with the aim of dissecting various aligner-related issues.[3–10] The main topics regarding the use of aligners were analyzed, with particular emphasis on the issues of greatest controversy and clinical impact. The most basic aspects were nevertheless included, summarizing the positions expressed by the group of experts.

The steering committee selected the most recent literature reviews on aligners and established a list of topics on which to formulate items, ultimately arriving at a total of 35 questions: 4 of a general nature, 9 on predictability of movements, 2 on attachments, 3 on dentoalveolar discrepancies, 3 on extractions, 5 on mixed dentition, 4 on retention, and 5 on extraclinical factors.

The survey itself was created using Google Forms software and sent via e-mail in the form of a link to each participant. As defined in the ACCORD (ACcurate COnsensus Reporting Document) guidelines,[14] experts were asked to answer each question by selecting their level of agreement on a scale of 1-5 (1, strongly disagree; 2, disagree; 3, agree; 4, strongly agree; 5, very strongly agree), 1-3 (1, disagree; 2, agree; 3, strongly agree), with multiple-choice questions or dichotomous answers (yes or no).

Table I. Panelists included in the Delphi study

Name of panelist	*Affiliation*
Aldo Giancotti	Department of Clinical Sciences and Translational Medicine, University of Rome "Tor Vergata," Rome, Italy
Andre El Zoghbi	Private practice, Choisy le Roi, France
Angela Arreghini	Adjunct Professor, Postgraduate School of Orthodontics, University of Ferrara, Ferrara, Italy
Bjorn Ludwig	Department of Orthodontics, University of Homburg, Saar, Germany
Calogero Dolce	Professor and Chair, Department of Orthodontics, University of Florida, Gainesville, Fla
Camilla Molinari	Private practice, Modena, Italy
Carlos Flores Mir	Professor and Senior Director of Graduate Studies, Mike Petryk School of Dentistry, University of Alberta, Edmonton Clinic Health Academy, Edmonton, Alberta, Canada
Chris Laspos	Assistant Professor, School of Denistry, European University Cyprus, Nicosia, Cyprus
Davide Mirabella	Adjunct Professor, Postgraduate School of Orthodontics, University of Ferrara, Ferrara, Italy
Enzo Pasciuti	Private practice, Varese, Italy
Filippo Pepe	Phd Student, Postgraduate School of Orthodontics, University of Ferrara, Ferrara, Italy
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Francesco Garino	Private practice, Turin, Italy
Gianluigi Fiorillo	Dental School, San Raffaele Vita-Salute University of Milan, Milan, Italy
Gina Theodoridis	Private practice, Athens, Greece
Giuseppe Siciliani	Professor, Postgraduate School of Orthodontics, University of Ferrara, Ferrara, Italy
Jörg Schwarze	Private practice, Cologne, Germany
Juan Carlos Varela	Faculty of Dentistry, Alfonso X El Sabio University, Madrid, Spain
Kenji Ojima	Private practice, Tokyo, Japan
Luca Lombardo	Professor and Chair, Postgraduate School of Orthodontics, University of Ferrara, Ferrara, Italy
Manuel Roman	Director, Master's Program in Orthodontics, University of Alcalá, Madrid, Spain
Mauro Cozzani	Istituto Giuseppe Cozzani, La Spezia, Italy
Mercedes Revenaz	Private practice, Bologna, Italy
Niki Arveda	Adjunct Professor, Postgraduate School of Orthodontics, University of Ferrara, Ferrara, Italy
Oliverio Teresa	Adjunct Professor, Postgraduate School of Orthodontics, University of Ferrara, Ferrara, Italy
Paolo Manzo	Adjunct Professor, Postgraduate School of Orthodontics, University of Ferrara, Ferrara, Italy
Ravindra Nanda	Professor and Head, Department of Orthodontics, School of Dental Medicine, University of Connecticut, Farmington, Conn
Riccardo Riatti	Adjunct Professor, University of Trieste, Trieste, Italy
Robert L. Boyd	Professor Emeritus, Department of Orthodontics, University of the Pacific, San Francisco, Calif
Sandra Tai	Clinical Assistant Professor, Department of Orthodontics, University of British Columbia, Vancouver, British Columbia, Canada
Susana Palma	Private practice, Ciuciad Real, Spain
Teresa Pinho	Full Professor, UNIPRO, Oral Pathology and Rehabilitation Research Unit, University Institute of Health Sciences (IUCS), CESPU, Gandra, Portugal
Tommaso Castroflorio	Postgraduate School of Orthodontics, University of Genoa, Genoa, Italy
Ute Schneider Moser	Adjunct Associate Professor, Department of Orthodontics, School of Dental Medicine, University of Pennsylvania, Philadelphia, Pa
Vicki Vlaskalic	Clinical Instructor, Department of Orthodontics, University of Melbourne, Melbourne, Victoria, Australia
Vincenzo D'Anto	Associate Professor, Department of Neurosciences, Reproductive Sciences and Oral Sciences, School of Orthodontics, University of Naples Federico II, Naples, Italy

The items for which the consensus threshold was not reached in the first round were used as a guide for reformulation into a more specific form. The specificity of the question was based on 2 main aspects, including increasing and/or reducing the extent of possible clinical movements and restriction of possible response options. The number of rounds that would be necessary was not defined in advance, and a total of 3 rounds was conducted. Despite the 3 rounds, no consensus was reached on some issues.

Although various approaches to reporting consensus have been described in the literature,[15,16] the most commonly used method involves specifying a percentage of agreement within the panel of experts.[17]

The range generally accepted as indicative of consensus is wide (50%-97%) and, in many Delphi studies, is not defined a priori.[18] In this Delphi study, the consensus threshold was defined a priori as a percentage of agreement of ≥70%, representing a median value among those commonly used in the literature. This level of agreement has been considered appropriate in previous studies and is consistent with the quality indicators recommended for the Delphi methodology.[19] This threshold was not changed during the survey.

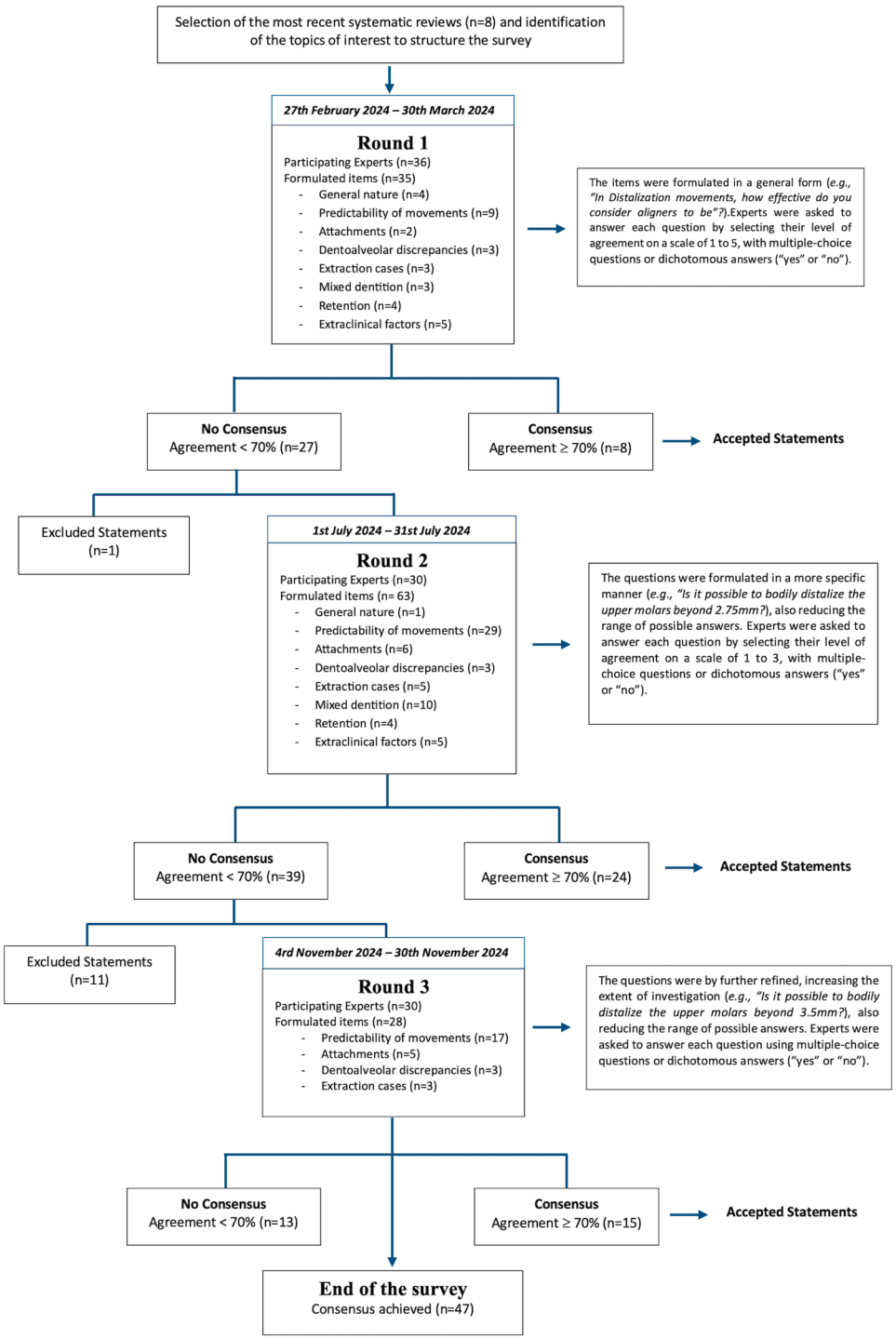

Fig. Delphi flow chart:schematic description of the 3 Rounds, showing the statements investigated and the percentages of agreement ≥70% (Consensus) and <70% (No Consensus) obtained at each phase until the end of the survey.

When consensus was reached, the item was accepted; otherwise, it was reformulated for the next round. If the steering committee determined that consensus could not be reached because of differing opinions among experts, the statement was excluded from subsequent rounds.

Table II. Statements that achieved consensus

Statement	*Agreement, %*	*Consensus*	*Round*
Effectiveness of aligners in performing different types of tooth movement			
Tipping	72% (level 5 of effectiveness)	Yes	1
Mesialization			
Maxillary molars <2.75 mm	75% (not effective)	Yes	2
Mandibular molars >2.75 mm	87.5% (not effective)	Yes	2
Distalization			
Mandibular molars >2.75 mm	83.3% (not effective)	Yes	2
Maxillary molars >3.50 mm	83.3% (not effective)	Yes	3
Intrusion			
Maxillary premolars and canines >1.50 mm	87.5% (not effective)	Yes	2
Mandibular premolars and canines >1.50 mm	87% (not effective)	Yes	2
Maxillary molars >1.50 mm	87.5% (not effective)	Yes	2
Mandibular molars >1.50 mm	95.8% (not effective)	Yes	2
Mandibular incisors >1.50 mm	71.7% (not effective)	Yes	2
Maxillary incisors >2.00 mm	70.8% (not effective)	Yes	2
Extrusion			
Maxillary premolars and canines >1.50 mm	73.9% (not effective)	Yes	2
Mandibular premolars and canines >1.50 mm	75% (not effective)	Yes	2
Maxillary molars >1.5 mm	91.7% (not effective)	Yes	2
Mandibular molars >1.5 mm	87.5% (not effective)	Yes	2
Rotation			
Incisors <10°	75% (highly effective)	Yes	2
Incisors between 10° and 20°	91.7% (highly effective)	Yes	3
Incisors >20°	79.1% (moderately effective)	Yes	3
Premolars and canines <10°	75% (highly effective)	Yes	3
Premolars and canines >20°	75% (minimally effective)	Yes	3
Molars <5°	100% (highly effective)	Yes	3
≤1.5° per aligner at the incisors	75%	Yes	3
≤1.5° per aligner at the premolars and canines	83%	Yes	3
≤1.5° per aligner at the molars	75%	Yes	3
Effectiveness of attachments in achieving treatment goals			
Rotation	70.8% (moderately effective)	Yes	3
Torque	79.2% (moderately effective)	Yes	3
Distalization	75% (moderately effective)	Yes	3
Extrusion	75% (highly effective)	Yes	3
Utilization rate and effectiveness of aligners in extraction patients			
Premolar extraction	70.8% (0%-40% of extraction patients)	Yes	3
Mandibular incisor extraction	79.2% (highly effective)	Yes	3
4 premolar extractions	70.8% (minimally effective)	Yes	3
Use of aligners and treatment goals in mixed dentition			
Orthopedic goals on the transverse plane	76% (no)	Yes	1
Use in children aged 8-13 y	70.8% (yes)	Yes	2
Orthopedic movements only	71.4% (no)	Yes	2
Orthopedic goals in Class III malocclusion	85.7% (no)	Yes	2
Orthopedic goals in deepbite malocclusion	71.4% (no)	Yes	2
Orthopedic goals in open bite malocclusion	71.4% (no)	Yes	2
Influence of different extraclinical factors on the choice of aligner to use			
Scientific background	87% (high influence)	Yes	2
Customer service	75% (high influence)	Yes	2
Necessity of panoramic radiograph, teleradiograph, and digital setup for patients treated with aligners			
Panoramic radiograph, teleradiograph	80% (yes)	Yes	1
Digital setup	100% (yes)	Yes	1
Retention			
The rate of patients for whom retention is planned	100% (80%-100% of the patients)	Yes	1
Planned retention duration	84% (forever)	Yes	1
Retention type in the mandibular arch	78.3% (fixed)	Yes	1
Retention type in the maxillary arch	84% (removable)	Yes	1

Table II. Continued

Statement	*Agreement, %*	*Consensus*	*Round*
Factors influencing the type of retention to use			
Less compliance	91.7% (fixed retention)	Yes	1
Better hygiene and periodontal perspective	87% (removable)	Yes	1

Note. Statement refers to the item that was evaluated during the survey, whereas the agreement indicates the percentage of experts in agreement.

Table III. Percentage agreement on the necessity of panoramic radiograph, teleradiography, and digital setup for patients treated with aligners

	Agreement, %	
Statement	*Yes*	*No*
Panoramic radiograph and teleradiography	80%*	
Digital setup	100%*	

Note. Statement indicates factors investigated in the survey, whereas agreement refers to the percentage of experts in agreement.
*Statements that reached consensus (≥70%).

RESULTS

The chair sent the invitation to 36 potential panel members. All 36 accepted the invitation and were subsequently included in the panel. Of the experts who accepted, 6 dropped out during the survey, which ultimately ended with 30 participants.

First round

The first round began on February 27, 2024, and ended on March 30, 2024. The panel members' response rate was 100%. Consensus was reached on 8 of the 35 items posed: 2 on the use of panoramic radiography, teleradiography and digital setup, 1 on the effectiveness of aligners in achieving the tipping movement, 1 on not using aligners for transverse skeletal effects in mixed dentition, 1 on retention planning at the end of treatment, 1 on the lifetime duration of the same, 1 on the choice of removable retainers for the maxillary arch and 1 for fixed retention in the mandibular arch. Of the 27 items on which no consensus was reached, 26 were reformulated to investigate the various topics with more specificity and re-proposed as a total of 63 new items: 1 of a general nature, 29 on the effectiveness of aligners in achieving the various movements, 6 on attachments, 3 on dentoalveolar discrepancies, 5 on extractions, 10 on mixed dentition, 4 on retention and 5 on extraclinical factors.

Second round

The second phase began on July 1, 2024, with a response deadline set for July 31, 2024. Among the 36 participants, 6 dropped out, and the second round was therefore completed by 30 experts, who reached consensus on 24 of the 63 items. The steering committee met to finalize a new list of questions; of the 39 items with no consensus in the second round, 11 were discarded, and 28 were reformulated for the third.

Third round

The third round began on November 4, 2024, with a response deadline set for November 30, 2024. The panel members' response rate was 100%. Of the 28 items, consensus was reached on 15, which were accepted. As for the remaining 13, the steering committee determined that consensus could not be reached because of the diverging opinions among experts. Thus, the Delphi survey ended in the third round with a total of 47 consensus statements (Fig; Table II).

DISCUSSION

General considerations

The first part of the survey was dedicated to general considerations necessary to better understand the selected sample of experts. A consensus was nevertheless reached on the use of both panoramic radiography and teleradiography for the correct diagnosis of patients (80%) and on the use of a digital setup to deal with aligner treatments, of which the consensus was unanimous (Table III).

Table IV shows the percentage of patients that our experts treat with aligners in clinical practice. Fifty percent adopt them from 0% to 40%, 25% from 40% to 70%, and the remaining 25% from 70% to 100%.

Another factor investigated in this round was the use of hybrid treatment (ie, aligners in combination with ≥1 auxiliary [expanders, distalizing or mesializing appliances, sectionals, attachments, miniscrews, etc.]). It was found that 50% of experts use hybrid treatment in 0% to 40% of aligner patients, whereas 60% use it in 0%-20% and 20% use it in 20%-40%. This last figure is particularly interesting as it indicates that 80% of

Table IV. Percentage agreement on patients treated with aligners and on the use of hybrid treatment

	Agreement, %							
	First round					*Second round*		
Statement	*0%-20%*	*20%-40%*	*40%-60%*	*60%-80%*	*80%-100%*	*0%-40%*	*40%-70%*	*70%-100%*
Patients treated with an aligner		28%				50%		
Use of hybrid treatment	60%					–	–	–

Note. Statement refers to factors investigated in the survey, whereas the agreement indicates the first and second round percentage of experts agreeing on the rate of patients treated with aligners and on the use of hybrid treatments.

experts rely on a hybrid treatment in <40% of aligner patients, which suggests that the group of experts has considerable confidence in the biomechanical abilities of aligners to resolve most malocclusions.

Efficacy of aligners in performing various types of dental movement

Tipping

Consensus was reached, with 72% of experts agreeing that aligners are able to achieve tipping movements with maximum efficacy (Table V). These results are in line with the literature reports that aligners achieve the greatest accuracy in uncontrolled tipping movements, particularly buccolingual/palatal inclination of the crown (56%).[20–22] The reason for this high predictability of movement is due to the simple biomechanics of the uncontrolled tipping movement, which does not require any torque, just a single force exerted on the tooth crown.[22]

Distalization

In the second round, a percentage agreement of 58.3% was reached regarding the inability of clear aligners to achieve distalization of the maxillary molars beyond 2.75 mm; when the distalization threshold was raised to 3.5 mm in the third round, the percentage of agreement among experts increased, and a consensus of 83.3% was reached. However, for mandibular molars, consensus was reached in the second round, in which 83.3% of experts agreed that it is impossible to distalize the mandibular molars in a bodily fashion beyond 2.75 mm with clear aligners (Table V).

The literature confirms these results but seems to be even more cautious as to the extent of the bodily distalization that can be achieved with aligners,[23] indicating that this is a maximum of 2 mm for the maxillary molars; beyond this threshold, unwanted coronal tipping effects may result because of the reduced biomechanical ability of the aligner to upright the root. This can be associated with distal coronal rotation of the first molar, which, although assisting in improving the molar class, would not be bodily distalization per se. The discrepancy between the literature and the panel's opinion could be attributed to the rigor with which real bodily movement is assessed in clinical practice, in which it is particularly difficult to effectively ascertain how the improvement of the molar class has occurred. Several mechanisms, including the use of intermaxillary elastics, the starting coronal tip and rotation of the first molar, stripping and concomitant dentoalveolar expansion, can confuse the clinician in this regard. Even if accurate superimposition is attempted, it remains difficult to effectively assess the actual bodily distalization, and this can sometimes be overestimated by the clinician. These movements are more complex if performed in the mandibular arch because of the greater bone density with respect to the maxilla,[24,25] as well as anatomic restrictions posed by the submandibular fossa, the mylohyoid crest, the considerable thickness of the soft tissues, and the possible presence of third molars.[26,27]

Mesialization

Consensus was reached as 75% and 87.5% of experts, respectively, believe that aligners are unable to achieve bodily mesialization of the maxillary and mandibular molars >2.75 mm (Table V). Molar mesialization, as stated below in the Discussion, is considered the most difficult movement to achieve with aligners. In this regard, the literature underscores that vertical and horizontal bowing effects are extremely common.[28]

Intrusion

Consensus was obtained as regard intrusion of the maxillary molars, mandibular molars, maxillary canines and premolars, canines and mandibular premolars, with 87.5%, 95.8%, 87.5%, and 87% of experts, respectively, agreeing that aligners are not effective

Table V. Analysis of the effectiveness of aligners in performing tipping, mesialization, distalization, intrusion, and extrusion movements without miniscrews or elastics

	Agreement, %		
Tooth type and extent	*1–5 Effectiveness scale*	*Yes*	*No*
Tipping			
Round 1			
All teeth	72% (level 5)*		
Round 2			
–			
Round 3			
–			
Mesialization			
Round 1			
All teeth	44% (level 3)		
Round 2			
Maxillary molars <2.75 mm			75%*
Mandibular molars >2.75 mm			87.5%*
Round 3			
–			
Distalization			
Round 1			
All teeth	36% (level 4)		
Round 2			
Maxillary molars >2.75 mm			58.3%
Mandibular molars >2.75 mm			83.3%*
Round 3			
Maxillary molars >3.5 mm			83.3%*
Intrusion			
Round 1			
All teeth	52% (level 3)		
Round 2			
Maxillary premolars and canines >1.5 mm			87.5%*
Mandibular premolars and canines >1.5 mm			87%*
Maxillary molars >1.5 mm			87.5%*
Mandibular molars >1.5 mm			95.8%*
Maxillary incisors >1.5 mm			69.6%
Mandibular incisors >1.5 mm			71.7%*
Round 3			
Maxillary incisors >2 mm			70.8%*
Extrusion			
Round 1			
All teeth	40% (level 2)		
Round 2			
Maxillary premolars and canines >1.5 mm			73.9%*
Mandibular premolars and canines >1.5 mm			75%*
Maxillary molars >1.5 mm			91.7%*
Mandibular molars >1.5 mm			87.5%*
Maxillary incisors >1.5 mm			54.2%
Mandibular incisors >1.5 mm			54.2%
Round 3			
Maxillary incisors >2 mm			66.7%
Mandibular incisors >2 mm			58.3%

Note. Movements indicate tooth movements investigated in the survey, whereas tooth type and extent refer to teeth investigated for each movement and extent of the movements for each tooth type, and agreement indicates the percentage of experts agreeing on the effectiveness of aligners by movement and tooth type.
*Statements that reached consensus (≥70%).

Table VI. Analysis of the effectiveness of aligners in performing rotation movements without auxiliaries

	Agreement, %							
Tooth type and extent	*Effectiveness scale 1-5*	*Highly effective*	*Moderately effective*	*Minimally effective*	*% Agreement in staging methods/aligner*			
Round 1								
Premolars and canines	44% (level 3)					–		
Molars	28% (level 4)							
Incisors	48% (level 4)							
Round 2						≤1°	>1.0° to ≤1.5°	>1.5°
Premolars and canines <10°		54.2%			Premolars and canines	47.8%		
Premolars and canines between 10° and 20°			50%		Molars	45.8%		
Premolars and canines >20°				58.3%	Incisors		37.5%	
Molars <5°		54.2%						
Molars between 5° and 10°		62.5%						
Molars >10°				50%				
Incisors <10°		75%*						
Incisors between 10° and 20°		50%						
Incisors >20°			58.3%					
Round 3								
Premolars and canines <10°		75%*				≤1.5°	>1.5°	
Premolars and canines between 10° and 20°			56.5%		Premolars and canines	83%*		
Premolars and canines >20°				75%*	Molars	75%*		
Molars <5°		100%*			Incisors	75%*		
Molars between 5° and 10°		54.2%						
Molars >10°				62.5%				
Incisors between 10° and 20°		91.7%*						
Incisors >20°			79.1%*					

Note. Movement refers to tooth movement investigated in the survey, whereas tooth type and extent indicate teeth investigated for each movement and extent of the movements for each tooth type; agreement indicates percentage agreement among experts on the effectiveness of aligners by movement and tooth type, and staging methods/aligner indicates the amount of movement programmed for each aligner step.
*Statements that reached consensus (≥70%).

Table VII. Analysis of the most difficult movements to achieve with aligners

	Agreement, %					
Round	*Mesialization*	*Distalization*	*Torque*	*Rotation*	*Extrusion*	*Intrusion*
1	36%	–	36%	4%	20%	4%
2	33.3%	–	41.7%	–	25%	–
3	60.9%	–	39.1%	–	–	–

Note. Agreement indicates the percentage of experts agreeing on the most difficult movements to achieve with aligners.

for bodily intrusion movements >1.5 mm in the absence of miniscrews. For the maxillary incisors, 70.8% consensus was reached in the third round, when a greater threshold of movement (>2 mm) was specified and the bodily nature of the movement was further emphasized. As for the mandibular incisors, 70% of the panel agreed that aligners are not effective at performing intrusion beyond the 1.5 mm threshold (Table V). These opinions are confirmed by the literature, which underscores that vertical movements, as compared with transverse or sagittal movements, are the most difficult to achieve with aligners, with the greatest discrepancy between the planned movement and that achieved (−0.71 mm).[29,30]

Furthermore, the most recent systematic reviews that have examined the treatment of deepbite show an average correction of no more than 1.5 mm.[4,31] Possible explanations for this shortfall include a posterior bite-block effect of aligners and an inability to adequately direct apical intrusive forces, along with a reported lack of ability to extrude posterior teeth.[32]

Extrusion

Consensus was obtained as regard extrusion of the maxillary molars, mandibular molars, maxillary canines and premolars, canines and mandibular premolars, with, respectively, 91.7%, 87.5%, 73.9%, and 75% of experts agreeing that aligners are not effective for bodily extrusion movements >1.5 mm without the use of elastics. As for the maxillary and mandibular incisors, 66.7% and 58.3% of the experts, respectively, considered aligners ineffective at achieving extrusion >2 mm (Table V). There is a slight discrepancy between the panel's views and the literature, which is more cautious, especially concerning the incisors, reporting that the maximum possible movement is equal to 1.5 mm, as compared with the 2.0 mm cited by the panel. Concerning corrections on the vertical plane, the literature indicates that bite closure and opening are mainly ascribable to vestibular or lingual crown tipping and the respective extrusion or intrusion movement that follows.[4,31] Minimal changes in the vertical position of the molars and the angle of the mandibular plane have been found.[31] In this context, the use of auxiliaries such as miniscrews and elastics seems to be essential in moderate to complex malocclusions.

Rotation

Premolars and canines. In terms of rotation efficacy, consensus was only achieved for slight rotations (<10°), for which aligners are considered highly effective, and for major rotations (>20°), for which they are considered minimally effective (Table VI). Specifically, in the third round, 75% of experts agreed that, in the absence of auxiliaries (buttons and chains), aligners are highly effective for rotations <10°. As for rotations of between 10° and 20°, 56.5% considered the aligners to be moderately effective, and, finally, 75% considered aligners to be minimally effective for rotations >20°.

Analyzing the staging mode, a consensus was reached, with 82.6% of experts declaring that they adopt a ≤1.5° staging protocol, which confirms the great difficulty in achieving rotations of canines and premolars with aligners (Table VI).

Molars. Consensus was only reached with regard to the resolution of rotations <5°. As regard rotations of between 5° and 10° and especially those >10°, opinions were strongly divided by almost 50%. For rotations <5°, 100% agreed that aligners were highly effective, whereas only 54.2% considered aligners highly effective for rotations between 5° and 10°, and 62.5% of experts considered aligners minimally effective for rotations >10°. A consensus on staging was reached in the third round, with 75% of experts stating that they adopt a ≤1.5° staging protocol (Table VI).

Incisors. Consensus was reached regarding the rotation of the incisors. Specifically, 75% of experts consider aligners to be highly effective for rotations <10°. Consensus was also reached for rotations of between 10° and 20°, with 91.7% agreement in the third round, for which aligners are deemed highly effective. Finally, for rotations >20°, 79.1% consider them moderately effective.

Analysis of staging methods revealed a consensus for all tooth types, with the experts considering a value of ≤1.5° per aligner, thereby confirming their great difficulty in achieving rotations (Table VI).

Summarizing all the above, we can conclude that the panel encountered the greatest difficulty when using aligners to perform rotations of the premolars and canines >20° and rotations of the molars >10°. The main reason for this is closely related to the rounded anatomy of these tooth groups, which limits the surfaces against which the aligner can develop adequate force couples and therefore the force that can be exerted. This is in agreement with the literature, which reports that accuracy is significantly reduced when the rotation to be corrected exceeds 15°.[4,33] Specifically, the lowest accuracy for rotations >10° is seen at the premolars, at approximately 40%.[4,34] Therefore, rotations of rounded teeth remain a topic of discussion and require careful planning in moderate to severe malocclusion.

Dentoalveolar expansion, a staging of <1.5° per aligner, and an adequate number of steps seem to be key factors in achieving derotation. Staging also has an important impact on the efficacy of treatment: for rotations with a planned movement of <1.5° per aligner, the accuracy is 41.8%, but this drops to 23% if a >1.5° movement per aligner is planned.[34,35]

Most difficult movements to achieve with aligners

In the third round, mesialization was decreed as the most complex movement to achieve by 60.9% of the experts, against 39.1% of the panel who opted for torque (Table VII). Several articles that have focused on torque control of the anterior teeth suggest that, in most patients, a large proportion of the torque planned for the anterior teeth is, in fact, ascribable to palatal crown tipping combined with extrusion.[36–38]

As for the mandibular incisors, the actual torque expression is reported to range 40%-60% of that planned, with neither the use of power ridges nor varying weekly wear protocols making much difference to the accuracy.[33,37,39] If we focus on the maxillary incisors, the predictability of torque is approximately 50%.[37] The literature agrees that to minimize the loss of planned movement, a greater number of aligners, overcorrection of root movement, and the need to have excellent retention, at least for the canines, are necessary.

Mesialization is a movement that has been amply studied in research into premolar extractions. Indeed, effective management of the extraction space requires a certain amount of mesialization of the posterior sectors to take place, particularly in patients with medium anchorage. This significantly increases the risk of vertical and transverse bowing, and the literature emphasizes the importance of anchorage preparation before and during molar mesialization. In this regard, planning of 1.7° anchorage preparation is suggested for every 0.25 mm of mesialization and 2° in patients with maximum anchorage. The literature also notes that bodily mesialization is particularly complex in the mandibular arch, in which less posterior anchorage is lost thanks to the higher bone density.[40] Given the objective difficulties in complex malocclusion, the use of auxiliaries and a hybrid approach is recommended, in addition to the various precautions taken during planning.[41]

Efficacy of attachments in furthering treatment goal

From the panel's responses, as reported in Table VIII, we can conclude that there is a broad consensus among experts in considering the role of attachments to be very or moderately effective, depending on the movements to be implemented. It is useful to underline that 68% of experts use attachments in most of their patients (80%-100%).

For rotational movements, a consensus of 70.8% was reached that attachments are moderately effective. The literature is not very homogeneous on this topic[42]; although some research has stated that the use of attachments increases the effectiveness of aligners,[43] many other scientific articles have found no statistically significant difference between groups of patients treated with vs without attachments.[34,44]

Given the difficulty, the use of larger attachments is recommended, as is slowing down staging. In this regard, vertical rectangular attachments yielded the best outcomes in premolar rotations when combined with staging of up to 1.2° per aligner in a finite element study.[35]

For torque movements, too, there was a consensus of 79.2% that attachments are moderately effective. The literature agrees that torque expression is particularly complex and suggests that one of the key factors in minimizing the issue is to obtain excellent alignment retention not only at the incisors, but also in the middle and posterior sectors of the arch.[11,37,42] In this regard, the role of vertical rectangular attachments at the canines is emphasized, further to maintaining the right fit on the incisors during retraction and torque expression.[36,38,39,45] During this movement, in fact, the aligner tends to dislodge occlusally from the incisors, creating a misfit and making it impossible to generate an adequate force couple. Achieving maximum aligner retention in the middle sectors of the arch and planning an intrusion movement of the frontal sector seem to

Table VIII. Effectiveness of attachments in achieving treatment goals by different dental movements, and the type of attachments most frequently used in bodily movements

	Agreement, %					Agreement on attachment type, %			
Statement	*Effectiveness scale 1-5*	*Effectiveness scale 1-3*	*Highly effective*	*Moderately effective*	*Minimally effective*	*Rectangular horizontal*	*Rectangular vertical*	*Beveled*	*Optimized*
Round 1									
Effectiveness	48% (level 4)					–			
Round 2									
Effectiveness		41.7% (level 2)				29.2%	54.2%	8.3%	8.3%
Rotation		45.8% (level 3)							
Torque		37.5% (levels 1 + 3)							
Distalization		41.7% (level 2)							
Extrusion		66.7 % (level 3)							
Round 3									
Effectiveness				58.3%		–			
Rotation				70.8%*					
Torque				79.2%*					
Distalization				75%*					
Extrusion			75%*						

Note. Statement refers to factors investigated in the survey (effectiveness of attachments in reaching treatment goals and their effectiveness in achieving different tooth movements), whereas agreement indicates the percentage of experts agreeing on the effectiveness of the attachments, and attachment type indicates the analysis of the attachments most frequently used for bodily movements.
*Statements that reached consensus (≥70%).

play key roles in retaining as much of the planned movement as possible.

Likewise, a consensus of 75% was reached that attachments are moderately effective for distalization movements. In the literature, several articles report that, in combination with attachments, aligners are able to perform distalization of up to 3 mm, confirming the view of our experts.[24,46] However, the singular role of attachments remains to be clarified; although several authors agree on using large horizontal or vertical rectangular attachments to generate root uprighting during distalization,[47] others have concluded that attachments play no significant role in achieving molar distalization.[48,49] Other researchers have stated that the actual role of attachments becomes important not so much during the distalization phase but rather in the anchoring phase and in maintaining the position reached by the molars during the subsequent retraction of the incisors.[48,50]

There is a consensus of 75% that attachments are highly effective in extrusion movements, as they offer a true thrust surface that the aligner can rely on to exert pressure. In this context, the recommended attachments are rectangular or beveled.[51,52]

However, as borne out by the literature, it is necessary to underline that the predictability of pure extrusion through aligners remains very low, approximately 20%-50%,[21,53] even if attachments are applied, and the average movement that can be obtained is approximately 1.5 mm. The experts' consensus on the great effectiveness of attachments must be contextualized within this range of movement, beyond which it is recommended to adopt the use of vertical elastics.

The last aspect investigated concerned the type of attachment most used by experts for bodily movements.

With a clear prevalence, 83.4%, rectangular attachments were the most adopted type, with 54.2% of experts preferring vertical rectangular and 29.2% horizontal rectangular (Table VIII). Only 16.6% say they mostly use optimized or beveled attachments. This finding is entirely concordant with the recent literature, which suggests the use of larger attachments, which are most conducive to generating force couples and ensuring correct retention.[42,47,51]

Use of aligners in dentoalveolar discrepancies

Table IX shows that there is a division in the panel's opinions, and consensus was therefore not reached on aligner use in either transverse or vertical and sagittal discrepancies. Only 50% of experts consider aligners to be highly effective at resolving transverse dentoalveolar discrepancies, whereas 66.7% believe aligners are moderately effective on the vertical plane, and 62.5% that

Table IX. Utilization rate and effectiveness of aligners in dentoalveolar discrepancies

	Agreement, %								
	Aligner utilization rate, %								
Discrepancy type	*0%-20%*	*20%-40%*	*40%-60%*	*60%-80%*	*80%-100%*	*Effectiveness scale 1-3*	*Highly effective*	*Moderately effective*	*Minimally effective*
Round 1									
Transverse	36%								
Vertical					32%				
Sagittal	28%				28%				
Round 2									
Transverse						50% (level 3)			
Vertical						58.3% (level 2)			
Sagittal						41.7% (level 2 + 3)			
Round 3									
Transverse							50%		50%
Vertical								66.7%	
Sagittal							62.5%		

Note. Discrepancy type refers to the dentoalveolar plane investigated in the survey, whereas the agreement indicates the rate of agreement among experts, and the aligner utilization rate indicates the percentage of patients treated with an aligner by different dentoalveolar discrepancy types.

they are highly effective on the sagittal plane. The lack of consensus among experts and the debate on this topic is based above all on their ability to express root torque and perform bodily movements, particularly in the posterior sectors.[54] In this regard, the literature emphasizes their evident limitations, attributing the causes to the biomechanical deficiency of aligners in expressing force couples, as well as any anatomic restrictions because of the contact of the posterior tooth roots with the vestibular cortex.[55] Overcorrection of root movement must be carefully weighed as, if excessive, it could create unwanted coronal movements and adverse effects, in turn responsible for occlusal interference that is difficult to correct.[32,56] This indicates that dentoalveolar discrepancies are resolved largely thanks to uncontrolled tipping movements, for which the effectiveness of aligners remains high.[4]

It should be emphasized that this topic warrants further investigation. Meanwhile, it is advisable to conduct a very careful diagnosis of each patient, paying particular attention to the initial position of the root apex when assessing the extent of overcorrection necessary.

Use of aligners in extraction cases

A consensus of 79.2% was reached for patients in which a single mandibular incisor is extracted, with the panel considering aligners to be highly effective (Table X). The literature supports this belief while emphasizing that predictability is limited. The most critical issues are found in control of the root apex, but it is reported that the discrepancy between setup and actual movements can be minimized through the strategic choice of the incisor to be extracted and the use of vertical rectangular attachments.[57]

A consensus of 70.8% was also reached that aligners are minimally effective in patients requiring the extraction of 4 premolars (Table X). The panel drew a similar conclusion regarding the extraction of 2 maxillary premolars, but failed to reach consensus; the agreement was only 62.5%. Nonetheless, both these conclusions largely concord with the literature, which also underscores the importance of case selection to achieving good outcomes.[45] Particular difficulties, specifically a risk of bowing, may be encountered in patients requiring large root movements, and in the control of the torque of the anterior teeth during space closure.[11,58]

The slightly lower percentage in patients with the extraction of only 2 maxillary premolars could be explained by the fact that the closure of mandibular extraction spaces usually requires greater root movement in the posterior sectors, particularly if molar mesialization is required.

In this regard, the importance of planning overcorrections, using rectangular attachments, sequencing the movement, and, in the most complex malocclusion, considering the use of skeletal anchorage and sectionals is emphasized.[41,59]

Use of aligners in mixed dentition

As Table XI shows, 70.8% of experts say that in patients with mixed dentition, they use aligners from 8-13 years old, which is the second transitional phase. Within this group, 71.4% use them for orthodontic and nonorthopedic purposes.

Table X. Utilization rate and effectiveness of aligners in extraction patients

	Agreement, %							
	Extraction patients treated with aligners, %			Effectiveness scale		Effectiveness		
Teeth to be extracted	0%-40%	40%-70%	70%-10%	1-5	1-3	Highly	Moderately	Minimally
Round 1								
Extraction patients	52%							
Mandibular incisor extraction				36% (level 4)				
Premolar extraction				36% (level 1)				
Round 2								
Mandibular incisor extraction		45.8%			45.8% (level 3)			
Premolar extraction	70.8%*							
4 premolar extractions					62.5% (level 1)			
2 premolar extractions					50% (level 1)			
Round 3								
Mandibular incisor extraction						79.2%*		
4 premolar extractions								70.8%*
2 premolar extractions								62.5%

Note. Teeth to be extracted refers to analysis of general extraction and specific extraction patterns, whereas agreement indicates the percentage of experts in agreement, and percentage of extraction patients treated with aligners indicates analysis of the rate of extraction treated with aligners by the experts.
*Statements that reached consensus (≥70%).

Table XI. Use of aligners and treatment goals in mixed dentition

	Agreement, %			
Statement	Yes	No	Orthopedic movement	Orthodontic movement
Round 1				
Aligner use in mixed dentition	60%			
Purpose of the treatment				60%
Orthopedic goals on the transverse plane		76%*		
Orthopedic goals on the sagittal plane		68%		
Orthopedic goals on the vertical plane		68%		
Round 2				
Use <8 years old		62.5%		
Use between 8-13 years old	70.8%*			
Orthodontic movements only	52.4%			
Orthopedic movements only		71.4%*		
Orthopedic goals on the sagittal plane		68.2%		
Orthopedic goals in Class II malocclusion		61.9%		
Orthopedic goals in Class III malocclusion		85.7%*		
Orthopedic goals on the vertical plane		68.2%		
Orthopedic goals in deepbite malocclusion		71.4%*		
Orthopedic goals in open bite malocclusion		71.4%*		

Note. Statement refers to factors investigated in the survey on the use of aligners in mixed dentition, whereas agreement indicates the percentage of experts agreeing on the use of aligners in mixed dentition and on the purpose of the treatment.
*Statements that reached consensus (≥70%).

Analyzing the orthopedic effects on the transverse plane, consensus was reached on not using aligners, thus giving priority to skeletal expansion through other, more effective appliances, as the literature states.[60-62]

A similar percentage, 68%, was found when considering the sagittal and vertical planes, although consensus was not reached. Specifically, 38.1% of the panel use them for the orthopedic treatment of Class II malocclusion, whereas only 14.3% for Class III

Table XII. Agreement rate on retention statement

		Agreement, %			
Statement	*Round*	*80%-100% of patients*	*Forever*	*Fixed retention*	*Removable retention*
Retention	1	100%*	84%*		
Mandibular arch	1			78.3%*	
Maxillary arch	1				84%*

Note. Statement refers to factors investigated in the survey, whereas agreement is the percentage of experts agreeing on the rate of patients in which retention is planned, its duration, and type.
*Statements that reached consensus (≥70%).

Table XIII. Factors influencing the type of retention to use

	Agreement, %	
Statement	*Fixed retention*	*Removable retention*
Better maintenance of results	66.7 %	
Less compliance	91.7%*	
Better hygiene and periodontal perspective		87%*

Note. Statement refers to factors investigated in the survey that can influence the type of retention to use, whereas agreement is the rate of agreement among experts on the type of retention to use in the presence of the different influencing factors.
*Statements that reached consensus (≥70%).

Table XIV. Influence of different extraclinical factors on the choice of aligner to use

	Agreement, %		
Extraclinical factor	*High influence*	*Moderate influence*	*Low influence*
Round 1			
Price		56%	
Scientific background	68%		
Commercial promotion		40%	40%
Effectiveness supported by opinion leaders		40%	40%
Customer service	60%		
Round 2			
Price			56.5%
Scientific background	87%*		
Commercial promotion			58.3%
Effectiveness supported by opinion leaders	56.5%		
Customer service	75%*		

Note. Extraclinical factors are factors investigated in the survey that can influence the type of aligner to use, whereas agreement is the rate of agreement among experts on the influence of the different factors analyzed.
*Statements that reached consensus (≥70%).

malocclusion. However, on the vertical plane, only 28.6% of experts said that they use aligners to correct an open bite and deepbite.

The reduced percentage of aligner use in orthopedic treatment of Class II malocclusion clashes with the scientific evidence. In fact, the literature indicates that aligners, using the mandibular advancement system, can achieve good orthopedic effects, comparable to those of traditional functional equipment, while attaining better control of the incisors.[63–65] However, it is worth mentioning that a recent systematic review did not find similar results in favor of aligners.[66]

Regarding the orthopedic use of aligners in Class III malocclusion, the literature is scarce, and there is no scientific evidence, which is why our experts rely on traditional treatments.

Retention

All experts stated that they plan retention for the end of treatment, and a broad consensus was reached that this should be lifelong, whereas a minority plan is use for a duration of 5 years (Tables XII and XIII). Regarding the mandibular arch, consensus (78.3%) was reached in preference of fixed retention, which was considered safer and less reliant on patient compliance, even though it makes maintaining good hygiene more challenging. Consensus on the use of removable retainers for the maxillary arch was also reached (84%), due mainly to the greater ease of oral hygiene procedures and the possible technical difficulty of placing a fixed retainer. The literature in this regard is limited to confirming the need to use retention at the end of treatment, especially in patients in whom ideal occlusion has not been achieved, but as yet, there is no clear scientific evidence on which type of retainer is best able to preserve outcomes.[67–69]

Extraclinical factors

Given the wide range of products on the market, the final section of the survey was dedicated to analyzing the extraclinical factors that can influence the experts' choice regarding the type of aligner to use (Table XIV).

Price is a factor that significantly divides the group of experts, playing a much-discussed role, given the wide variability of prices on the market. 56.5% of experts consider price to be of little influence, whereas 43.5% that it is to be very influential.

In addition to the price, commercial promotion and marketing also divide the group of experts, and are considered by 58.3% to have little influence in the choice of the aligner to be adopted.

In contrast, scientific background is seen as a wide consensus and is considered very influential by 87% of the experts interviewed.

Clinical efficacy supported by opinion leaders is considered influential by 56.5% of experts.

Finally, the last extraclinical parameter investigated concerned customer service, which seems to be a decidedly important element in clinicians' satisfaction. In fact, 75% consider it a very influential factor in choosing the aligner to rely on.

Clinical relevance

The panel agreed that aligners have significant biomechanical limitations, which can be summarized as reduced effectiveness in controlling root and bodily movements of the teeth. This factor negatively influences the quality of the results obtainable in the most complex malocclusions, increases the risk of undesirable effects in extraction, and encourages the use of hybrid and auxiliary systems such as elastics, sectionals, and skeletal anchorage. These results lead us to think that most dentoalveolar malocclusions are resolved thanks to uncontrolled tipping movements, in which the effectiveness of the aligners remains consistently high. These topics require further investigation, but in the meantime, the key factors for achieving good quality results remain careful patient selection, accurate diagnosis, and, in particular, careful evaluation of the initial position of the root apices.

Limitations

A critical aspect of the Delphi study is the selection of participants. In this study, participants were selected by the steering committee on the basis of their personal knowledge of the literature, with the aim of constituting a panel of expert users of the most widely used systems in the world. This approach aimed to ensure a balanced representation of internationally renowned researchers and acknowledged clinical experts in the field of aligner treatments.

Consensus statements, representing the best general expertise of industry experts, acquire particular relevance in fields in which scientific evidence is inconsistent or scarce, as they can provide ideas and lay the foundations for implementing research. However, it should be emphasized that consensus among experts, no matter how renowned or experienced, can never replace high-quality clinical evidence, which must always remain the real guide for the treatment of patients.

CONCLUSIONS

This study, performed via a modified international Delphi method, aimed to provide guidance to orthodontists on the current potential of aligners by taking into account the experience of a large group of experts and comparing their opinions with the most recent scientific publications on the subject. The study generated 47 consensus statements concerning not only purely biomechanical aspects but also extraclinical factors, trying to highlight the real potential of aligners while simultaneously emphasizing their current limitations.

Although the Delphi method offers valuable food for thought, future studies, including randomized controlled trials, are needed to further investigate these findings and address the remaining uncertainties. Such efforts would help refine orthodontic treatment protocols and improve patient outcomes.

AUTHOR CREDIT STATEMENT

Niki Arveda contributed to conceptualization, original draft preparation, data curation, investigation, methodology, supervision, validation, and visualization; Giuseppe Siciliani contributed to conceptualization, project administrator, investigation, methodology, supervision, validation, and visualization; Marta Calza contributed to original draft preparation, data curation, supervision, validation, and visualization; Luca Lombardo contributed to original draft preparation, data curation, investigation, methodology, supervision, validation, and visualization; Tommaso Castroflorio contributed to supervision, validation, and visualization; Francesco Garino contributed to supervision, validation, and visualization; Aldo Giancotti contributed to supervision, validation, and visualization; Juan Carlos Varela contributed to supervision, validation, and visualization; Calogero Dolce contributed to supervision, validation, and visualization; Bjorn Ludwig contributed to supervision, validation, and visualization; Paolo Manzo contributed to supervision, validation, and visualization; Ravindra Nanda contributed to supervision, validation, and visualization; Oliverio Teresa contributed to supervision, validation, and visualization; Angela Arreghini contributed to supervision, validation, and visualization; Francesca Cremonini contributed to supervision, validation, and visualization; Davide

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