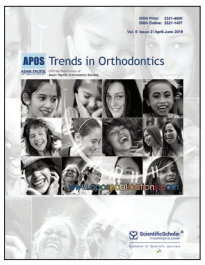
www.apospublications.com

ScientificScholar®
Knowledge is power
Publisher of Scientific Journals

APOS Trends in Orthodontics



Critical Review

Clear aligner therapy in contemporary orthodontics: A scoping review of scholarly literature

Samar M. Adel[1], Ismaeel Hansa[2], Nikhilesh R. Vaid[3]

[1]Department of Orthodontics, Faculty of Dentistry, Alexandria University, Alexandria, Egypt, [2]Department of Orthodontics, European University College, Dubai, United Arab Emirates, [3]Department of Orthodontics, Saveetha Medical and Technical University, Chennai, Tamil Nadu, India.

***Corresponding author:**
Samar M. Adel,
Department of Orthodontics,
Faculty of Dentistry, Alexandria University, Alexandria, Egypt.

orthosamar@gmail.com

Received: 23 November 2022
Accepted: 23 January 2023
EPub Ahead of Print: 13 April 2023
Published: 31 January 2024

DOI
10.25259/APOS_215_2022

Quick Response Code:

ABSTRACT

Objectives: Over the last two decades, clear aligners have become a mainstay in contemporary orthodontic practice primarily due to improvements in digital and 3D printing technologies, a growing interest in esthetic orthodontics, especially in the adult population, and aggressive manufacturer marketing internationally.

Material and Methods: PubMed, Google Scholar, Cochrane Library, and EMBASE databases were searched from January 1998 to November 2021. The search terms used were "Invisalign" OR "clear aligner." A total of 7000 records were searched, of which 369 potentially relevant articles were retrieved in full. 190 studies met the selection criteria following screening and were included in the scoping review.

Results: This review scopes and analyses published orthodontic literature about CA according to a year-wise distribution into 3 groups, 2001–2010/2011–2020/2021. Most of the studies were published in the period between 2011 and 2020, with 138 studies accounting for 73%. The year 2021 followed, with 31 studies accounting for 16%, which was greater than the number of studies published in 10 years from 2001 to 2010. Studies were also classified based on the study designs with most of the published studies representing the lowest level of evidence including case reports, case series, narrative reviews, expert opinions, and editorials accounting for 137 studies, whereas case-control studies were the least reported studies with only 4 studies reported in the literature. In addition, they were categorized into seven main domains: (1) Biological considerations associated with clear aligner therapy (CAT), (2) Treatment outcomes considerations associated with CAT, (3) Geometrical considerations associated with CAT (clinical), (4) Biomechanical considerations associated with CAT (Laboratory/Finite element analysis), (5) Biomaterial considerations associated with CAT, (6) Patient education and experience and aesthetic and social perception of CAT, and (7) Miscellaneous. Treatment outcome considerations associated with CAT had the greatest percentage representing 36% of the total published domains, while the final place was occupied by the biomechanical considerations associated with CAT accounting for only 4% of the published domains about CAT.

Conclusion: Treatment outcome was the domain most commonly reported by studies accounting for (36%). Most of the published studies are at the lowest level of evidence including case reports, case series, narrative reviews, and expert opinions. The vast majority of studies utilized only a single clear aligner brand. There is a greater need for research that studies CAT from a holistic perspective.

Keywords: Clear aligner therapy, Invisalign, Scoping review, Treatment effects, Aligners

INTRODUCTION

Over the last two decades, clear aligners have become a mainstay in contemporary orthodontic practice primarily due to improvements in digital and 3D printing technologies, a growing interest

in esthetic orthodontics, especially in the adult population, and aggressive manufacturer marketing internationally.[1-3]

Although clear aligners have become widely utilized, there is a paucity of scholarly research testing this treatment modality.[4-9] Contrary to expectations, orthodontic products are often clinically adopted without appropriate clinical evidence. However, if the specialty has to obtain precision and proficiency with this modality, a thorough investigation of existing clear aligner literature is imperative. This will allow future studies to target areas of deficiency within this field.

The discrepancy between the predicted and actual clinical outcomes with clear aligner therapy (CAT) is around 50% necessitating midcourse corrections, refinements, additional aligners, or even a conversion to fixed appliances before the end of treatment.[10] This percentage accuracy was further found to be affected by the registration algorithm software used for the superimposition of digital models.[4] Studies assessed different aspects of CAT effectiveness including biological aspects, treatment outcomes, geometrical and biomechanical considerations, biomaterials as well as patient-related outcomes.

Scoping reviews (ScRs), in general, aim to study the extent, range, and type of research on a given topic and to help direct future research. ScRs are especially beneficial when applied to novel topics, in which a scarcity of randomized controlled trials prevents systematic reviews from providing meaningful conclusions, as is the case for orthodontic clear aligners. This ScR, therefore, aims to determine the scope and extent of the published literature on clear aligners in orthodontics, as well as identify the types of studies published, and summarize the outcomes studied.

MATERIAL AND METHODS

A ScR of the published literature was performed following the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) extension for PRISMA-ScRs guidelines [Figure 1]. A review protocol was created to address the research questions and studies' eligibility criteria [Table 1] but was not previously registered. PubMed, Google Scholar, Cochrane Library, and EMBASE databases were searched from January 1998 to November 2021. In addition, Google Scholar and OpenGrey were searched for grey literature. Reference lists of relevant articles were manually searched and "Citation Networks" of relevant articles in Web of Science were checked to identify studies that could have been missed in the electronic database searches. A search alert was created for each database using its respective search strategy to be notified of any new relevant studies, and alerts were monitored on regular basis until the end of November 2021. The initial date was chosen as it coincided with the initial development of Invisalign. The search terms used were "Invisalign" OR "Clear Aligner" OR "Aligner." Although no specific language restriction was applied, the search terms used were only in the English alphabet. Titles and abstracts were screened to satisfy the ScR eligibility criteria.

The abstracts of all suitable articles were evaluated by two reviewers independently. Full texts of those articles meeting the selection criteria and those that were ambiguous were then obtained for screening. A third reviewer aided in resolving uncertainty regarding final inclusion until a consensus was reached. Excluded studies with reasons were tabulated [Table 2]. Full-text analysis of the identified original research was performed and data extraction was charted according to "PICO" guidelines with collected information that included the first author and year of publication, study design, number of participants, interventions, comparison, outcomes (both primary and secondary), method of measurement, and outcome domain [Table 3]. The primary and secondary outcomes were determined from within the text of the study. If not explicitly mentioned, the aim, sample size calculation, or first reported outcome in the results section were used, respectively. Any other outcomes reported were designated as secondary outcomes. The data extraction and outcome domains were chosen after a review of the results and refined independently by two reviewers. The outcome domains were thus categorized into seven main domains, as enumerated below:

a. Biological considerations associated with CAT
b. Treatment outcomes considerations associated with CAT
c. Geometrical considerations associated with CAT (clinical)
d. Biomechanical considerations associated with CAT (laboratory/finite element analysis [FEA])
e. Biomaterial considerations associated with CAT
f. Patient education, experience and aesthetic/social perception of CAT
g. Miscellaneous.

RESULTS

Search and selection of studies

The initial database and additional search resulted in 7000 records, of which 369 potentially relevant articles were retrieved in full. 190 studies met the selection criteria following screening and were included in the ScR with the results of the search depicted in the PRISMA flow chart [Figure 1]. The studies included in the review are shown in [Table 3] and represented graphically in [Figures 2-4], whereas 179 excluded studies with reasons are enumerated in [Table 2] and represented graphically in [Figure 5].

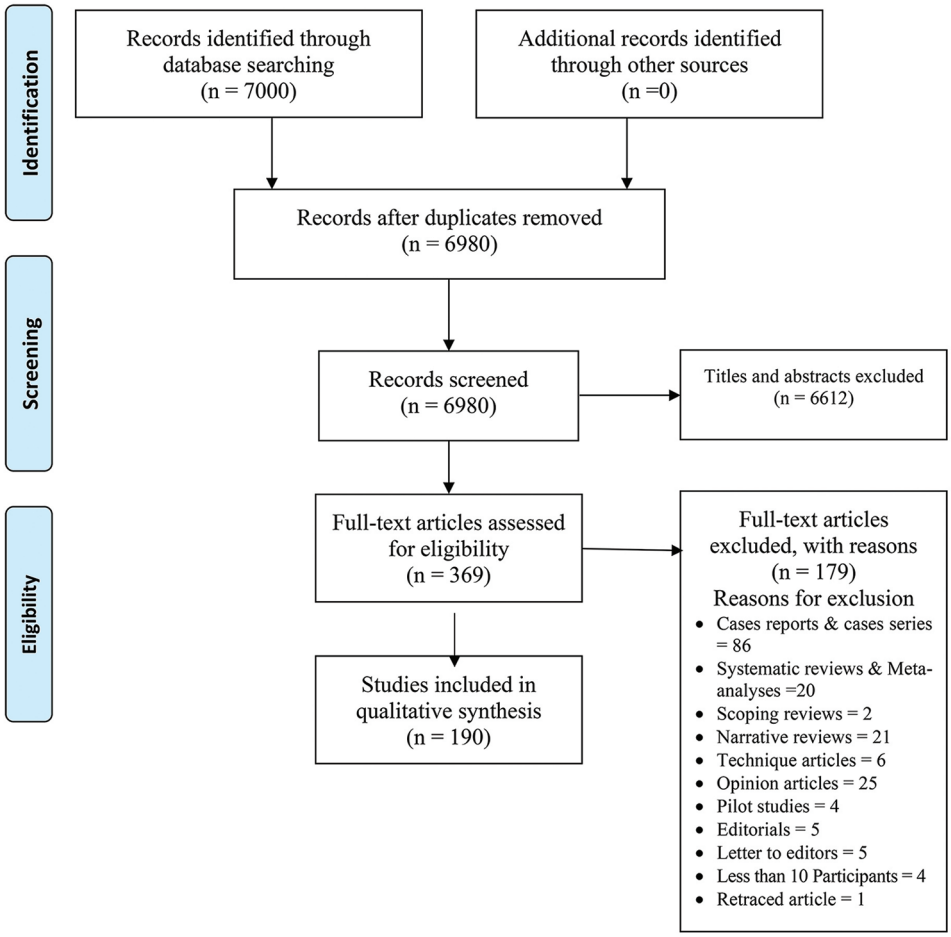


Figure 1: Preferred reporting items for systematic reviews and meta-analysis.

Table 1: Scoping review selection criteria.

Inclusion criteria	Exclusion criteria
Study design: All types of studies including randomized controlled trials, controlled clinical trials, cohort studies, retrospective studies, and case-control studies	Case reports and case series
Participants: Patients aged 10 years and older receiving orthodontic treatment	Studies with <10 participants
Intervention: Any type of clear aligner therapy	Personal opinion and descriptive technique papers
Comparison: Any type of comparison with conventional mode of orthodontic treatment method or approach	Letters to editors or interviews
Outcomes: All types of reported outcomes (primary and secondary)	Editorials
	Proceedings from research summits
	Systematic reviews, meta-analyses, narrative reviews and scoping reviews
	Proof of concept, workshops, and presentations
	Pilot studies and retracted articles

General characteristics of included studies in the ScR

Year-wise distribution of studies

Studies were classified into three groups according to a year time frame

a. 2001–2010: 21 studies
b. 2011–2020: 138 studies
c. 2021: 31 studies.

The included publications ranged in date from 2001 to 2021. The bar graph in [Figure 2] demonstrates that most of the studies were published in the period between 2011 and 2020, with 138 studies accounting for 73%. Interestingly though, the year 2021 followed, with 31 studies accounting for 16%, which was greater than the number of studies published in 10 years from 2001 to 2010 with only 21 studies representing 11%.

Table 2: Studies excluded from the scoping review (*n*=179).

Author/Year	Reason for exclusion
Weir 2017[11]	Review article
Robertson *et al.*, 2020[12]	Systematic review
Ke *et al.*, 2019[1]	Systematic review
Rossini *et al.*, 2014[13]	Systematic review
Caminiti and Lou 2019[14]	Less than 10 participants
Lagravère and Flores-Mir 2005[15]	Systematic review
Tamer *et al.*, 2019[16]	Literature review
Papadimitriou *et al.*, 2018[17]	Systematic review
Rossini *et al.*, 2014[18]	Systematic review
Hennessy and Al-Awadhi 2016[19]	Opinion article
Zheng *et al.*, 2017[20]	Systematic review and meta-analysis
Galan-Lopez *et al.*, 2019[21]	Systematic review
Sword and Haywood 2020[22]	Case report
Kook *et al.*, 2019[23]	Case report
Flores-Mir 2019[24]	Systematic review with meta-analysis
Lu *et al.*, 2018[25]	Meta-analysis
Kuncio 2014[26]	Review article
Kassam and Stoops 2020[27]	Systematic review
Cardoso *et al.*, 2020[28]	Systematic review
Phan and Ling 2007[29]	Opinion article
Zhang *et al.*, 2020[30]	Systematic review
Shotell 2020[2]	Opinion article
Tripathi *et al.*, 2016[31]	Case report
Iliadi *et al.*, 2020[32]	Systematic review and meta- analysis of clinical and *in vitro* research
Lombardo *et al.*, 2020[33]	Case report
Blevins 2019[34]	Editorial
Marya *et al.*,2020[35]	Review
Staderini *et al.*, 2019[36]	Case report
Al-Jewair *et al.*, 2020[37]	Case series with less than 10 participants
Kim and Echarri 2007[3]	Narrative article
Fang *et al.*, 2019[38]	Systematic review and meta-analysis
Gierie 2018[39]	Overview
Al-Zainal *et al.*, 2020[40]	Systematic review and meta-analysis
Kravitz *et al.*, 2018[41]	Technique article
Fry 2017[42]	Opinion article
Ojima *et al.*, 2018[43]	Case report
Pinho and Rocha 2020[44]	Case series
On Tse 2019[45]	Case report
Ruan and Jiang 2017[46]	Case report
Yu *et al.*, 2013[47]	Systematic review
Caruso *et al.*, 2020[48]	Case reports
Feizi *et al.*, 2020[49]	Narrative review
Keim 2017[50]	Editorial/opinion article
Boyd 2008[51]	Participants less than 10
Kaur *et al.*, 2020[52]	Scoping review
Kankam *et al.*, 2018[53]	Case series and technique article
Gandhi *et al.*, 2021[54]	Systematic review and meta-analysis
Boyd 2009[55]	Case reports [3 cases]
Shipley 2018[56]	Pilot study
Park and Kim 2009[57]	Case report
Harnick 2012[58]	Case report
Hannequin 2020[59]	Case report
Hennessy and Al-Awadhi 2016[60]	Narrative review
Chang *et al.*, 2021[61]	Narrative review
Ojima *et al.*, 2020[62]	Case report
Mheissen *et al.*, 2020[63]	Systematic review
Lee *et al.*, 2011[64]	Case reports [3 cases]
El-Bialy 2020[65]	Case series: Less than 10 participants
Lombardo *et al.*, 2017[66]	Less than 10 participants
Joffe 2003[67]	Opinion article
Peck 2021[68]	Editorial
Zhu *et al.*, 2019[69]	Case report
Ojima *et al.*, 2020[70]	Case report
Giancotti *et al.*, 2020[71]	Case report
Sheridan 2014[72]	Opinion article
Chang *et al.*, 2019[73]	Case report
Wheeler 2004[74]	Editorial
Keser and Dibart 2011[75]	Case report
Tartaglia *et al.*, 2021[76]	Narrative review
Huang and Huang 2018[77]	Case report
Malik *et al.*,2013[78]	Narrative review
Bous *et al.*, 2020[79]	Technique article and case report
Schwartz 2012[80]	Case report
Cetta 2018[81]	Technique article
Park and Kim 2009[82]	Case report
Wong 2002[83]	Narrative review
Waring *et al.*, 2013[84]	Narrative review
Reinhardt 2016[85]	Opinion article
Kau *et al.*, 2020[86]	Case report
Bawaskar 2015[87]	Case report
Eckhart 2009[88]	Case report
Chami *et al.*, 2018[89]	Pilot study
Owen 2001[90]	Technique article
Cassetta *et al.*, 2020[91]	Case report
Ellis 2004[92]	Letter to editor
Greco *et al.*, 2020[93]	Case report
Miller 2009[94]	Case report
El-Bialy 2020[95]	Case report
Melkos 2005[96]	Narrative review
Putrino *et al.*, 2021[97]	Scoping review
Whitehouse 2004[98]	Opinion article
Ojima *et al.*, 2014[99]	Case report
Eliades and Bourauel 2005[100]	Editorial
Turpin 2005[101]	Editorial
Voudouris *et al.*, 2018[102]	Opinion article
Wu 2014[103]	Letter to editor
Pagani *et al.*, 2016[104]	Case report
Levrini *et al.*, 2012[105]	Case report

(Contd...)

(Contd...)

Table 2: *(Continued)*.

Author/Year	Reason for exclusion
Awosika *et al*., 2017[106]	Case report
Fry 2017[107]	Case report
Ojima *et al*., 2016[108]	Case report
Beers *et al*., 2003[109]	Narrative review
Jyothikiran *et al*., 2014[110]	Narrative review
Lou and Caminiti 2021[111]	Opinion article
Zawawi 2014[112]	Case report
Ellis 2012[113]	Letter
Johal and Bondemark 2021[114]	Opinion article
Antelo *et al*., 2018[115]	Case report
Park and Kim 2010[116]	Case report
Levrini *et al*., 2015[117]	Case report
Needham *et al*., 2015[118]	Case report
Smallwood 2009[119]	Narrative review
Christensen 2002[120]	Opinion article
Garino *et al*., 2014[121]	Opinion article
Frongia and Castroflorio 2006[122]	Case report
Giancotti *et al*., 2006[123]	Case report
Kim and Park 2008[124]	Case report
Garino and Park 2012[125]	Opinion article
Feinberg *et al*., 2016[126]	Opinion article
Mampieri and Giancotti 2013[127]	Review
Eissa *et al*., 2018[128]	Pilot study
Lin *et al*., 2014[129]	Case report
Giancotti and Mampieri 2012[130]	Case report
Ali and Miethke 2012[131]	Narrative review
Brezniak and Wasserstein 2008[132]	Case report
Torres *et al*., 2011[133]	Case report
Abraham *et al*., 2016[134]	Case report
Womack and Day, 2008[135]	Case report
Giancotti *et al*., 2014[136]	Case report
Vlaskalic and Boyd 2002[137]	Opinion article
Rocke 2008[138]	Technique article
Schupp *et al*., 2010[139]	Case report
Schupp *et al*., 2010[140]	Case report
Barlattani *et al*., 2010[141]	Case report
Aulakh 2013[142]	Case report
Norris *et al*., 2002[143]	Case report
Giancotti *et al*., 2015[144]	Case series
Cassetta *et al*., 2016[145]	Case report
Fischer 2010[146]	Case report
Ruiz *et al*., 2009[147]	Less than 10 participants
Schupp *et al*., 2010[148]	Case report
Wheeler 2005[149]	Opinion article
Kumar *et al*., 2021[150]	Letter to Editor
Hönn and Göz 2006[151]	Case report
Lombardo *et al*., 2021[152]	Case report
Uribe *et al*., 2011[153]	Case report
Dickerson 2017[154]	Case report
Miller *et al*., 2002[155]	Case report
Levrini *et al*., 2013[156]	Pilot study
Long 2012[157]	Case report
Maganzini 2006[158]	Letter to editor
Giancotti and Di Girolamo 2009[159]	Case report
Patient's Page, 2013[160]	Opinion article

(Contd...)

Table 2: *(Continued)*.

Author/Year	Reason for exclusion
Giancotti *et al*., 2008[161]	Case report
Sheridan 2004[162]	Opinion article
Galluccio 2021[163]	Narrative review
Chenin *et al*., 2003[164]	Case report
Crosby and Lee 2009[165]	Opinion article
Womack 2006[166]	Case report
Boyd 2007[167]	Case report
Boyd 2005[168]	Case report
Sousa Dias and Tsingene 2011[169]	Case report
Cai *et al*., 2021[170]	Opinion article
Giancotti and Farina 2010[171]	Case report
Vlaskalic and Boyd 2001[172]	Case report
Marcuzzi *et al*., 2010[173]	Case report
Bradley 2013[174]	Opinion article
McFarland 2007[175]	Case report
Corsair 2007[176]	Case report
Sterental 2008[177]	Narrative review
Turatti *et al*., 2006[178]	Case report
Hamula and Brewka 2005[179]	Opinion article
Bishop *et al*., 2002[180]	Case report
Giancotti and Ronchin 2006[181]	Case report
McKenna 2001[182]	Opinion article
Barzilay and Dayan 2016[183]	Case report
Salomone and Turatti 2020[184]	Technique article
Lin *et al*., 2016[185]	Retracted article
Pithon *et al*., 2019[186]	Systematic review

Study designs of included studies

The Hierarchy of evidence for studies published about CAT in [Figure 3] illustrates that most of the published studies were at the lowest level of evidence including case reports, case series, narrative reviews, expert opinions, and editorials accounting for 137 studies. This was followed by cohort studies with 79 studies that were either retrospective or prospective in nature. Animal and laboratory studies were equal to the prospective clinical trials accounting for 39 studies each. 20 systematic reviews and meta-analyses were identified and represented the highest level of evidence. Case–control studies were the least reported studies with only four studies reported in the literature.

Distribution of seven outcome domains reported in the literature

The pie chart reveals the percentage distribution of the seven main outcome domains reported in the literature about CAT. Treatment outcome considerations associated with CAT had the greatest percentage representing 36% of the total published domains. Biological considerations associated with CAT come in next, accounting for 29.5% of the domains reported. This was followed by the biomaterial considerations associated with CAT representing 12.1%. At comparable

Table 3: List and details of studies included in the scoping review *n*=190.

Author (year)	Study type	Participants	Intervention	Comparison	Outcome (Primary)	Outcome (Secondary)	Outcome Domain
Miethke and Vogt 2005[257]	Prospective controlled clinical trial	30 consecutive patients each with FA and with CA	Periodontal health of patients during treatment with the Invisalign system and with FA	• CA and FA • Three consecutive control visits	Evaluation of the periodontal health in patients during treatment with either FA or the Invisalign system		A
Miethke and Brauner 2007[258]	Prospective cohort study	30 patients each with aligners or fixed lingual appliances	Periodontal health of patients during treatment with the Invisalign system and with fixed lingual appliances	CA and FA	Evaluation of the periodontal health of patients during treatment with the Invisalign system or fixed lingual appliances		A
Eliades *et al.*, 2009[259]	Experimental *in vitro* study	Three sets, each consisting of a maxillary and a mandibular appliance, of as-received aligners	Cytotoxicity and estrogenicity of Invisalign appliances	Samples of eluents were diluted to 3 concentrations (5%, 10%, and 20% vol/vol)	Study the *in vitro* cytotoxic and estrogenic properties of Invisalign appliances		A
Sombuntham *et al.*, 2009[260]	Animal study	15 rats were divided into 3 groups	Early tooth movement with a clear plastic appliance in rats	• Group I was the untreated controls; group II received a clear plastic appliance made from a model, with the maxillary left first molar repositioned mesially 0.5 mm from the origin; and group III had a closed-coil spring to move the molar mesially, changes in paradental tissues were evaluated on days 1, 4, and 7	Investigate early histologic changes of paradental tissues in response to a clear plastic appliance in rats		A
Low *et al.*, 2011[261]	Prospective clinical trial	56 Chinese male/female volunteers (aged 19–39 years)	Ultrastructure and morphology of biofilms on thermoplastic orthodontic appliances in "fast" and "slow" plaque formers	• Slow and fast plaque formers • Tiles were collected at intervals of 1, 3, 6, 12, 24, and 48 h, as well as 3, 7, and 14 days	Investigate the morphological features and distribution of biofilms on Invisalign orthodontic appliances, in a sample of "slow" and "fast" plaque formers using SEM		A
Shalish *et al.*, 2012[189]	Prospective cohort study	68 adult patients (45 females and 23 males) who comprised 3 groups: 28 Buccal, 19 Lingual, and 21 Invisalign patients	Adult patients' adjustability to orthodontic appliances: Labial, Lingual, and Invisalign™	• Labial, Lingual, and Invisalign™ • First week and again on day 14	Assess patients' perception of pain and analgesic consumption	Assess 4 areas of dysfunction: oral dysfunction, eating disturbances, general activity parameters, and oral symptoms	A and B (Aadjustability to CA)
Krieger *et al.*, 2013[262]	Retrospective radiometric cohort study	100 patients (17–75 years of age) with a class I occlusion and anterior crowding before treatment, treated exclusively with Invisalign	Apical root resorption during orthodontic treatment with aligners	• Pre- and post-treatment panoramic radiographs • Different teeth, gender, age or sagittal and vertical orthodontic tooth movement	Investigate the incidence and severity of apical root resorptions during orthodontic treatment with aligners		A
Fujiyama *et al.*, 2014[263]	Prospective cohort study	145 cases for the edgewise group (EG; *n*=55), Invisalign group (IG; *n*=38), and edgewise and Invisalign group (EIG; *n*=52)	Analysis of pain level in cases treated with Invisalign aligner in comparison with FA	• CAT and FA • VAS scores were collected during the first three stages (first stage: 0–7 days, second stage: 14–21 days, and third stage: 28–35 days) and at the end of the treatment (overall VAS score	Evaluate and compare the difference in the level of pain using the VAS between cases treated with the edgewise appliance and Invisalign	Identify the cause of pain and discomfort in the Invisalign cases	A
Premaraj *et al.*, 2014[264]	Experimental *in vitro* study	Plastic was powdered with a 12-in half-circle, flat-bottom file, producing particles that were about 86×56 µm to 186×161 µm in size (length×width)	Oral epithelial cell reaction after exposure to Invisalign plastic material	Soaking Invisalign plastic in either saline solution or artificial saliva for 2, 4, and 8 weeks	Evaluate the cellular responses of oral epithelium exposed to Invisalign plastic *in vitro*		A
Han 2015[265]	Retrospective cohort study	35 patients who underwent orthodontic treatment	Combined periodontal and orthodontic treatment with FA and CA in patients with periodontitis	• CA and FA • Clinical parameters were assessed at baseline and after orthodontic treatment and the duration of treatment was compared between these two groups	Evaluate the effect of orthodontic treatment on periodontal tissue	Compare orthodontic treatment with FA to CAT in periodontitis patients	A
Azaripour *et al.*, 2015[266]	Cross sectional study	100 patients (FO=50, Invisalign®=50)	Gingival parameters and patient satisfaction with CAT	CAT and FA	Evaluate gingival and PDL parameters during orthodontic treatment of patients with FOA or Invisalign®	Evaluate patient's satisfaction during orthodontic treatment of patients with FOA or Invisalign®	A
Abbate *et al.*, 2015[267]	Randomized prospective clinical trial	50 teenagers aged 10–18 years with similar initial orthodontic conditions	Periodontal health in teenagers treated with removable aligners and FA	• CAT and FA patients • Comparisons done at beginning of treatment and 3, 6, and 12 months later	To explore the microbiological and periodontal changes occurring in adolescents during 12 months of orthodontic therapy with CA and FA	Assess compliance with oral hygiene procedures, full mouth plaque score, and full mouth bleeding score at the beginning of treatment and 12 months later	A
Levrini *et al.* 2015[268]	Prospective controlled clinical trial	77 patients	Periodontal health status in patients treated with the Invisalign(®) system and FA	• Invisalign(®) group, FA group and control group • T0 (beginning of the treatment), T1 (1-month) and T2 (3-months)	Compare the periodontal health and the microbiological changes via real-time polymerase chain reaction in patients treated with FA and Invisalign(®) system		A
Hellak *et al.*, 2016[269]	Retrospective cohort study	60 digital CBCT scans from 30 patients (28 women, two men; 30 CBCTs pre-treatment, 30 posttreatment)	Influence of Invisalign treatment with IER on bone volume for adult crowding	• 30 CBCTs pre-treatment, 30 post-treatment • Mandible and maxilla	Use 3D datasets to identify associations between treatment for adult crowding using Invisalign and IER and changes in the bone volume		A
Levrini *et al.*, 2016[270]	Prospective clinical study	20 subjects (6 males and 14 females) undergoing orthodontic therapy with CA	ATP Bioluminometers analysis on the surfaces of CA after the use of different cleaning methods	Different cleaning methods (water, brushing with toothpaste, and brushing with toothpaste and use of sodium carbonate and sulphate tablet)	Quantify the bacteria concentration on the surface of Invisalign using three different cleaning methods	Validate the efficacy of the bioluminometer in assessing the bacteria concentration	A
Allareddy *et al.*, 2017[271]	Retrospective cohort study	173 medical device reports	Adverse clinical events reported during Invisalign treatment		Examine adverse clinical events after the use of the Invisalign system	Provide an overview of the actions taken by the manufacturer to address these events	A
Gay *et al.*, 2017[272]	Prospective cohort radiometric study	71 class I adult healthy patients (mean age 32.8±12.7) treated with aligners	Root resorption during orthodontic treatment with Invisalign	Root and crown lengths of 1083 teeth were measured in panoramic radiographs at the beginning (T0) and at the end (T1) of CAT	Investigate the incidence and severity of RR in adult patients treated with aligners		A
Castroflorio *et al.*, 2017[273]	Prospective split mouth clinical trial	10 healthy, adult patients	Biochemical markers of bone metabolism during early orthodontic tooth movement with Invisalign aligners	• 1 w and 3 w • Tested teeth and control teeth	Evaluate the expression of receptor activator of nuclear factor-kappa ligand, osteoprotegerin, osteopontin, interleukin 1β, and transforming growth factor ß1 in the gingival crevicular fluid of teeth subjected to orthodontic forces released by aligners		A
Iglesias-Linares *et al.*, 2017[274]	A case–control genetic association study	372 Caucasian patients treated with CA (Invisalign) or FA	OIEARR in patients treated with FA versus CA	CA and FA	Determine whether orthodontic treatment with CA versus FA is associated with a different frequency of OIEARR when genetic, radiographic, and clinical factors are accounted for		A
Hellak *et al.*, 2018[275]	Retrospective cohort 3D CBCT study	60 CBCT scans from 30 adult patients (28 women, 2 men; 30 CBCTs pre-treatment, 30 post-treatment)	Influence on interradicular bone volume of Invisalign treatment for adult crowding with IER	• Four levels in the anterior tooth areas of the maxilla and mandible • Differences in bone between T0 and T1	Use 3D datasets to identify associations between treatment for adult crowding, using Invisalign aligner and IER	Assess changes in the volume of interradicular bone	A
Almasoud 2018[276]	Prospective cohort study	64 patients	Pain perception among patients treated with passive self-ligating FA and Invisalign® aligners during the 1st week of orthodontic treatment	• Self-ligating FA and Invisalign® aligners • Their responses were recorded at 4 h, 24 h, day 3, and day 7	Compare the perception of pain between patients treated with passive self-ligating FA and those treated with Invisalign aligners		A
Aman *et al.*, 2018[277]	Retrospective cohort study using CBCT	160 patients who received comprehensive orthodontic treatment with CA	Apical root resorption during orthodontic treatment with Invisalign clear aligners using CBCT	• Pre-treatment and post-treatment CBCT examinations • Maxillary central and lateral incisors	Investigate the incidence and severity of orthodontically induced inflammatory root resorption on maxillary incisors with CA therapy using CBCT	Identify possible risk factors for orthodontically induced inflammatory root resorption	A
Yi *et al.*, 2018[278]	Retrospective cohort study	80 non-extraction patients	EARR in non-extraction cases after CAT or FA	CAT and FA	Comparatively evaluate the amount of EARR in non-extraction patients receiving CAT or FA	Investigate the potential predictive factors of EARR: duration of treatment, gender, age, skeletal pattern or degree of malocclusion	A
Katchooi *et al.*, 2018[279]	Randomized prospective clinical trial	26 adult subjects	Effect of supplemental vibration on orthodontic treatment with aligners	Either an active (A) or a sham (B) AcceleDent Aura device (OrthoAccel Technologies, Inc)	• Investigate the effects of AcceleDent on Invisalign treatment • The outcomes were the ability to complete the initial set of aligners and the incisor irregularity measurements for those who completed their regimen of aligners	Assess aligner compliance, pain levels, and oral health-related quality of life data	A
Guo *et al.*, 2018[280]	3m prospective cohort study	10 female patients with CA	Profiling of subgingival plaque biofilm microbiota in female adult patients with CA	3 time points: before orthodontic treatment (T0), 1 month after orthodontic treatment (T1) and 3 months after orthodontic treatment (T2)	Investigate changes of the subgingival microbial community	Examine subgingival microbial community association with clinical characteristics during the first 3 months of CAT	A
Patini *et al.*, 2018[281]	Retrospective cohort study	A CA (TG) of 68 patients and a control group of 33 untreated patients (UG)	Invisalign Clear aligners' effects on aesthetics: evaluation of facial wrinkles	• Treated with CA and untreated • Comparison based on age: subgroup 1 if under 40 years of age and subgroup 2 if over 40 years • Facial aesthetics of the lower third was evaluated at the beginning (T0) and at the end (T1) of the study period	Evaluate the facial esthetic effects of orthodontic treatment performed with CA and to compare it to an untreated control group, on lower third facial aging in adult patients through the use of the Wrinkle Severity Rating Scale at the beginning (T0) and at the end (T1) of the study period		A
Parrini *et al.*, 2018[282]	Prospective cohort study	15 untreated patients and 15 patients treated with CA	Postural changes in orthodontic patients treated with CA	• Treated patients with CAT and untreated patients • Patients treated with CA were compared at baseline, after 1, 3 and 6 months	Evaluate possible correlations between orthodontic treatment and posture: the kyphotic angle, the lordotic angle, the upper thoracic inclination, and the pelvic inclination		A
Farouk *et al.*, 2018[283]	Retrospective study	30 patients with an average age of 26±11 years and Class I malocclusion	Effect of the application of HFV on tooth length concurrent with CAT	• Group I received adjunctive HFV • Group II, the control, did not receive adjunctive mechanical treatment • Before (T1) and after (T2) treatment	Evaluate the possible change in teeth lengths as an indicator of OITRR after HFV treatment concurrent with Invisalign Smart Track® aligners as evaluated by CBCT		A
Pogal-Sussman- Gandia *et al.*, 2019[284]	Prospective cohort study	30 patients undergoing active two-arch Invisalign® treatment were examined	Effects of Invisalign® treatment on speech articulation	Patients' speech was recorded once with the trays inserted and once with the trays removed	Determine the effects of Invisalign® aligners on patients' perception on speech articulation and abilities to articulate consonants	Assess quality and rate of speech	A
Oliverio *et al.*, 2019[285]	Randomized prospective clinical trial	38 volunteers who were undergoing orthodontic treatment with F22 aligner	Tooth whitening in association with CAT	• Group 1 (8 patients): Application of 3% hydrogen peroxide for 9 h/day on days 7–14 of aligner wear • Group 2 (8 patients): Application of 10% carbamide peroxide for 9 h/day on days 7–14 of aligner wear • Group 3 (8 patients): Application of 16% carbamide peroxide for 9 h/day on days 7–14 of aligner wear • Group 4 (14 patients): Application of 16% carbamide peroxide for 9 h/day on days 1–14 of aligner wear	Evaluate the efficacy of different at-home whitening protocols during orthodontic CAT	• Qualitative analysis of whitening agent distribution within the F22 aligners • Assess difference in transparency of aligners • Compare the light transmittance and absorbance of the aligners before and after whitening	A
Wang *et al.*, 2019[286]	Prospective cohort study	15 subjects aged 20–25 years, non-smokers, without any diagnosed systemic diseases, and having received no antibiotics in the 3 months before sampling	Alterations of the oral microbiome in patients treated with the Invisalign system or with FA	Comparison between CAT group, FA group and no treatment group	Influence of different treatments on oral microbotome regarding the diversity of oral microbial composition and the richness and evenness of samples	• Investigate oral microbotome at phyla and genus levels between different treatments regarding predominancy and abundancy • Investigate differences in microbial function	A

(Contd...)

Table 3: *(Continued).*

Author (year)	Study type	Participants	Intervention	Comparison	Outcome (Primary)	Outcome (Secondary)	Outcome Domain
Abu Alhaija *et al*., 2019[287]	Randomized prospective clinical trial	45 subjects: 25 in FA group and 20 in CA group	Comparative study of initial changes in PBF between CA and FA	• CA and FA • Maxillary right and mandibular left teeth • Different time intervals (20 min, 48 h, 72 h, and 1 month) after the fitting of the nickel titanium archwire in group 1 and after the delivery of the second aligner in group 2	Evaluate and compare the initial changes of PBF using clear aligner and fixed orthodontic treatment		A
Lombardo *et al*., 2020[288]	Prospective cohort longitudinal study	2 groups of patients to be treated, respectively, with CAs (14 patients; 9 females and 5 males; mean age 21 years±0.25) and FAs (13 patients; 8 females and 5 males; mean 14 years±0.75)	Short-term variation in the subgingival microbiota in 2 groups of patients treated with CA and FA	• CA and FA • The right upper central incisor and right first molar at four different time points: before appliance fitting (T0), and at 1 month (T1), 3 months (T3) and 6 months (T6) thereafter	Evaluate the subgingival microbiological changes during the first 6 months of therapy with CAs and FAs		A
Antonio-Zancajo *et al*., 2020[289]	Prospective clinical trial	120 patients (54 men, 66 women) divided into 4 groups of 30 patients each	Pain and oral-health-related quality of life in orthodontic patients during initial therapy with CON, low-Friction, and lingual Brackets and aligners (Invisalign)	Different types of orthodontic appliances: CON and CON low-friction brackets, lingual brackets, and aligners	Compare pain and its relationship with the oral quality of life of patients with different types of orthodontic appliances: CON and CON low-friction brackets, lingual brackets, and aligners		A
Tran *et al*., 2020[290]	Multi-site prospective cohort study	27 adults about to start CAT	Impact of CAT on tooth pain and masticatory muscle soreness	Comparison between baseline, dummy aligner, Invisalign first active aligner and second active aligner	Investigate tooth pain and masticatory muscle soreness and tenderness in patients undergoing CAT	Explore whether psychological traits affected these primary outcomes	A
Albhaisi *et al*., 2020[291]	Prospective randomized clinical trial	49 patients (39 female, 10 males; mean age±standard deviation, 21.25±3 years) (42 completed the study)	Enamel demineralization during CAT compared with FA	Comparison between CAT and FA groups before treatment (T0) and 3 months later (T1)	Investigate the relationship between CAT and the development of white spot lesions and compare it with FA therapy by means of mean amount of fluorescence loss (ΔF)	Assess number of newly developed lesions, deepest point in the lesion (ΔFMax), lesion area (pixels), and plaque surface area (ΔR30)	A
Mulla Issa *et al*., 2020[292]	A cross-sectional study	80 patients coming for regular appointments undergoing orthodontic treatment	Periodontal parameters in adult patients with CAT versus three other types of brackets	CAT versus the three other types of brackets, that is, CON metal, CON ceramic, and metal self-ligating	Assess the gingival parameters in the CAT versus the 3 other types of brackets, that is, CON metal, CON ceramic, and metal self-ligating		A
Zhao *et al*., 2020[293]	6-month prospective clinical study	25 adult patients receiving Invisalign aligner	Dynamics of the oral microbiome and oral health among patients receiving CAT	Comparison between before the treatment (Group B) and at a 6-months follow-up (Group P)	Assess the impacts of Invisalign appliances on the oral bacterial community and biodiversity	Record clinical periodontal parameters and daily oral hygiene habits	A
Li *et al*., 2020[294]	Retrospective cohort study	A total of 373 roots from 70 subjects, with similar baseline characteristics and ABO discrepancy index scores	Prevalence and severity of apical root resorption during orthodontic treatment with CA and FA by CBCT	CAT and FA	Investigate and compare the prevalence and severity of ARR in patients treated with CA and FA using CBCT	Investigate which types of teeth had the greatest severity of RR	A
Levrini *et al*., 2020[295]	FEA *in vitro* study and prospective clinical study	10 patients were selected for the clinical study	Dental bleaching during orthodontic treatment with aligners	• 3 sample areas of gel application on the maxillary central incisors (the incisal edge, the middle part, and the gingival edge) were analyzed • Teeth 41 and 32 (control teeth, with reservoirs) were compared with that on teeth 31 and 42 (study teeth, without reservoirs)	Determine the tooth whitening effectiveness of trays with no reservoirs (Invisalign aligners or Vivera retainers used as bleaching trays), initially with a FEA and subsequently with a clinical study using spectrophotometry		A
Al Nazeh *et al*., 2020[296]	Prospective longitudinal cohort study	50 patients (26 females and 24 males; mean age=27.62±8.25 years, SE=1.17, 95% CI=24.71–29.89 years)	Relationship between oral health impacts and personality profiles among orthodontic patients treated with CA	Before and after treatment with Invisalign orthodontic treatment	Assess oral health impacts before and after Invisalign orthodontic treatment and their relationships with personality characteristics		A
Meazzini *et al*., 2020[297]	Prospective cohort study	100 syndromic Caucasian patients affected by various CFA from 2 different hospitals	Comparison of pain perception in patients affected by cleft and CFA treated with FA or Invisalign	CA and FA	Compare the difference in pain perception CAT and FA in patients affected by cleft and CFA		A
Barreda *et al*., 2020[298]	Prospective clinical trial	19 patients with orthodontic expansion requirement treated with Invisalign® aligners	Clinical and tomographic evaluation of PDL health status and maxillary buccal bone changes in expansion treatment using CA	• Measurements were done before starting treatment (T0) and at 12 months (T1) • Bone thickness was measured at two levels: 4 mm (CEJ+4) and 6 mm (CEJ+6) apical to the CEJ	Evaluate changes in periodontal status and maxillary buccal bone by considering clinical and tomographic parameters during the first year of orthodontic expansion with Invisalign® aligners		A
Kaur and El-Bialy 2020[299]	Retrospective clinical study	34 patients (9 males, 25 females; average age 41.37±15.02) who finished their orthodontic treatment using an intraoral LIPUS device and Invisalign CA in a private clinic	Shortening of overall orthodontic treatment duration with LIPUS	• 34 patients who finished their orthodontic treatment using an intraoral LIPUS device and Invisalign clear aligners • A control group (34) matching for the same malocclusions was randomly selected from finished treatment cases of the same clinician	Determine if there is a reduction in the overall treatment duration in orthodontic patients using low- LIPUS and Invisalign SmartTrack® clear aligners	Assess compliance of the patients using LIPUS with CA in comparison to control group	A
Xie *et al*., 2020[300]	Experimental *in vitro* study and animal study	6 mm disc from the aligners to represent the aligners	Gold Nanoclusters-Coated orthodontic devices can inhibit the formation of Streptococcus mutans Biofilm	• Highest concentration of QA-GNCs in well 1 and gradient diluted QA-GNCs in well 2–11 • The well 12 was the negative control group without any drug	Test modifying orthodontic devices (e.g., Invisalign aligner) with QA-GNCs as an antibiotic reagent to prevent bacterial contamination and biofilm formation	Test the effect of incubation time (2, 4, 6, 8, 10, 12, 24 h) on the coatings	A
Zhang *et al*., 2020[301]	Both *in vitro* and *in vivo* animal assays		Biological Safe Gold Nanoparticle- Modified dental aligner prevents the Porphyromonas gingivalis biofilm formation	Compared with the traditional oral administration method	Investigate the anti-P. gingivalis properties of surface-modified Invisalign with a stable antimicrobial coating system, optical antibacterial density measurement, contact assay, and SEM were performed	• Investigate the effect of AuDAPT on biofilm formation • Evaluate the biocompatibility of AuDAPT-based coating, including its influence on human periodontal ligament fibroblast cell (hPDLC) viability and irritation of the rat oral mucosa	A
Xie *et al*., 2020[302]	Experimental *in vitro* study	The whole Invisalign aligners (the maximum length, width, and height are about 6, 5, and 1 cm, respectively)	Near-Infrared Light-Activated phototherapy by Gold Nanoclusters for dispersing biofilms	DNase-AuNCs TG with untreated control groups Ordinary medical gargle (compound chlorhexidine gargle) and alcohol (75%) in biofilm dispersing	• Design and synthesize and assess DNase-decorated AuNCs (DNase-AuNCs), which are capable of dispersing bacterial biofilms and killing the encapsulated bacteria • Examine phototherapy of bacterial biofilms on an Invisalign Aligner	• Assess effect of irradiation time and Laser intensity on the phototherapy effects of DNase-AuNCs • Biosafety test of DNase-AuNCs	A
Nemec *et al*., 2020[303]	Experimental *in vitro* study	One set of aligners (Invisalign, Align Technology, San Jose, CA, USA) containing 69 upper and lower aligners was ordered	Behaviour of human oral epithelial cells grown on Invisalign® SmartTrack® Material		Examine the cell functional and morphological parameters of human oral squamous carcinoma cells directly grown on aligners made of SmartTrack material	• Investigate cell morphology, proliferation/ viability, cell death, and gene expression of several functional proteins • Investigate inflammatory cytokines, such as interleukin (IL)-8, and IL-6 and intercellular adhesion molecule 1	A
Gao *et al*., 2020[304]	Prospective cohort study	Total of 110 patients (55 pairs)	Comparison of pain perception, anxiety, and impacts on oral health-related quality of life between patients receiving CA and FA during the initial stage of orthodontic treatment	• CA and FA • Different days: first to day 14	Compare pain perception, anxiety, and impacts on oral health-related quality of life between adult patients receiving CA and FA during the initial stage of orthodontic treatments		A
Wang *et al*., 2020[305]	Randomized prospective controlled clinical trial	28 subjects were enrolled in the investigational arm and 15 in the control group	Effects of root resorption after orthodontic treatment using pulsating force	Effect of the device on root resorption during orthodontic treatment was compared with a control group of patients who received Invisalign treatment	Study the effect of the device on root resorption during orthodontic treatment using CBCT and compared with a control group of patients who received Invisalign treatment		A
Lou *et al*., 2021[306]	Prospective cohort study	17 healthy adults without TMD (16 females, 1 male; mean age±standard deviation, 35.3±17.6 years)	Evaluation of masticatory muscle response to CAT using ambulatory electromyographic recording	Comparisons over 4 weeks week 1 without aligners (baseline), week 2 with a passive aligner (dummy), week 3 with their first active aligner (active1), and week 4 with their second active aligner (active2)	Measure the activity of the masseter during CAT using ambulatory electromyography	Explore whether psychological traits modulate the masticatory muscle response to CAT	A
Campos Zeffa *et al*., 2021[307]	Prospective cohort longitudinal Study	12 Angle Class I and II orthodontic patients undergoing treatment with FA and 15 patients treated with CA	Influence of CON or Invisalign treatment on mineral and trace element salivary levels with Total Reflection X-ray Fluorescence	• CAT and FA • Before treatment (pre) and after 3 months of treatment (post)	Evaluate the salivary concentration of chemical elements in patients undergoing orthodontic treatment with FA and removable aligners	Evaluate secretion rate of chemical elements	A
Liu *et al*., 2021[308]	Retrospective study	320 incisors from 40 Class II patients treated with aligners (Invisalign)	Volumetric CBCT evaluation and risk factor analysis of EARR with CAT	Pretreatment (T0) and posttreatment (T1)	Investigate the prevalence and severity of EARR volumetrically with CAT using CBCT	Determine the possible risk factors and develop a prediction model for EARR	A
Al-Dboush *et al*., 2021[309]	Retrospective study	84 subjects who were treated using CAT	Impact of photobiomodulation and LIPUS adjunctive interventions on orthodontic treatment duration during CAT	28 patients were treated using CAT with a daily use of LIPUS for 20 min, 28 patients were treated using CAT with a daily use of PBM for 10 min, and 28 patients were treated using CAT alone	Assess the efficiency of LIPUS and PBM interventions in accelerating orthodontic tooth movement during CAT		A
Antonio-Zancajo *et al*., 2021[310]	Prospective clinical trial	120 patients divided into four groups	Comparative analysis of periodontal pain according to the type of precision orthodontic appliances: vestibular, lingual and aligners	Four groups: Conventional (CON), Low Friction (LF), Lingual (LO) and Aligners (INV)	Analyze the pain (intensity, location and type) that patients presented after the placement of different types of orthodontic appliances: CON, LF, lingual and aligners		A
Seleem *et al*., 2021[311]	Prospective clinical controlled trial	28 patients at Western University dental center	Effect of 10% carbamide peroxide on tooth shade, plaque index and gingival index during invisalign treatment	Two groups where the experimental Group applied daily bleaching material (10% CP, Ultradent Inc., South Jordan, UT, USA), while the control group did not for 4 weeks at baseline and in 2-week intervals for 6 weeks	Investigate whether 10% CP use during Invisalign treatment can enhance tooth shade esthetics while decreasing plaque levels and improving gingival health indices		A
Miller *et al*., 2003[190]	Retrospective validation study	Two identical digital models of one subject's orthodontic treatment	Validation of Align Technology's Treat III digital model superimposition tool and its case application	Compare two identical digital models using 12 selected points from the palatal rugae	Assessment of the efficacy and accuracy of three-dimensional computer-based predictive orthodontic systems requires that new methods of treatment analysis be developed and validated		B (Translation and rotation)
Djeu *et al*., 2005[191]	Retrospective cohort study	48 patients (Invisalign and braces groups)	Outcome assessment of Invisalign and traditional orthodontic treatment compared with the American Board of Orthodontics objective grading system	Comparison between Invisalign group and FA group	Objectively compare treatment outcome of Invisalign compared with braces	Assess duration, strengths and weaknesses of Invisalign compared with braces	B (ABO-OGS)
Duong and Kuo 2006[192]	Prospective clinical trial	*n*=20	Finishing with Invisalign.	EX40 Aligner was compared to thinner aligner E×30 and compared to ClinCheck goal	Explore procedure for finishing and the optimal material for finishing	Obtain data regarding the types of tooth positions that require overcorrection and the amount of overcorrection required to achieve the results shown at the final stage on Clincheck	B
Miller *et al*., 2007[193]	Prospective, longitudinal cohort study	60 adult orthodontic patients (33 with Invisalign aligners, 27 with FA)	A comparison of treatment impacts between Invisalign aligner and FA therapy during the 1st week of treatment	• CAT and FA • A baseline survey was completed before the start of treatment; diary entries were made for 7 consecutive days to measure various impacts of the subjects' orthodontic treatment over time	Evaluate the differences in quality of life impacts between subjects treated with Invisalign aligners and those with FA during the 1st week of orthodontic treatment		B (Quality of life impacts)

(Contd...)

Table 3: *(Continued).*

Author (year)	Study type	Participants	Intervention	Comparison	Outcome (Primary)	Outcome (Secondary)	Outcome Domain
Kuncio *et al.*, 2007[194]	Prospective cohort study	Final sample size for both groups was 11	Invisalign and traditional orthodontic treatment postretention outcomes compared using the American Board of Orthodontics objective grading system	• CA and FA • Cases were evaluated immediately after appliance removal (T1) and at a postretention time (T2), and 3 years after appliance removal	Compare the postretention dental changes between patients treated with Invisalign and those treated with FA		B (Postretention dental changes)
Kravitz *et al.*, 2009[195]	Pprospective clinical study	37 Patients treated with anterior Invisalign	Efficacy of tooth movement with Invisalign	Comparison between predicted and achieved tooth movement	Evaluate the efficacy of tooth movement with Invisalign		B (Expansion, constriction, intrusion, extrusion, mesiodistal tip, labiolingual tip, and rotation)
Schaefer and Braumann 2010[196]	Prospective cohort study	31 patients with good periodontal health	Halitosis, oral health and quality of life during treatment with Invisalign(®) and the effect of a low-dose chlorhexidine solution	• Group 1: CHX/no CHX, • Group 2: no CHX/CHX)	Examine how halitosis, oral dryness and general oral health were impacted during treatment with the Invisalign(®) system	Evaluate the effect of a low dose chlorhexidine solution (CHX)	B (Quality of life)
Krieger *et al.*, 2011[197]	Retrospective study	35 patients aged between 15 and 59 were measured	Accuracy of Invisalign® treatments in the anterior tooth region	Pre- and post-treatment models as well as the initial and final position of the ClinCheck	Analyse to what extent the pretreatment model at the beginning of the treatment corresponds to the initial position in the ClinCheck®	Analyze to what extent the predicted treatment result corresponds to the actual result of the therapy at the end of the treatment	B (Overjet, Overbite, dental midline shift)
Pavoni *et al.*, 2011[198]	Prospective clinical study	20 subjects	Analysis of dento-alveolar effects in using Self-ligating versus Invisalign	LF self-ligating brackets TIME 3 compared to the Invisalign technique	Evaluate the changes in the transverse dimension and the perimeter of the maxillary arch produced by LF self-ligating brackets TIME 3 compared to the Invisalign technique	Assess difference between the treatment durations of both modalities	B (Changes in the transverse dimension and the perimeter of the maxillary arch)
Krieger *et al.*, 2012[199]	Retrospective study	50 patients (15–63 years of age)	Achievement of predicted tooth movement in anterior region by Invisalign	Pre- and post-treatment casts as well as initial and final ClinChecks® models	Compare casts to their corresponding digital ClinCheck® models at baseline	Compare the tooth movement achieved at the end of aligner therapy (Invisalign®) to the predicted movement in the anterior region	B (upper/lower anterior arch length and intercanine distance, overjet, overbite, dental midline shift, and the irregularity index according to Little Irregularity Index)
Simon *et al.*, 2014[200]	Split mouth retrospective design	30 consecutive patients who required orthodontic treatment with Invisalign®	Treatment outcome and efficacy of an aligner technique-regarding incisor torque, premolar derotation and molar distalization	• Different movements were compared (1) Incisor Torque>10°, (2) Premolar derotation >10° (3) Molar distalization>1.5 mm. • The groups (1–3) were subdivided: in the first subgroup (a) the movements were supported with the use of an attachment, while in the subgroup (b) no auxiliaries were used (except incisor torque, in which Power Ridges were used) • Achieved OTM compared with predicted	Investigate the efficacy of orthodontic treatment using the Invisalign® system	Analyze the influence of auxiliaries (Attachment/ Power Ridge) as well as the staging (movement per aligner) on treatment efficacy	B and C (Incisor torque, premolar derotation and molar distalization)
Ercoli *et al.*, 2014[201]	Prospective clinical study	20 patients in age from 16 to 45 years (mean 31.7±8.7 years)	Comparison of two different clear aligner systems	Compare two different clear aligner systems: "Nuvola®" system with "Fantasmino®" system	Compare the "Nuvola®" system with "Fantasmino®" system (patient's satisfaction, improvement of the irregularity index, speech impairment, and mean wear time)	Examine their material properties, and define the indications for use of the aligners	B and E (patient's satisfaction, improvement of the irregularity index, speech impairment, and mean wear time)
Li *et al.*, 2015[202]	A multicenter randomized prospective controlled trial	152 adult orthodontic patients	The effectiveness of the Invisalign appliance in extraction cases using the the ABO model grading system	CAT and FA patients	Assess treatment outcomes of the Invisalign and compare results with braces using ABO model grading system in extraction cases		B (Extraction cases)
Grünheid *et al.*, 2016[203]	Retrospective study	30 patients treated with CA and 30 patients treated with FA	Effect of CAT on the buccolingual inclination of mandibular canines and the intercanine distance	• CAT and FA • Pre- and post-treatment measurements	Compare the changes in buccolinugal inclination of mandibular canines and intercanine distance in patients treated with CA to those treated with preadjusted edgewise appliances		B (Buccolingual inclination of mandibular canines and the intercanine distance)
Duncan *et al.*, 2016[204]	Retrospective chart review	61 adult white patients	Changes in mandibular incisor position and arch form resulting from Invisalign correction of the crowded dentition treated nonextraction	• 20 mild (2.0–3.9 mm), 22 moderate (4.0–5.9 mm), and 19 severe (>6.0 mm) • T0 and T1 values	Investigate changes in mandibular incisor position resulting from Invisalign correction of the crowded dentition without extraction		B (Mandibular incisor position without extraction)
Best *et al.*, 2016[205]	Cross sectional study	Orthodontists (n=1000) and general dentists (n=1000) who were providers of aligner treatment	Treatment management between orthodontists and general practitioners performing CAT	Orthodontists and general practitioners	Investigate differences in case selection, treatment management, and aligner treatment expertise between orthodontists and general practitioners		B (Expertise)
Hennessy *et al.*, 2016[206]	Randomized prospective clinical trial	44 patients (mean age, 26.4±7.7 years)	Comparing mandibular incisor proclination produced by fixed labial appliances and CA	CA and FA	Compare the mandibular incisor proclination produced by FA and third generation CA		B (Mandibular incisor proclination)
Ravera *et al.*, 2016[207]	Multicenter retrospective study	40 lateral cephalograms obtained from 20 non-growing subjects (9 male, 11 female; average age 29.73 years)	Maxillary molar distalization with aligners in adult patients	Comparing pretreatment and near-end treatment lateral cephalograms (T0) pretreatment and (T2) post-treatment	Test the hypothesis that bodily maxillary molar distalization was not achievable in aligner orthodontics		B (Maxillary molar distalization)
Weir 2016[208]	Prospective clinical study	12 patients, consecutively treated by the removal of a single lower incisor and Invisalign appliances	Invisalign treatment of lower incisor extraction cases	Pretreatment, treatment and post-treatment photographic records	Demonstrate the use of the Invisalign appliance in lower incisor extraction cases		B (Lower incisor extraction cases)
Moshiri *et al.*, 2017[209]	Retrospective study	30 adult patients with anterior open bite treated using Invisalign (22 females, 8 males; mean age at start of treatment: 28 years and 10 months; mean anterior open bite at start of treatment: 1.8 mm)	Cephalometric evaluation of adult anterior open bite, non-extraction treatment with Invisalign	Compare pre- and post-treatment cephalograms	Evaluate, by means of cephalometric appraisal, the vertical effects of non-extraction treatment of adult anterior open bite with clear aligners		B (Vertical movements)
Houle *et al.*, 2017[210]	Retrospective study	64 adult white patients	Predictability of transverse changes with Invisalign	ClinCheck measurements with the post-treatment measurements	Investigate the predictability of arch expansion using Invisalign		B (Transverse)
Gu *et al.*, 2017[211]	Retrospective case-control study	Records of 48 Invisalign patients and 48 fixed appliances patients	Evaluation of Invisalign treatment effectiveness and efficiency compared with CON FA using the Peer Assessment Rating index	Invisalign patients and FA patients	Compare the treatment effectiveness and efficiency of the Invisalign system with CON FA in treating orthodontic patients with mild to moderate malocclusion in a graduate orthodontic clinic	Analyze improvement between the Invisalign and FA groups	B (PAR Index/mild to moderate malocclusion)
White *et al.*, 2017[212]	A blinded randomized, prospective trial	41 adult Class I nonextraction patients to either traditional fixed appliance (6 males and 12 females) or aligner (11 males and 12 females) treatment	Discomfort associated with Invisalign and traditional brackets	• CA and FA • Initial treatment appointment, after 1 month and after 2 months	Evaluate differences in discomfort levels between patients treated with aligners and traditional FA	Assess analgesic consumption and sleep disturbances	B (Discomfort level)
Grünheid *et al.*, 2017[213]	Retrospective cohort study	30 patients who had nonextraction Invisalign treatment	Accuracy of Invisalign in nonextraction cases	Differences between actual treatment outcome and predicted outcome	Evaluate the accuracy of Invisalign technology in achieving predicted tooth positions with respect to tooth type and direction of tooth movement		B (Mesial-distal, facial-lingual, and occlusal-gingival directions, as well as for tip, torque, and rotation)
Shin 2017[214]	Retrospective cohort study	68 normal overbites, 40 deepbites and 12 openbites	Management of overbite with Invisalign appliance	Normal overbites, deepbites and openbites	Investigate the vertical dimension changes in patients with various pretreatment overbites who were treated with Invisalign appliance	Identify the dental and skeletal changes associated with this bite closing or opening	B
Solano-Mendoza *et al.*, 2017[215]	Retrospective study	116 patients subjected to expansion with Invisalign®	Effectiveness of the Invisalign® system in expansion movement with EX30' aligners	Planned expansion with ClinCheck® and actual clinical quantification using upper post-treatment model comparisons	Validate a new method for quantifying the predictability of expansion movement with the Invisalign® system	Determine whether there are statistically significant differences between planned expansion with ClinCheck® and actual clinical quantification using upper post-treatment model comparisons	B (Expansion)
Khosravi *et al.*, 2017[216]	Retrospective study	3 practitioners, all experienced with the Invisalign technique 120 adult patients who underwent orthodontic treatment only with the Invisalign appliance	Management of overbite with Invisalign appliance	Comparison between normal overbites patients, deep bite patients and open bite patients	Assess changes in anterior and posterior vertical dimensions during treatment with Invisalign by linear and angular measurements	Assess the primary mechanism by which aligners manage the vertical dimension	B (Vertical control)
Pacheco-Pereira *et al.*, 2018[217]	Prospective cohort study	81 patients, 29.6% men and 70.4% women, exclusively treated with the Invisalign system participated	Patient satisfaction and quality of life changes after Invisalign treatment		Assess patient satisfaction and changes in oral health-related quality of life immediately after orthodontic treatment using the Invisalign system		B (Patient satisfaction)
Garnett *et al.*, 2018[218]	Retrospective study	17 FA patients and 36 CA patients	Cephalometric comparison of adult anterior open bite treatment using CA and FA	Compare FA and CAT	Compare FA and CAT in correcting anterior open bite and in controlling the vertical dimension in adult patients with hyperdivergent skeletal patterns		B (Vertical movements)
Crouse 2018[219]	Retrospective study	Records of 220 cases	Patient compliance with Removable CAT	Comparisons between genders and ages	Investigate levels of cooperation with CA and differences based on age and sex		B (Compliance)
Charalampakis *et al.*, 2018[220]	Retrospective study	20 Class I adult patients treated with Invisalign; they completed their first series of aligners and had to have a "refinement" series	Accuracy of specific tooth movements with Invisalign	• Predicted tooth movement was compared with the achieved amount for each movement • Initial, predicted models and achieved models were compared	Determine the accuracy of specific tooth movements with Invisalign		B (Vertical, horizontal, rotational movements, and transverse widths)

(Contd...)

Table 3: *(Continued).*

Author (year)	Study type	Participants	Intervention	Comparison	Outcome (Primary)	Outcome (Secondary)	Outcome Domain
Lanteri *et al*., 2018[221]	Retrospective study	100 patients treated with Invisalign compared with a control group treated with FA	The efficacy of orthodontic treatments for anterior crowding with Invisalign compared with FA using the Peer Assessment Rating Index	CAT and FA	Determine the efficacy of Invisalign in a large sample of patients compared to FA	Assess need for refining aligners and for fixed retainers after treatment and duration of treatment	B (Amount of anterior dental crowding (Little Index) and the Peer Assessment Rating (PAR Index) scores)
Tepedino *et al*., 2018[222]	3D Retrospective cohort study	39 adult patients, who were consecutively treated with CA	Movement of anterior teeth using clear aligners	Comparison between predicted and achieved torque movements of anterior teeth	Evaluate the predictability of Nuvola® aligner system in achieving torque movements of anterior teeth		B (Torque of anteriors)
Sfondrini *et al*., 2018[223]	Retrospective study	Cephalometric data of 25 patients with similar skeletal and dental pretreatment parameters were collected	Buccolingual inclination control of upper central incisors of aligners	CON brackets (Victory, 3M), self-ligating appliances (Damon Q, Ormco), and aligners (Invisalign, Align Technology)	Compare the radiographic buccolingual inclination of upper incisors in patients treated with three different orthodontic techniques		B (BL inclination)
Flores-Mir *et al*., 2018[224]	Cross sectional survey	Adult patients (n=145) treated with bracket-based or Invisalign therapy; 122 patients were assessed	Patient satisfaction and quality of life status after 2 treatment modalities	CA and FA	Assess patient satisfaction and quality of life among adults through 2 validated comprehensive questionnaires	Compare patient satisfaction and status in oral health-related quality of life immediately after orthodontic treatment in patients treated with Invisalign and those who received standard bracket-based treatment	B (Patient satisfaction)
Ko *et al*., 2018[225]	Cross sectional study	16 orthodontists, all of whom were in practice for a minimum of 5 years and did not routinely use digital models (other than for Invisalign® cases)	Recommendations for CAT using digital or plaster study casts	Digital model versus plaster model	Assess which types of malocclusions are recommended for treatment with clear aligners	Determine if recommendations for aligner treatment differed when using digital versus plaster models	B (Recommended treated malocclusions)
Kankam *et al*., 2019[226]	Retrospective chart review and 3D morphometric study	33 patients, with a mean age of 19.99 years undergoing triple-jaw surgery (LeFort I osteotomy, bilateral sagittal split osteotomy, and genioplasty)	Comparing outcomes in Orthognathic Surgery using CA Versus CON FA	Comparison outcomes between CAT and FA groups in surgical cases	Evaluate perioperative outcomes (operating time, concurrent extraction of teeth, fat grafting, duration of hospital stay, diet advancement, and use of narcotic analgesics) between CAT and FA	3D quantify postoperative edema between CAT and FA	B (Surgical cases)
Christou *et al*., 2019[227]	A case-control study	Records from 58 patients, 29 of whom received Invisalign treatment (mean age 19.03 years) and 29 of whom received traditional fixed-appliance treatment (mean age 13.83 years)	Smile outcome comparison of Invisalign and FA treatment	• Patients treated with CAT and FA • Pretreatment scores, post-treatment scores, and differences between within-group smile score before and after treatment were determined for each group	Evaluate and compare smile treatment outcomes between patients treated with Invisalign CA and those treated with traditional FA by integrating variables such as lip symmetry, smile index, smile cant, buccal corridors, and gingival display into smile outcome evaluation		B (Smile)
Caruso *et al*., 2019[228]	Retrospective study	10 subjects (8 females 2 males; mean age 22.7±5.3 years)	Impact of molar teeth distalization with clear aligners on occlusal vertical dimension		Analyse the effects on vertical dentoskeletal dimension of young adults treated with sequential distalization with orthodontic aligners (SN-GoGn between T0 and T1)	Measure linear position of the upper molars, the molar class relationship parameter, and the upper incisive inclination	B (Molar distalization with vertical control)
Dai *et al*., 2019[229]	Retrospective study	30 patients who received maxillary first premolar extraction treatment with Invisalign	First premolar extraction treatment with Invisalign	Achieved and predicted tooth movement of maxillary first molars and central incisors	Compare achieved and predicted tooth movements of maxillary first molars and central incisors in first premolar extraction cases treated with Invisalign	Explore the influence of age (adolescents vs. adults), attachment (G6-optimized vs. 3-mm vertical, 3-mm horizontal, and 5-mm horizontal), and initial crowding on the differences between predicted and achieved tooth movement	B (Premolar extraction)
Izhar *et al*., 2019[230]	Prospective clinical study	10 cases with mild anterior crowding treated with aligner therapy	Comparative assessment of clinical and predicted treatment outcomes of CAT	• Compare predicted software models showing orthodontic tooth movement and clinical models • Compare the stage models of both the groups	Assess the predicted software models and clinical models and compare the stage models of both groups so as to evaluate the efficacy of tooth movement with CA		B (Irregularity scores)
Alajmi *et al*., 2020[231]	Retrospective cohort study	60 adult patients	Short-Term Oral impacts experienced by patients treated with Invisalign or CON FA	Comparison between CAT group, FA group	Rate the experience of patients after appliance activation in regard to oral impact experience and satisfaction of both treatment modalities (speech, chewing abilities, food restrictions, mucosal ulcerations)	Assess effects on daily routine, use of analgesics, and overall treatment satisfaction	B (Short-Term Oral Impacts)
De Felice *et al*., 2020[232]	Randomized prospective clinical trial	10 clinicians were randomly recruited using the Doctor Locator by Align Technology (California) Four consecutive patients treated with CAT and manual stripping were selected for a total of 40 subjects and 80 dental arches	Accuracy of IER during CAT	Planned IPR versus actual IPR performed	Compare the accuracy of the actual space obtained through IPR compared to the amount of IPR planned through the digital setup during CAT		B (IPR)
Haouili *et al*., 2020[233]	Prospective follow-up clinical study	38 patients treated with Invisalign Full or Invisalign Teen	Efficacy of tooth movement with Invisalign	Comparison between predicted and achieved tooth movements with Invisalign	Provide an update on the accuracy of tooth movement with Invisalign	Assess the strengths and weaknesses of tooth movement with Invisalign	B (Mesial-distal crown tip, buccal-lingual crown tip, extrusion, intrusion, and mesial-distal rotation)
Long *et al*., 2020[234]	Cross-sectional study	120 eligible patients (100 patients for developing and testing the evaluation system and 20 patients for validating this system)	An objective system for appraising CAT difficulty: CAT complexity assessment tool (CAT–CAT)		Develop an objective evaluation system for assessing CAT difficulty	Examine the independent association of each variable (e.g., overbite and crowding) with the complexity level and to select appropriate clear aligner patients	B (CAT difficulty)
Harris *et al*., 2020[235]	Single-center retrospective study	45 patients with a mean age of 30.73±8.0 years and initial open bite of–1.21±1.15 mm	Open bite closure using clear aligners		Evaluate the dental and skeletal effects that occur in the correction of anterior open bite with CA		B (Vertical movements)
Borda *et al*., 2020[236]	Retrospective study	56 teenage patients with mild malocclusions	Outcome assessment of CA versus FA treatment in a teenage population with mild malocclusions	Comparison between CAT and FA	Assess the efficacy and efficiency of treatment in adolescents presenting with mild malocclusions, comparing outcomes using CA to FA		B (Mild malocclusions)
Zhou and Guo 2020[237]	Prospective clinical trial	20 Chinese adult patients who underwent arch expansion with Invisalign aligners	Efficiency of upper arch expansion with the Invisalign system	Comparison between the expected and actual expansion amounts between pretreatment records and immediately after expansion	• Quantify the efficiency of arch expansion using the Invisalign system in patients • Investigate the movement patterns by comparing actual expansion outcomes of crown and root with virtual planned expansion in ClinCheck software	Ascertain whether the preset expansion amount and initial molar torque correlated with the efficiency of bodily expansion movement	B (Expansion)
Morales-Burruezo *et al*., 2020[238]	Retrospective study	114 patients with transverse malocclusion	Efficacy and predictability of arch expansion with Invisalign	• Comparing planned measurements (width of canines, premolars and molars rotations and inclinations) with the real measurements achieved at the end of the first treatment phase • Three data sets; T1: initial measurements at start of treatment; T2: Clincheck predicted measurements at end of first treatment phase; T3: measurements taken at start of the second treatment phase	Determine the efficacy of the Invisalign system for arch expansion	Assess the predictability of the measurements planned by Clincheck software for the use of the transparent aligners at the end of the first treatment phase	B (Arch expansion)
Lucchese *et al*., 2020[239]	Retrospective study	72 digital models of 18 consecutive patients treated with Invisalign and Smart Track aligners	Arch depth and arch perimeter measurements before and after CAT	• Invisalign and Smart Track • T0–T1 (14 weeks) • Upper arch was compared to lower arch	Assess values of arch depth and perimeter of arch before and after the treatment using CA		B (Arch depth and perimeter of arch)
Deregibus *et al*., 2020[240]	Prospective clinical study	27 class II patients	Morphometric analysis of dental arch form changes in Class II patients treated with CA	Maxillary and mandibular digital casts were compared at three different times: pretreatment (T0), the accepted Clincheck® (Align Technology, San José, CA, USA) (T1), and retention phase models (T2)	Evaluate the arch form changes in Class II Caucasian patients treated with Invisalign®		B (Class II)
Hansa *et al*., 2020[9]	Retrospective cohort study	90 consecutively treated Invisalign patients (45 control, 45 DM)	Outcomes of CAT with and without DM	CAT with and without DM	The effects of Invisalign CAT with and without DM were compared for treatment duration, number of appointments, number of emergency appointment, refinements and refinement aligners, time to first refinement	Assess accuracy of Invisalign in achieving predicted tooth positions (aligner tracking)	B (Maxillary anterior dentition in rotational movements and mandibular anterior dentition for buccal-lingual linear movement)
Amodeo *et al*., 2020[241]	Retrospective study	12 patients affected by class III dento-skeletal malocclusion (4 females and 8 males), with age range from 22 and 42 years old)	Surgery First and Invisalign System: Combined Digital Approach	The CON orthognathic approach, or an orthodontics-first approach	Analyzing the benefits and reporting the experience and results of complex cases using surgical treatment with Surgery First and those of an orthodontic treatment with Invisalign technique		B (Surgery first with CAT)
Hansa *et al*., 2020[242]	Retrospective cohort study	A sample of 155 consecutively treated Invisalign® patients (67 control, 88 DM)	Clinical outcomes and patient perspectives of DM® GoLive® with Invisalign®	Control group with no monitoring and DM group	Compare the effects of Invisalign® with and without DM® GoLive® on the following parameters: treatment duration, number of appointments, number of refinements, total number of refinement aligners, and time to initial refinement	The patients' perspectives on DM® were also evaluated using an online questionnaire	B (Dental Monitoring)
Gaffuri *et al*., 2020[243]	Prospective clinical study	24 patients	Comparative effectiveness of Invisalign FA in First-Premolar Extraction Cases	CA and FA	Compare the efficacy of clear aligners with that of preadjusted edgewise appliances (MBT) in premolar-extraction treatment, as scored by the ABO Objective Grading System and ABO standard cephalometric analysis		B (Premolar- extraction treatment)
Al-Nadawi *et al*., 2021[244]	Prospective clinical study	80 patients	Effect of CA wear protocol on the efficacy of tooth movement	• Group A (7-day changes), group B (10-day changes), and group C (14-day changes) • Post-treatment scans were compared with the final virtual treatment simulations	Compare the efficacy of orthodontic tooth movement with three aligner wear protocols: 7 day, 10 day, and 14 day		B (Posterior segment for maxillary intrusion, distal-crown tip and buccal-crown torque, and mandibular intrusion and extrusion)

(Contd...)

Table 3: *(Continued).*

Author (year)	Study type	Participants	Intervention	Comparison	Outcome (Primary)	Outcome (Secondary)	Outcome Domain
Lione *et al*., 2021[245]	Prospective clinical study	28 subjects (16 females, 12 males, mean age 31.9±5.4 years)	Maxillary arch development with Invisalign system	Before treatment (T1), at the end of treatment (T2), and on final virtual models (T2 ClinCheck) Different teeth in maxillary arch	Evaluate tooth movements during maxillary arch expansion with CAT		B (Maxillary arch expansion)
Kalemaj and Levrini 2021[246]	Prospective cohort study	50 patients treated with CAT by six orthodontists were included	Quantitative evaluation of implemented IER during aligner therapy	At the beginning of treatment and after the first set of aligners p-IPR and i-IPR	Investigate the correspondence between p-IPR and i-IPR in an everyday-practice scenario	Estimate factors that might influence i-IPR to make the process more efficient	B (IPR)
Al-Balaa *et al*., 2021[247]	Retrospective study	22 patients, with a mean age of 23.74 years	Predicted and actual outcome of anterior intrusion with Invisalign assessed with CBCT	• Pretreatment and posttreatment CBCT scans • Comparison between the predicted and actual measurements of anterior intrusion of the teeth was performed	Compare predicted anterior teeth intrusion measurements with the actual clinical intrusion measurements using CBCT		B (Anterior teeth intrusion)
Jiang *et al*., 2021[248]	Retrospective cohort study	Pre-CBCT and posttreatment CBCT scans from 69 patients who completed nonextraction treatment with CA were collected	How well do integrated 3D models predict alveolar defects after treatment with clear aligners?	Pre-CBCT and post-treatment CBCT	Evaluate the accuracy of integrated models constructed by pre-CBCT in diagnosing alveolar defects after treatment with CA		B (Prediction of alveolar defects)
Jiang *et al*., 2021[249]	Retrospective clinical study	Pretreatment and posttreatment CBCT scans were collected from 69 patients	Efficacy of incisor movement with CA	• Assessment of incisor pure tipping, controlled tipping, translation, and torque • Pretreatment model, post-treatment model, virtual model	Evaluate the efficacy of different types of incisor movements with CA in the sagittal plane		B (Incisor pure tipping, controlled tipping, translation, and torque)
Laganà *et al*., 2021[250]	Retrospective study	30 Subjects (14 males, 16 females; mean age of 24.53±13.41 years)	Enamel interproximal reduction during treatment with clear aligners: digital planning versus OrthoCAD analysis	Digital planning versus OrthoCAD analysis	Compare the amount of IPR provided on ClinCheck software with the amount of IPR carried out by the orthodontist during treatment with CA		B (IPR)
Dianiskova *et al*., 2021[251]	Retrospective study	49 Consecutively patients (mean age±SD 12.9±1.7 years), 32 females and 17 males	Treatment of mild Class II malocclusion in growing patients with CA versus fixed multibracket therapy	CA and FA	Compare the dental and skeletal effects of intermaxillary elastics on the correction of mild Angle's Class II division 1 malocclusion with CA versus fixed multibracket in growing patients		B (Class II)
Caruso *et al*., 2021[252]	Retrospective controlled study	20 patients were examined, 10 of whom treated with MA and 10 treated with TB	MA with clear aligners in the treatment of skeletal Class II	• MA (Invisalign MA) versus TB (TB Appliance) • Pre-treatment and post-treatment lateral skull radiographs	Analyse the dentoskeletal effects of the Invisalign MA device in the treatment of skeletal Class II malocclusions		B (skeletal Class II malocclusions)
Patterson *et al*., 2021[253]	Retrospective study	80 adult patients	Class II malocclusion correction with Invisalign	• Group 1 with Class I molar malocclusions • Group 2 with Class II molar malocclusions • Comparisons between the 2 groups at pre-treatment, post-treatment ClinCheck (Align Technology) prediction, and post-treatment	Determine whether Class II malocclusion can be treated with clear aligners after completing treatment with the initial set of aligners		B (Class II)
Riede *et al*., 2021[254]	Retrospective study	30 patients	Effectiveness of CAT in maxillary expansion or contraction and occlusal contact adjustment	• A pre-treatment model, a scan-based CC model, a post-treatment clinical model, and a CC model reflecting the treatment outcome as initially simulated • SmartTrack® compared to previously used E×30® material	Evaluate the precision of aligner (Invisalign®) treatment with the current material (SmartTrack®) in achieving expansion or contraction of the maxilla	Evaluate occlusal contacts as simulated in the proprietary planning software (ClinCheck®, CC)	B (Maxillary expansion or contraction and occlusal contact adjustment)
Henick *et al*., 2021[255]	Retrospective study	Invisalign group (*n*=24), FA (*n*=24)	Effects of Invisalign (G5) with virtual bite ramps for skeletal deep overbite malocclusion correction in adults	CA and FA	Investigate the skeletal and dentoalveolar effects of Invisalign's G5 protocol with virtual bite ramps in the treatment of adults with skeletal deep bites		B (Vertical movements)
Graf *et al*., 2021[256]	Retrospective study	98 adult patients of whom 33 patients were treated according to predefined inclusion and exclusion criteria	Effectiveness and stability of CAT using the Peer Assessment Rating Index	Baseline (T0), after finishing orthodontic treatment with Invisalign® (T1; Align Technology Inc., Santa Clara, CA, USA) and after a mean retention period of 10 months (T2)	Measure treatment effects of aligner treatments in adult patients directly after treatment	Assess the stability of these effects after a short-term retention period using the PAR Index	B (PAR Index/Stability)
Kravitz *et al*., 2008[359]	Prospective clinical study	53 canines (33 maxillary and 20 mandibular) were measured from the virtual TREAT models of 31 participants treated with anterior Invisalign	Influence of attachments and interproximal reduction on the accuracy of canine rotation with Invisalign	• Three treatment modalities: AO, interproximal reduction only (IO), and neither attachments nor interproximal reduction (N) • Pretreatment virtual model of the predicted final tooth position was superimposed on the post-treatment virtual model	Evaluate the influence of attachments and interproximal reduction on canines undergoing rotational movement with Invisalign		C
Castroflorio *et al*., 2013[360]	Prospective cohort study	12 Upper incisors in Invisalign patients needing lingual root torque as part of their treatment. Six consecutive patients (four females, two males, age 26.3±10.2 years)	Upper-incisor root control with invisalign appliances		Test the efficiency of Align Technology's Power Ridge in controlling the buccolingual inclination of upper incisors		C
Dasy *et al*., 2015[361]	Experimental *in vitro* study	3 casts were manufactured	Effects of variable attachment shapes and aligner material on aligner retention	• Two casts contained attachments (ellipsoid and beveled) were compared with one without any attachments to serve as a control • Four types of aligners were thermoformed: CA-soft, CA-medium, and CA-hard, with various thicknesses, and Essix ACE	Evaluate the retention of four types of aligners on a dental arch with various attachments		C
Simon *et al*., 2014[362]	Experimental study with split mouth design	970 Aligners of the Invisalign system (60 series of aligners). The aligners came from 30 consecutive patients	Forces and moments generated by removable thermoplastic aligners: incisor torque, premolar derotation, and molar distalization	• 3 Tooth movements (incisor torque, premolar derotation, molar distalization) • With and without attachments	Quantify the forces and moments delivered by a single aligner and a series of aligners (Invisalign; Align Technology, Santa Clara, Calif)	Investigate the influence of attachments and power ridges on the force transfer	C and D
Mantovani *et al*., 2019[363]	Experimental *in vitro* study	6 resin casts obtained from STL files of a patient	SEM analysis of aligner fitting on anchorage attachments	• 3 different aligners (Invisalign [Align Technology, Santa Clara, CA, USA], CA Clear Aligner [Scheu-Dental, Iserlohn, Germany] and F22 [Sweden and Martina, Due Carrare, Italy]) • 2 different types of resin used to build attachments: CON bulk-fill resin and flowable resin	Evaluate the fitting of three different aligners (Invisalign [Align Technology, Santa Clara, CA, USA], CA Clear Aligner [Scheu-Dental, Iserlohn, Germany] and F22 [Sweden and Martina, Due Carrare, Italy]) on anchorage attachments using SEM	Analyze the influence of 2 different types of resin used to build attachments on aligner fitting	C
Barreda *et al*., 2017[364]	Randomized prospective clinical trial	40 attachments were bonded to the buccal surface of maxillary teeth	Surface wear of resin composites used for Invisalign® attachments	Comparison between two resin composites (Filtek Z350 XT, 3MESPE and Amelogen Plus TW, Ultradent Products Inc.) used for making Invisalign® attachments over 6 months period	Evaluate surface wear over 6 months in two resin composites (Filtek Z350 XT, 3MESPE and Amelogen Plus TW, Ultradent Products Inc.) used for making Invisalign® attachments	Evaluate attachment shape	C
D'Antò *et al*., 2019[312]	Experimental *in vitro* study	25 attachments for each group and a total of 75 attachments	Influence of dental composite viscosity in attachment reproduction	Three composite resins were selected based on three different degrees of viscosity: A low-viscosity flowable resin (ENAMEL plus HRi® Flow HF, GDF GmbH), a medium-viscosity orthodontic composite (Bracepaste® Medium Viscosity Adhesive, AO), and a high -viscosity dental restorative material (ENAMEL plus HRi® Enamel, GDF GmbH)	Evaluate the role of different composite materials in the correct reproduction of attachment shape and position		C and E
Thai *et al*., 2020[365]	Case control study	250 adult subjects	Esthetic perception of CAT attachments using eye-tracking technology	Clear aligner with minimal attachment	Assess and compare esthetic perceptions of CAT with attachments and esthetic brackets by measuring differences in eye fixations using eye-tracking technology	Importance of appliance esthetics during treatment on a scale of 1 (not important) to 10 (very important)	C
Cortona *et al*., 2020[366]	Experimental *in vitro* study	A CAD model including a complete lower dental arch (with element 4.5 mesially rotated 30°)	Orthodontic rotational movement of a lower second premolar obtained with CA	Comparing different staging and attachment configurations	Evaluate, using the finite element method, the orthodontic rotational movement of a lower second premolar obtained with CA, analyzing different staging and attachment configurations		C
Lin *et al*., 2021[367]	Split-mouth prospective clinical study	55 participants (13 men and 42 women, mean age±SD: 24.2±5.9 years)	Assessment of preparation time and 1-year Invisalign aligner attachment survival using flowable and PC	FC group (Filtek Z350XT Flowable Restorative) and the PC group (Filtek Z350XT Universal Restorative)	Compare preparation time of aligner attachment between a FC and a PC	Compare 1-year Invisalign aligner attachment survival between a FC and a PC	C
Yaosen *et al*., 2021[368]	Prospective cohort Study	94 patients undergoing CAT (27 males and 67 females)	Risk factors of composite attachment loss in orthodontic patients during orthodontic CAT		Assess the incidence of attachment loss during orthodontic CAT	Identify rick factors that may predict such event	C
Vardimon *et al*., 2010[369]	Prospective cohort study	Maxillary aligners (*n*=61) were examined from 3 patients requiring maxillary incisor retraction and stationary anchored premolars	*In vivo* von Mises strains during Invisalign treatment	Series 1 was worn by the patient during the biweekly course of treatment, and series 2 was used for the *in vivo* von Mises strain measurements worn by the patient only during strain measurements location (incisor and premolar) and time (days 1, 2, 9, and 15).	Evaluate the force behavior by analyzing the von Mises strains developed in an aligner during biweekly wear	Compare the changes in von Mises strains between the active and anchorage dental units	D
Mantovani *et al*., 2018[370]	Experimental *in vitro* study	(STL) files obtained by intraoral scanning of a patient with a Class I malocclusion, a total of 160 micrometric measurements were obtained	SEM evaluation of aligner fit on teeth	• 2 aligner systems, Invisalign and CA-Clear Aligner • Different teeth and different regions on teeth	Determine how well aligners fit the teeth using SEM	Determine whether there were differences in fit between aligners made by Invisalign (Align Technology) and CA-Clear Aligner (Scheu-Dental, Iserlohn, Germany)	D
Skaik *et al*., 2019[313]	Experimental *in vitro* study	A series of clear aligners was designed and fabricated	Effects of time and clear aligner removal frequency on the force delivered by different PETG -modified materials determined with thin-film pressure sensors	CON PET-G and the second material was modified PET-G	Identify the various factors (time and CA removal frequency) that influence the force changes generated by PET-G materials		D and E
Son *et al*., 2020[371]	Experimental *in vitro* study	Clear aligner and pressure sensor	Pressure differences from CA movements	0 mm, 0.25 mm and 1.00 mm movements	Assess pressure differences from CA movements assessed by pressure sensors		D
Kim *et al*., 2020[372]	Experimental FEA	Through 3D FEA, simple tooth shape and mandibular canine shape were extracted	Optimal position of attachment for removable thermoplastic aligner on the lower canine using FEA	• Lingual side of the tooth compared to the buccal side • Various shapes of attachments for each of the four orthodontic treatment situations (extrusion, intrusion, rotation, and torque)	Simulate various shapes of attachments for each of the four orthodontic treatment situations (extrusion, intrusion, rotation, and torque) using the FEA to derive the optimum shape of attachment for each situation	Analyze the best position for attachments by simulating various attachment positions for each orthodontic treatment situation using the derived attachment shapes.	D
Jiang *et al*., 2020[373]	3D *in vitro* experimental finite element study	A 3D FEM of maxillary dentition was constructed for first premolar extraction	Clear aligners for maxillary anterior en masse retraction	Compare three protocols with different amounts of retraction and intrusion on incisors	Evaluate tooth behaviours under various maxillary incisor retraction protocols for CAT	Evaluate location of PDL stresses	D (Incisor retraction and intrusion)

(Contd...)

Table 3: *(Continued).*

Author (year)	Study type	Participants	Intervention	Comparison	Outcome (Primary)	Outcome (Secondary)	Outcome Domain
Ma and **Li** 2021[374]	*In vitro* experimental FEA	The CBCT data of a patient received invisible orthodontics without diabetes and other systemic diseases were collected	Optimal orthodontic displacement of CA for mild, moderate and severe periodontal conditions	Stage I: mild periodontitis, (M1); Stage II: moderate periodontitis, (M2); Stage III: severe periodontitis, (M3) Left lower lateral incisor, left lower central incisor, right lower lateral incisor, and right lower central incisor Three different periodontal conditions (M1, M2, and M3) with axial inclination 90° and 100°	Explore an optimal orthodontic displacement of clear aligner using a three-dimensional (3D) FEM for periodontally compromised patient		D
Seo *et al*., 2021[375]	*In vitro* experimental FEA	Three 3D dental FE models were constructed	Comparative analysis of stress in the periodontal ligament and center of rotation in the tooth after orthodontic treatment depending on CA thickness	0.75 mm-thick aligner 0.05 mm-thick aligner	Investigate the biomechanical and clinical effects of aligner thickness on stress distributions in the periodontal ligament and changes in the tooth's center of rotation		D
Bollen *et al*., 2003[187]	Propsective clinical trial	51 subjects	Activation time and material stiffness of sequential removable orthodontic appliances	• 2 distinctly different materials (hard and soft) • 2 activation frequencies (1 week and 2 weeks)	Compare 2 distinctly different materials (hard and soft)	Compare 2 activation frequencies (1 week and 2 weeks) for this technique	E
Schuster *et al*., 2004[314]	Prospective clinical trial	Samples of Invisalign appliances were randomly selected from 10 patients	Structural conformation and leaching from *in vitro* aged and retrieved Invisalign appliances	• Before intraoral placement and after retrieval • Artificial aging for 2 weeks	Investigate the structure of Invisalign appliances (Align Technology, Santa Clara, Calif) after intraoral exposure	Qualitatively and quantitatively characterize the substances leached from the aligners after accelerated *in vitro* aging	E
Gracco *et al*., 2009[315]	Experimental *in vitro* study	One "as-received" Invisalign aligner and 10 Invisalign aligners worn by 10 randomly selected patients	Short-term chemical and physical changes in Invisalign appliances	Aligner immersed in artificial saliva for 14 days and 10 Invisalign aligners worn by 10 randomly selected patients for 14 days	Investigate the short-term optical, chemical and morphological changes in Invisalign appliances		E
Schott and Göz, 2011[316]	Experimental *in vitro* study	• 7 Invisalign TeenH aligners (A) were obtained directly from the manufacturer (Align Technology Inc, Santa Clara, Calif) • 14 Invisalign TeenH aligners (B) were provided by an orthodontic office that routinely uses the InvisalignH system	Color fading of the blue compliance indicator encapsulated in removable clear Invisalign TeenH aligners	• Color fading was observed as a function of time, pH, and temperature while compliance indicators were stored in drinking water or sour soft drinks and in conjunction with the use of cleaning tablets and a dishwasher • Color Fading of the Blue Compliance Indicators after soaking of unused aligners (A) in 250 mL of different aqueous media at different temperatures, pH, and time in comparison to the color change of the compliance indicators of 50 aligners after use by patients for 17–22/24 h over 14 Days (B)	Evaluate the color fading in aqueous solutions of the blue dot wear-compliance indicators of the Invisalign Teen® System outside the oral cavity	Compare findings of color fading outside oral cavity to the color changes observed when the aligners were being worn by patients	E
Lombardo *et al*., 2015[317]	Experimental *in vitro* study	9 samples of orthodontic aligners	Optical properties of orthodontic aligners-spectrophotometry analysis of three types before and after aging	• Three different manufacturers (Invisalign, Align Technology, Santa Clara, CA, USA; All-In, Micerium, Avegno, GE, Italy; F22 Aligner, Sweden and Martina, Due Carrare, PD, Italy) • Before and after two cycles of *in vitro* aging	Assess and compare absorbance and transmittance values of three types of CA before and after two cycles of *in vitro* aging		E
Alexandropoulos *et al*., 2015[318]	Experimental *in vitro* study	8 appliances were fabricated from each material	Chemical and mechanical characteristics of contemporary thermoplastic orthodontic materials	Four thermoplastic materials were tested: Clear Aligner (Scheu-Dental), ACE and A+ (Dentsply), and Invisalign (Align Technology)	Characterise the chemical and mechanical properties of contemporary thermoplastic orthodontic materials		E
Liu *et al*., 2016[319]	Experimental *in vitro* study	60 CA produced by three manufacturers (Invisalign, Angelalign, and Smartee)	Colour stabilities of three types of orthodontic clear aligners exposed to staining agents	• Three manufacturers (Invisalign, Angelalign, and Smartee) • Three staining solutions (coffee, black tea, and red wine) and one control solution (distilled water) • After 12-h and 7-days immersions	Evaluate and compare the colour stabilities of three types of orthodontic clear aligners exposed to staining agents *in vitro*		E
Gerard Bradley *et al*., 2016[320]	Experimental *in vitro* study	Appliances were cut (n=25)	Do the mechanical and chemical properties of Invisalign™ appliances change after use?	Samples of Invisalign appliances were collected following routine treatment for a mean period of 44±15 days (group INV), whereas unused aligners of the same brand were used as reference (group REF)	Investigate the mechanical and chemical alterations of Invisalign appliances after intraoral aging		E
Bräscher *et al*., 2017[321]	Cross sectional survey	72 patients (68% women, 32% men, mean age: 29.3±9.2 years) who had worn the new material for a mean of 6 months	Comparing (corrected) the SmartTrack® material to the previously used (corrected) aligner material	The SmartTrack® material was compared to the previously used (corrected) aligner material	Test how the transition from the previous material used for Invisalign to the new material SmartTrack® was accepted by patients during ongoing Invisalign®treatment, in terms of pain, pressure upon insertion, comfort, mucosal irritation, phonetics, discoloration, and taste		E
Condo' *et al*., 2018[322]	Experimental *in vitro* study	40 Invisalign® aligners	Mechanical properties of "two generations" of teeth aligners	20 LD30 aligners and 20 EX30 aligners Two subgroups, never used and intra-orally aged	Investigate and compare main technical and morphological features of Invisalign® aligners made with two different polymer blends: Exceed30 (EX30) and Smart Track (LD30), before and after use	• Evaluate the chemical structure of the two different polymers. • Evaluate, compare and analyze crystalline phases in the two materials and then identify the physical-chemical properties describing their mechanical behaviors before and after clinical use. • Compare possible differences in the mechanical behavior starting from samples with the same geometry	E
Agarwal *et al*., 2018[323]	Experimental *in vitro* study	70 specimens, (n=10 per method, 50.8 mm×12.7 mm×1.0 mm)	Long-term effects of seven cleaning methods on light transmittance, surface roughness, and flexural modulus of polyurethane retainer material	Invisalign® cleaning crystals (Align Technology Inc), Polident® (GlaxoSmithKline®, Brentford, UK), Listerine® mouthwash (Johnson and Johnson®, New Brunswick, NJ, USA), 2.5% vinegar, 0.6% sodium hypochlorite, 3% hydrogen peroxide, and toothbrushing with distilled water	Evaluate the long-term effects of seven different cleaning methods on light transmittance, surface roughness, and flexural modulus of a polyurethane retainer material		E
Wible *et al*., 2019[324]	Experimental *in vitro* study	Standardized polypropylene/ethylene copolymer retainer specimens (n=70, 50.8 mm×12.7 mm×1.0 mm)	Long-term effects of various cleaning methods on polypropylene/ethylene copolymer retainer material	Seven chemical cleaning solutions: Invisalign cleaning crystals, Retainer Brite, Polident, Listerine mouthwash, 2.5% acetic acid, 0.6% NaClO, and 3% H_2O_2 for 6 months Another group of specimens (n=10) were brushed with a standardized toothbrushing machine for 2 min twice a week	Evaluate long-term light transmittance, surface roughness, and flexural modulus of polypropylene/ethylene copolymer retainer material after exposure to different cleaning methods		E
Papadopoulou *et al*., 2019[325]	Experimental *in vitro* study	40 appliances with attachments were retrieved after the end of orthodontic treatment from different patients	Changes in roughness and mechanical properties of Invisalign® Appliances after one and 2 weeks use	CA used for 1 week and CA used for 2 weeks and unused control group	Estimate the possible changes of surface roughness and the mechanical properties of Invisalign® appliances over one-and 2-weeks of service		E
Ihssen *et al*., 2019[326]	Experimental *in vitro* study	A total of 60 specimens made from PETG aligner films (CA Clear Aligner, Scheu Dental, Iserlohn, Germany)	Effect of *in vitro* aging by water immersion and thermocycling on the mechanical properties of PETG aligner material	Three groups (immersed in distilled water, subjected to accelerated ageing by thermocycling, control)	Investigate elastic properties of PETG aligner films *in vitro* under extreme temperature changes simulated by thermocycling, environmental temperature and water absorption		E
Lombardo *et al*., 2020[327]	Experimental *in vitro* study	A total of 204 linear 2D measurements were made on 18 microtomographic images	MicroCT X-ray comparison of aligner gap and thickness of six brands of aligners	• 6 aligner systems (Airnivol, ALL IN, Arc Angel, F22, Invisalign and Nuvola) • Different regions regions were the central incisor, canine and first molar	Investigate and compare the gap (i.e. fit) and thickness of six aligner systems (Airnivol, ALL IN, Arc Angel, F22, Invisalign and Nuvola) using industrial CT		E
Bernard *et al*., 2020[328]	Experimental *in vitro* controlled trial	Removable appliances (300 specimens, 100 per brand)	Colorimetric and spectrophotometric measurements of orthodontic thermoplastic aligners exposed to various staining sources and cleaning methods	• Different staining agents common in a regular diet (coffee, black tea, red wine, cola) are compared to a control solution *in vitro* over 12 h or 7 days • Three brands evaluated were Invisalign®, ClearCorrect® and Minor Tooth Movement® • Invisalign® cleaning crystals or the Cordless Sonic Cleaner combined with a Retainer Brite® tablet	Evaluate the color stability of the polymer forming three different American brands of aligners	Evaluate stain-removal potential of two cleansers either Invisalign® cleaning crystals or the Cordless Sonic Cleaner combined with a Retainer Brite® tablet	E
Fang *et al*., 2020[329]	Experimental *in vitro* study	20 sets of "as-received" (0-week) and retrieved (2-week; worn for 2 weeks, 20±2 h/day) Invisalign aligners collected from 4 different patients	Changes in mechanical properties, surface morphology, structure, and composition of Invisalign material in the oral environment	"As-received" (0-week) and retrieved (2-week; worn for 2 weeks, 20±2 h/day) Invisalign aligners	Fill in the current knowledge gap by systematically evaluating LD30 before and after clinical treatment	Attempt to demonstrate the aging of aligner materials from intraoral use by examining material surface morphology, internal structure, and chemical composition changes, as well as illustrating a corresponding change of mechanical properties	E
Tamburrino *et al*., 2020[330]	Experimental *in vitro* study	3 thermoplastic polymers	Mechanical Properties of thermoplastic polymers for aligner manufacturing	3 thermoplastic polymers commonly used to fabricate clear aligners, namely Duran®, Biolon® and Zendura®	Evaluate the effect of the thermoforming process, storage in artificial saliva and their combination on the mechanical properties of three thermoplastic polymers commonly used to fabricate CA		E
McCarty *et al*., 2020[331]	Experimental *in vitro* study	n=10/group	Effect of print orientation and duration of ultraviolet curing on the dimensional accuracy of a 3D printed orthodontic CA design	• 3 different build angles with respect to the build platform: parallel (Horizontal), perpendicular (Vertical), and 45° (45–°) • 3 postprint processing treatment groups: 0 min of UV light and heat exposure (No Cure); 20 min of UV light exposure at 80°C (20 min), and 40 min of UV light exposure at 80°C (40 min)	Investigate the effect of print orientation and UV light curing duration on the dimensional accuracy of a CA design fabricated directly using 3D printing		E
Memè *et al*., 2021[332]	Experimental *in vitro* study	12 new Invisalign® aligners	ATR-FTIR Analysis of orthodontic Invisalign® Aligners subjected to various in vitro aging treatments	Coffee, tea, Coca Cola® and UV radiation for 24 and 48 h.	Assess a new objective approach, coupling spectroscopic and chemometric tools, to evaluate the changes occurring in Invisalign®aligners, the most widely used brand, exposed *in vitro* to coffee, tea, Coca Cola® and UV radiation for 24 and 48 h		E
Palone *et al*., 2021[333]	Experimental *in vitro* study	6 passive upper aligners of different brands were adapted to a single printed cast	Micro-computed tomography evaluation of general trends in aligner thickness and gap width after thermoforming procedures involving six commercial CA	• Tooth type (central incisor, canine, and first molar), 2D reference points, and aligner type • (Airnivol, ALL IN, Arc Angel, F22, Invisalign, and Nuvola)	Evaluate and compare the general effects of thermoforming processes on both gap width and thickness via micro-CT investigation of passive aligners with the same nominal thickness obtained from six manufacturers		E

(Contd...)

Table 3: *(Continued).*

Author (year)	Study type	Participants	Intervention	Comparison	Outcome (Primary)	Outcome (Secondary)	Outcome Domain
Isman and Isman 2021[334]	Experimental *in vitro* study	5 different orthodontic materials	Identification of various orthodontic materials as foreign bodies	Titanium-molybdenum alloy wire (TMA; ORMCO, Orange, CA, USA; 0.017×0.025 in cross-sectional dimensions and 1 cm long); stainless steel bracket tooth #34 (American Orthodontics, Sheboygan, WI, USA); a monocrystalline, sapphire ceramic bracket tooth #34 (Skyortho Dental Supplies Medical, China); a polycrystalline alumina clear bracket, Damon clear bracket tooth #34 (ORMCO); and a 1×1 × 0.1 cm polyurethane-based thermoplastic material, Invisalign clear aligner (Align Technology, San Jose, CA, USA) Panoramic radiography, CBCT, MRI, and ultrasonography	Evaluated the *in vitro* detection sensitivity of orthodontic materials (serving as foreign bodies) using panoramic radiography, CBCT, MRI, and ultrasonography		E
Mantovani *et al.*, 2021[335]	Experimental *in vitro* study	20 different aligners	Micro computed tomography evaluation of Invisalign aligner thickness homogeneity	Different regions (molar, canine, incisor) and in different sites (gingival–buccal, buccal, occlusal, lingual, and gingival–lingual)	Measure the thickness homogeneity of Invisalign (Align Technology Inc, San José, Calif) aligners with micro-CT scans		E
Meier *et al.*, 2003[188]	Cross-sectional survey	89 patients	Analysis of patient profiling for CAT	Gender, age, profession, motivation for treatment, accepted treatment duration, and initial source of information	Produce a profile of those patients who are interested in treatment with the Invisalign system		F
Nedwed and Miethke 2005[336]	Cross-sectional questionnaire	55 patients	Motivation, acceptance and problems of invisalign patients	• After 3–6 months of Invisalign treatment • Lingual technique	Examined how well patients accepted and to what extent they were impaired by Invisalign treatment: adaptation time, occurrence and duration of pain, possible speech impairment, lingual and mucosal irritations, TMJ problems and subjective assessment of the success of therapy		F
Jeremiah *et al.*, 2011[337]	Cross-sectional study	130 undergraduates from the UK	Social perceptions of adults wearing orthodontic appliances	Five modified photographs of the same young adult female were used: (1) No appliance, (2) stainless steel fixed orthodontic appliance, (3) ceramic fixed orthodontic appliance, (4) gold fixed orthodontic appliance, and (5) clear colourless aligner	Ascertaine the influence of orthodontic appliances on subjective ratings for social competence, intellectual ability, psychological adjustment, and attractiveness in young adult orthodontic patients		F
Cooper-Kazaz *et al.*, 2013[338]	Prospective clinical study	68 adult patients divided into three groups (28 buccal, 19 lingual, and 21 clear aligners)	The impact of personality on adult patients' adjustability to orthodontic appliances	Three groups (28 buccal, 19 lingual, and 21 clear aligners)	Evaluate the impact of psychological traits on patients' choice of orthodontic appliances and their adjustability to orthodontic treatment		F
Kuhlman *et al.*, 2016[339]	Cross-sectional study	*n*=276	Esthetic perception of orthodontic appliances by Brazilian children and adolescents	• Different ages, sex and socioeconomic standards • Eight different situations: (A) with fixed sapphire esthetic brackets, clear elastomeric ligatures (American Orthodontics, Wisconsin, USA) and 0.020-in stainless steel archwire (GAC International, New York, USA); (B) with a clear tray aligner with attachments; (C) with fixed golden orthodontic brackets and clear elastomeric ligatures (American Orthodontics, Wisconsin, USA); (D) with a fixed metallic self-ligating system; (E) with fixed traditional metallic brackets with gray elastomeric ligatures; (F) with fixed sapphire esthetic brackets, clear elastomeric ligatures (American Ortho-dontics, Wisconsin, USA) and 0.018-in esthetic nickel titanium coated archwire (American Orthodontics, Wisconsin, USA); (G) with a clear tray aligner without attachments; (H) similar to (E), but with green elastomeric ligatures (Morelli, São Paulo, Brazil)	Understand how children and adolescents perceive esthetic attractiveness of a variety of orthodontic appliances	Analyze preferences according to patients' age, sex and socioeconomic status	F
Arun *et al.*, 2017[340]	Cross-sectional study	119 websites were included for analysis	Qualitative assessment of Internet information regarding Orthodontic treatment modalities	• Specialist orthodontists • General dentists • Cosmetic braces, fixed braces, removable braces, Quick braces and risks	Determine the quality, accuracy, reliability and usability of Internet information, regarding different orthodontic treatment modalities		F
Noll *et al.*, 2017[341]	Cross-sectional study	419,363 tweets applicable to orthodontics were collected	Twitter analysis of the orthodontic patient experience with braces versus Invisalign	CA and FA	Examine the orthodontic patient experience having braces compared with Invisalign by means of a large-scale Twitter sentiment analysis		F
Livas *et al.*, 2018[342]	Cross-sectional study	40 reviewed testimonials	Content, metrics and comment sentiment analysis of the most popular patient testimonials on YouTube		Investigate the popularity, content, metrics of Invisalign patient testimonials on YouTube, as well as the sentiment of the related comments		F
Ustdal and Guney 2020[343]	Cross-sectional survey	From the first 140 results, 100 videos were selected for analysis	YouTube as a source of information about orthodontic clear aligners		Evaluate the content, reliability, and quality of videos about orthodontic clear aligners on YouTube		F
Bustati and Rajeh 2020[344]	Online questionnaire cross-sectional study	388 responses were analyzed: mean age 20.4±4 years, 75% (291) female, and 58% (226) received their treatment at a public clinic	The impact of COVID-19 pandemic on patients receiving orthodontic treatment	CA and removable appliances compared to FA	Assess the challenges faced by patients receiving orthodontic treatment and their preferred solutions to overcoming these challenges during this pandemic		F
Adobes-Martin *et al.*, 2021[345]	Cross-sectional study	1564 tweets were analysed	Invisalign treatment from the patient perspective	Pre-treatment related, treatment related and patient/clinician relationship	Qualitatively describe the content of Twitter posts related to the treatment with Invisalign to get a better understanding of patient experience		F
Zybutz *et al.*, 2021[346]	Cross-sectional survey	68 patients	Patient experiences with removable functional appliances	ITMA and TB appliances	Compare patients' experiences with the TMA and TB appliances, both initially and after several months of wear		F
Noble *et al.*, 2009[347]	Cross-sectional survey	335 e-mails from 37 programs were obtained	Future practice plans of orthodontic residents in the United States	Sex, age, and year of program	Investigate the future clinical practice plans of orthodontic residents in the United States		G
Noble *et al.*, 2009[348]	Cross-sectional survey	54 residents in Canada	Motivations and future plans of Canadian orthodontic residents		Investigate factors influencing career choice and to identify future plans of Canadian orthodontic residents		G
Vicéns and Russo 2010[349]	Cross-sectional survey	A total of 406 questionnaires were mailed: 284 to general practitioners and 122 to orthodontists	Comparative use of Invisalign by orthodontists and general practitioners	Orthodontists and general practitioners	Test the hypothesis that there is no difference in the use of Invisalign between orthodontists and general practitioners		G
Al-Hamlan *et al.*, 2013[350]	Cross-sectional survey	36 orthodontic residents	Motivations and future practice plans of orthodontic residents in Saudi Arabia		Explore the criteria used by graduate students while selecting a career as orthodontists and their future aspirations		G
Jauhar *et al.*, 2016[351]	Cross-sectional survey	362 final year undergraduate students in four dental institutes in the UK	Undergraduate orthodontic teaching and factors affecting pursuit of postgraduate training		Assess the levels of knowledge of occlusal problems among final year undergraduate dental students	Assess their interest in various orthodontics techniques and training	G
Mackay *et al.*, 2017[352] Cross-sectional analysis	Interrupted time series	1,871 GP and orthodontic practices worldwide 319 low-volume, North American GPs	Impact of digital scanning in GDPs and orthodontic practices to determine the percent increase in gross receipts of Invisalign® treatment	• 48 months (24 pre- and 24 post-scanner introduction) of Invisalign receipt • GP and orthodontic practices located worldwide	Evaluate the impact of digital scanning in GDPs and orthodontic practices to determine the percentage of lift, that is, the percent increase in gross receipts, of Invisalign® treatment starts following the introduction of an i'Tero® intraoral scanner		G
Didier *et al.*, 2019[353]	Cross-sectional survey	Evaluators included 236 individuals, divided into 4 groups according to age and gender: males between 18–35 years (M), males over 35 years (M>35), females between 18–35 years (F), and females over 35 years (F>35)	Influence of orthodontic appliance design on employment hiring preferences	• One image was produced without orthodontic appliances, and 6 simulated the use of orthodontic appliances, including a CON metallic appliance with a gray elastic ligature, a CON metallic appliance with blue elastic ligature, a CON appliance with a transparent elastic ligature, a self-ligating metal appliance, a self-ligating esthetic appliance, and a clear aligner • Evaluators were divided into 4 groups according to age and gender: males between 18–35 years (M), males over 35 years (M>35), females between 18 and 35 years (F), and females over 35 years (F>35)	Evaluate the extent to which different types of orthodontic appliances influence the hiring process of an individual applying for a customer service position		G
d'Apuzzo *et al.*, 2019[354]	Web based cross-sectional survey	129 members of the European Aligner Society and 200 doctors of dental surgery	Different perspectives between orthodontists and general dentists in CAT	• Orthodontists were compared to general dentists • Clinicians using or not using CAT	Evaluate experience with clear aligners	• Evaluate patient demand and perception • Evaluate types of patients • Malocclusion treated with CA • Reasons for not using CAT	G
Batarse *et al.*, 2019[355]	Retrospective study	20 cases Forty-one panel members (56.1% male, 43.9% female) evaluated the survey	Referral patterns of pediatric dentists and general practitioners to orthodontists based on case complexity	General dentists (*n* 5 21; 51.2%) and pediatric dentists (*n* 5 20; 48.9%)	Investigate and compare general and pediatric dentists' subjective judgments of orthodontic case complexity	Determine how their perceptions of case complexity influence their decisions to refer the patient to an orthodontist	G
Linjawi *et al.*, 2020[356]	Cross-sectional electronic survey	*n*=195	Awareness, perception and readiness regarding CAT among orthodontists and other dental specialists	• GDPs, orthodontists, and other dental specialists • Age, gender, nationality, specialty, education level, and place of work	Compare the differences in awareness, perception and readiness for clear aligner usage among orthodontists, GDPs, and other dental specialists in Saudi Arabia		G
Hellyer 2021[357]	Cross-sectional survey	21 such sites (USA=13, UK=3, Australia=4)	Poor information on clear aligner websites		Assess sites for readability, quality of information provided and measured against American Medical Association benchmarks for websites		G
Bruni *et al.*, 2021[358]	A bibliometric and visualized cross-sectional analysis	Total of 378 articles	The 50 most-cited articles on CAT		Perform a bibliometric and visualized analysis to identify and critically assess the 50 most highly cited articles on CAT		G

OIEARR: Orthodontically induced external apical root resorption, VAS: Visual analogue scale, LIPUS: Low-intensity pulsed ultrasound, CON: Conventional, IER: Interproximal enamel reduction, CFA: Cranio-facial anomalies, SEM: Scanning electron microscopy, FEM: Finite element model, PAR: Peer assessment rating, LF: Low friction, TG: Treated group, EARR: External apical root resorption, QA: Quaternary ammonium, CAT: Clear aligner therapy, ITMA: Invisalign Teen with Mandibular Advancement®, MA: Mandibular advancement, TB: Twin block, PETG: Polyethylene terephthalate glycol, CA: Clear-aligner, FEA: Finite element analysis, AO: Attachments only, IO: Interproximal reduction only, p-IPR p-IPR: programmed interproximal reduction, i-IPR: Implemented interproximal reduction, DM®: Dental monitoring®, FC: Flowable composite, PC: Packable composite, PBM: Photobiomodulation, PBF: Pulpal blood flow, GPs: General practitioners, GDPs: General dental practices, QA-GNCs: QA-modified gold nanoclusters, CBCT: Cone beam computed tomography, MRI: Magnetic resonance imaging, GP: General Practitioner, STL: Standard Tessellation Language, FA: Fixed Appliances, ABO-OGS: American Board of Orthodontics' Objective Grading System, CEJ: Cemento-Enamel Junction, TMD: Tempromandibular Disorders, OTM: Orthodontic Tooth Movement, DM: Dental Monitoring, HFV: High Frequency Vibration

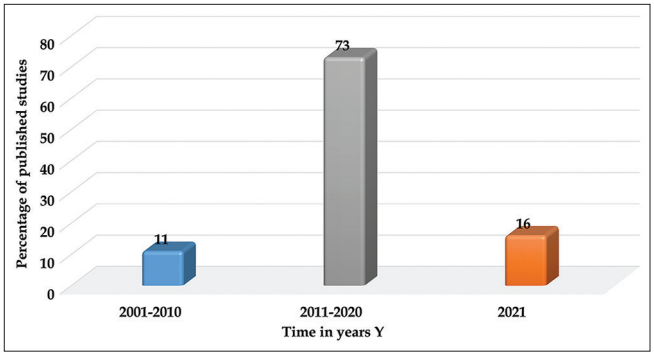


Figure 2: Bar graph showing the percentages of published studies in 3 time frames.

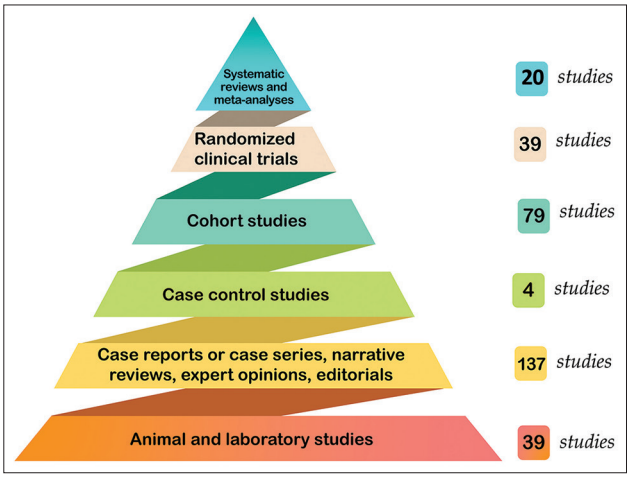


Figure 3: Hierarchy of evidence for studies published about clear aligner therapy.

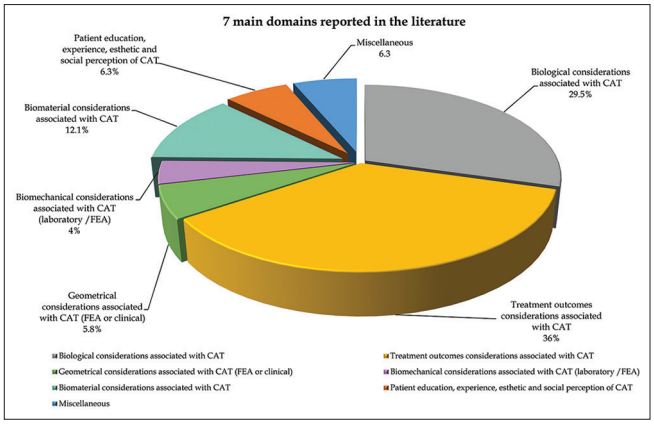


Figure 4: Pie chart illustrating the percentage distribution of the seven main domains reported in the literature. CAT: clear aligner therapy; FEA: Finite Element Analysis.

percentages, came the patient education, experience, aesthetic and social perception, miscellaneous considerations, as well as geometrical considerations associated with CAT, representing 6.3%, 6.3%, and 5.8%, respectively. The final place was occupied by the biomechanical considerations associated with CAT accounting for only 4% of the published domains about CAT.

Most of the excluded studies were case reports with a total number of 86 articles. This was followed by opinion articles, narrative reviews and systematic reviews and meta-analyses with 25, 21, and 20 articles, respectively. Other types of articles and reasons for exclusion represented only a small number of studies.[1-3,11-186] [Figure 5 and Table 2].

DISCUSSION

Clear aligners have revolutionized the practice of orthodontics since the introduction of Invisalign in 1998. The first mention of clear aligners in the academic literature occurred in 2001 and included an article on technique,[90] a case report,[172] and an opinion article.[182] The first scientific study of clear aligners occurred in 2003. Bollen *et al.*[187] studied the effect of different plastic stiffness and wear time on tooth movement, while Meier *et al.*[188] investigated the patient profile of those requesting and undergoing clear aligner treatment. Over the next decade, between 2001 and 2010, just 21 studies have been published. 138 studies have been published in the next decade (2011–2020). In 2021, 31 research articles have already been published, continuing this exponential increase. This surge of research output reflects the larger trend of increases in the usage and popularity of clear aligners.

The studies investigating CAT were characterized into seven outcome domains. The majority of clear aligner research focused on treatment outcome considerations (36%),[9,189-256] which is rightfully the most researched domain as it is fundamental to assessing the treatment effectiveness of CAT and comparing it to more established treatment modalities including fixed appliances using ABO-OGS, irregularity index, and PAR index. The efficacy of CA in achieving different tooth movements, in different planes of space, in extraction and surgical cases, and the recommended types of malocclusions to be treated with CA were also studied. Accuracy of predicted movements and IPR versus achieved ones, finishing and stability with CA, quality of life impacts, evaluation of smile with CA, evaluation of treatment outcomes with and without dental monitoring and the effect of CA wear protocol on the efficiency of tooth movement were additionally investigated in different studies under this domain. Biological considerations made up 29.5%.[189,257-311] This domain investigated and contrasted topics such as biofilm changes, periodontal health, gingival parameters, pain perception, masticatory muscle soreness and anxiety, apical root resorption, early tooth movement, bone metabolism and volume, pulpal blood flow, enamel demineralization, mineral and trace elements in saliva, adult patient's adjustability, oral health-related quality of life, cytotoxicity, and epithelial cell reaction after exposure

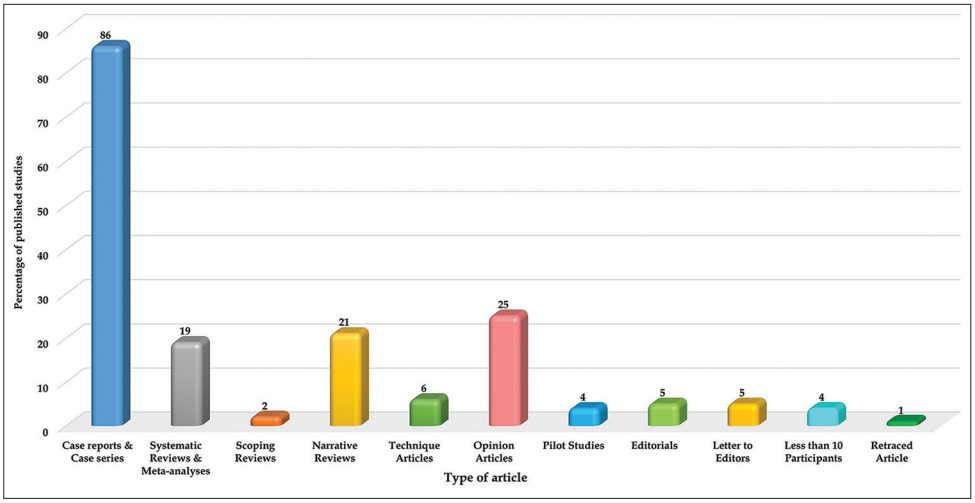


Figure 5: Bar graph showing the percentage distribution of different reasons for studies exclusion.

to CA material. In addition, the effect of the use of vibration, photo-biomodulation, and ultrasound on CAT was also studied. The effect of the use of CA on facial wrinkles, postural changes, speech articulation, as well as on tooth whitening was moreover investigated. This domain was followed by biomaterial considerations representing 12.1% of the studies and investigated factors such as mechanical, optical and chemical properties, the fit of aligners, colour stability and aging, different thickness and materials of aligners, different composite materials in the reproduction of attachments shape and position, the effect of different cleaning methods, and effect of print orientation on the dimensional accuracy of CA.[187,201,312-335] At 6.3% came patient education, experience, esthetic and social perception and adjustability,[188,336-346] as well as miscellaneous considerations including factors influencing career choice, future aspirations, use of CA by orthodontists and general practitioners, the impact of digital scanning on CA popularity and the documentation of the most highly cited articles.[347-358] Geometrical considerations associated with CAT, representing 5.8% of the studies, primarily explored attachment configurations clinically, the efficiency of power ridges, retention, and fit of CA with various attachments and incidence of attachments loss.[200,312,359-368] The final place was occupied by biomechanical considerations accounting for only 4% of the published outcome domains.[313,362,369-375] This domain examined *in vitro* studies on the force distribution applied by CAT and pressure differences from different movements, with some studies using FEA to further study the forces and moments produced by CA in different tooth movements. Future studies investigating clear aligners should perhaps place greater focus on Biomechanical, Geometrical, and Biomaterial considerations of clear aligner treatment. Studies of these domains will allow for a greater understanding of CAT as a whole, as opposed to studying a single brand.

With the rapid technological development of 3D printing, artificial intelligence (A.I.) and machine learning, and material sciences, an increase in customized appliances can be expected in the future, whether CAT or fixed appliances. A.I. is being used by commercial companies to improve CAT, but this has not been done independently. This area of study will hopefully be researched in the near future.

Another noteworthy result found was that the vast majority of research on CAT only studied a single brand, that is, Invisalign. Although some articles were unclear about which brand of aligners or materials were used,[230,265,278,280,282,304,306,326,339] only eight studies utilized other brands of aligners or materials[201,285,287,288,291,330,333,361] other than Invisalign. Are the results of the majority of studies then relevant to CAT as a modality, or a given brand? This seems to be a significant limitation in the current CAT literature. Ercoli *et al*.,[201] in 2014, were the first authors to compare two different aligner systems. These were then followed by Lombardo *et al*.[317] in 2015 and Mantovani *et al*. in 2019.[363] Lombardo *et al*.[327] and Palone *et al*.[333] have also recently compared the aligner thickness and gap width of 6 aligner systems.

In the future, independent research should be carried out to investigate outcomes of the various clear aligner systems and material components involved, to understand CAT in its entirety, as opposed to a single aligner brand of aligners. While aligners are an established clinical reality today, the incipient scholarly literature indicates many unanswered questions and unstudied domains. Future researchers can dwell on the findings of this ScR, before embarking on projects that can augment aligner literature.

While we attempted to determine the scope and extent of the published literature on clear aligners in orthodontics, as well as identify the types of studies published, and summarize the outcomes studied, some limitations are present. Our

search terms were in the English language; hence, articles in languages other than English may have been missed. Similarly, some articles may not have been found due to the search terms used. Studies with <10 participants were excluded which was done in an attempt to obtain more meaningful data which could assist in identifying the more common outcome domains. ScRs do not assess the methodologies and risk of bias of the included studies, rather the goal is to explore the literature as an overview.

CONCLUSION

Outcome domains studied in literature were: Treatment outcomes (36%); Biological considerations (29.5%); Biomaterial considerations (12.1%); Patient education, experience, esthetic and social perception (6.3%); Miscellaneous (6.3%); Geometrical considerations (5.8%); and Biomechanical considerations (4%).

Most of the published studies were at the lowest level of evidence including case reports, case series, narrative reviews, expert opinions, and editorials accounting for 137 studies. This was followed by cohort studies with 79 studies. Animal and laboratory studies and prospective clinical trials accounting for 39 studies each. 20 systematic reviews and meta-analyses were identified. Case–control studies were the least reported studies with only four studies reported in the literature.

The vast majority of studies utilized only a single clear aligner brand. There is a greater need for research that studies CAT from a holistic perspective.

Ethical approval

The research/study complied with the Helsinki Declaration of 1964.

Declaration of patient consent

Patient's consent not required as there are no patients in this study.

Financial support and sponsorship

Nil.

Conflicts of interest

Prof. (Dr.) Nikhilesh R. Vaid is the Emeritus Editor-In-Chief and Dr. Ismaeel Hansa is one of the assistant editors of the journal.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

REFERENCES

1. Ke Y, Zhu Y, Zhu M. A comparison of treatment effectiveness between clear aligner and fixed appliance therapies. BMC Oral Health 2019;19:24.
2. Shotell MD. The proliferation of clear aligner orthodontics: Workflows, materials, and designs. Compend Contin Educ Dent 2020;41:340-1.
3. Kim TW, Echarri P. Clear aligner: An efficient, esthetic, and comfortable option for an adult patient. World J Orthod 2007;8:13-8.
4. Adel SM, Vaid NR, El-Harouni N, Kassem H, Zaher AR. TIP, TORQUE & ROTATIONS: How accurately do digital superimposition software packages quantify tooth movement? Prog Orthod 2022;23:8.
5. Adel SM, Vaid NR, El-Harouni N, Kassem H, Zaher AR. Digital model superimpositions: Are different software algorithms equally accurate in quantifying linear tooth movements? BMC Oral Health 2022;22:103.
6. Vaid N, Doshi V, Vandekar M. What's "Trend" ing in Orthodontic literature? APOS Trends Orthod 2016;6:1-4.
7. Vaid NR, Orthod AT, Flores-Mir C, Lin JH, Chang CH, Eugene RW, *et al.* The emperor's new clothes! APOS Trends Orthod 2019;9:1-3.
8. AlSeraidi M, Hansa I, Dhaval F, Ferguson DJ, Vaid NR. The effect of vestibular, lingual, and aligner appliances on the quality of life of adult patients during the initial stages of orthodontic treatment. Prog Orthod 2021;22:3.
9. Hansa I, Katyal V, Ferguson DJ, Vaid N. Outcomes of clear aligner treatment with and without Dental Monitoring: A retrospective cohort study. Am J Orthod Dentofacial Orthop 2021;159:453-9.
10. Vaid NR, Sabouni W, Wilmes B, Bichu YM, Thakkar DP, Adel SM. Customized adjuncts with clear aligner therapy: "The Golden Circle Model" explained! J World Fed Orthod 2022;11:216-25.
11. Weir T. Clear aligners in orthodontic treatment. Aust Dent J 2017;62 Suppl 1:58-62.
12. Robertson L, Kaur H, Fagundes NCF, Romanyk D, Major P, Flores Mir C. Effectiveness of clear aligner therapy for orthodontic treatment: A systematic review. Orthod Craniofac Res 2020;23:133-42.
13. Rossini G, Parrini S, Castroflorio T, Deregibus A, Debernardi CL. Efficacy of clear aligners in controlling orthodontic tooth movement: A systematic review. Angle Orthod 2015;85:881-9.
14. Caminiti M, Lou T. Clear Aligner Orthognathic Splints. J Oral Maxillofac Surg 2019;77:1071.e1- 1071.e8.
15. Lagravère MO, Flores-Mir C. The treatment effects of Invisalign orthodontic aligners: A systematic review. J Am Dent Assoc 2005;136:1724-9.
16. Tamer İ, Öztaş E, Marşan G. Orthodontic treatment with clear aligners and the scientific reality behind their marketing: A literature review. Turk J Orthod 2019;32:241-6.
17. Papadimitriou A, Mousoulea S, Gkantidis N, Kloukos D. Clinical effectiveness of Invisalign® orthodontic treatment:

A systematic review. Prog Orthod 2018;19:37.
18. Rossini G, Parrini S, Castroflorio T, Deregibus A, Debernardi CL. Periodontal health during clear aligners treatment: A systematic review. Eur J Orthod 2015;37:539-43.
19. Hennessy J, Al-Awadhi EA. Clear aligners generations and orthodontic tooth movement. J Orthod 2016;43:68-76.
20. Zheng M, Liu R, Ni Z, Yu Z. Efficiency, effectiveness and treatment stability of clear aligners: A systematic review and meta-analysis. Orthod Craniofac Res 2017;20:127-33.
21. Galan-Lopez L, Barcia-Gonzalez J, Plasencia E. A systematic review of the accuracy and efficiency of dental movements with Invisalign®. Korean J Orthod 2019;49:140-9.
22. Sword RJ, Haywood VB. Teeth bleaching efficacy during clear aligner orthodontic treatment. Compend Contin Educ Dent 2020;41:e11-6.
23. Kook MS, Kim HM, Oh HK, Lee KM. Clear aligner use following surgery-first mandibular prognathism correction. J Craniofac Surg 2019;30:e544-7.
24. Flores-Mir C. Clear aligner therapy might provide a better oral health environment for orthodontic treatment among patients at increased periodontal risk. J Evid Based Dent Pract 2019;19:198-9.
25. Lu H, Tang H, Zhou T, Kang N. Assessment of the periodontal health status in patients undergoing orthodontic treatment with fixed appliances and Invisalign system: A meta-analysis. Medicine (Baltimore) 2018;97:e0248.
26. Kuncio DA. Invisalign: Current guidelines for effective treatment. N Y State Dent J 2014;80:11-4.
27. Kassam SK, Stoops FR. Are clear aligners as effective as conventional fixed appliances? Evid Based Dent 2020;21:30-1.
28. Cardoso PC, Espinosa DG, Mecenas P, Flores-Mir C, Normando D. Pain level between clear aligners and fixed appliances: A systematic review. Prog Orthod 2020;21:3.
29. Phan X, Ling PH. Clinical limitations of Invisalign. J Can Dent Assoc 2007;73:263-6.
30. Zhang B, Huang X, Huo S, Zhang C, Zhao S, Cen X, *et al.* Effect of clear aligners on oral health-related quality of life: A systematic review. Orthod Craniofac Res 2020;23:363-70.
31. Tripathi T, Singh N, Rai P, Kalra S. A modified clear aligner. Int J Orthod Milwaukee 2016;27:29-31.
32. Iliadi A, Koletsi D, Papageorgiou SN, Eliades T. Safety considerations for thermoplastic-type appliances used as orthodontic aligners or retainers. A Systematic review and meta-analysis of clinical and *in-vitro* research. Materials (Basel) 2020;13:1843.
33. Lombardo L, Palone M, Carlucci A, Siciliani G. Clear aligner hybrid approach: A case report. J World Fed Orthod 2020;9:32-43.
34. Blevins R. Phase I orthodontic treatment using Invisalign first. J Clin Orthod 2019;53:73-83.
35. Marya A, Venugopal A, Vaid N, Alam MK, Karobari MI. essential attributes of clear aligner therapy in terms of appliance configuration, hygiene, and pain levels during the pandemic: A brief review. Pain Res Manag 2020;2020:6677929.
36. Staderini E, Meuli S, Gallenzi P. Orthodontic treatment of class three malocclusion using clear aligners: A case report. J Oral Biol Craniofac Res 2019;9:360-2.
37. Al-Jewair T, Kurtzner K, Giangreco T, Warunek S, Lagravère-Vich M. Effects of clear aligner therapy for Class II malocclusion on upper airway morphology and daytime sleepiness in adults: A case series. Int Orthod 2020;18:154-64.
38. Fang X, Qi R, Liu C. Root resorption in orthodontic treatment with clear aligners: A systematic review and meta-analysis. Orthod Craniofac Res 2019;22:259-69.
39. Gierie WV. Clear aligner therapy: An overview. J Clin Orthod 2018;52:665-74.
40. Al-Zainal MH, Anvery S, Al-Jewair T. Clear aligner therapy may not prevent but may decrease the incidence of external root resorption compared to full fixed appliances. J Evid Based Dent Pract 2020;20:101438.
41. Kravitz ND, Johnson BM, Kilic H. A modified bonding technique for Invisalign attachments. J Clin Orthod 2018;52:715-6.
42. Fry R. Weekly aligner changes to improve Invisalign treatment efficiency. J Clin Orthod 2017;51:786-91.
43. Ojima K, Dan C, Watanabe H, Kumagai Y. Upper molar distalization with Invisalign treatment accelerated by photobiomodulation. J Clin Orthod 2018;52:675-83.
44. Pinho T, Rocha D. Ideal vs adapted digital smile diagnosis in multidisciplinary cases during clear aligner treatment. Int J Esthet Dent 2020;15:140-56.
45. On Tse RT. Merging clear aligner therapy with digital smile design to maximize esthetics and minimize tooth reduction. Compend Contin Educ Dent 2019;40:100-6.
46. Ruan MJ, Jiang RP. Spring-assisted molar intrusion in clear-aligner treatment. J Clin Orthod 2017;51:270-8.
47. Yu Y, Sun J, Lai W, Wu T, Koshy S, Shi Z. Interventions for managing relapse of the lower front teeth after orthodontic treatment. Cochrane Database Syst Rev 2013;9:CD008734.
48. Caruso S, Darvizeh A, Zema S, Gatto R, Nota A. Management of a facilitated aesthetic orthodontic treatment with clear aligners and minimally invasive corticotomy. Dent J (Basel) 2020;8:19.
49. Feizi A, Brooks JK, Schneider MP, Wright JR, Bashirelahi N. What every dentist needs to know about clear aligners. Gen Dent 2020;68:23-6.
50. Keim RG. The Evolution of Invisalign. J Clin Orthod 2017;51:69-70.
51. Boyd RL. Esthetic orthodontic treatment using the Invisalign appliance for moderate to complex malocclusions. J Dent Educ 2008;72:948-67.
52. Kaur H, Kochhar AS, Gupta H, Singh G, Kubavat A. Appropriate orthodontic appliances during the COVID-19 pandemic: A scoping review. J Oral Biol Craniofac Res 2020;10:782-7.
53. Kankam HK, Gupta H, Sawh-Martinez R, Steinbacher DM. Segmental multiple-jaw surgery without orthodontia: Clear aligners alone. Plast Reconstr Surg 2018;142:181-4.
54. Gandhi V, Mehta S, Gauthier M, Mu J, Kuo CL, Nanda R, *et al.* Comparison of external apical root resorption with clear aligners and pre-adjusted edgewise appliances in non-extraction cases: A systematic review and meta-analysis. Eur J Orthod 2021;43:15-24.
55. Boyd RL. Periodontal and restorative considerations with clear aligner treatment to establish a more favorable restorative environment. Compend Contin Educ Dent 2009;30:280-2, 284, 286-8 passim.
56. Shipley TS. Effects of high frequency acceleration device on

aligner treatment-a pilot study. Dent J (Basel) 2018;6:32.
57. Park JH, Kim TW. Deep-bite correction using a clear aligner and intramaxillary elastics. J Clin Orthod 2009;43:152-7.
58. Harnick DJ. Using clear aligner therapy to correct malocclusion with crowding and an open bite. Gen Dent 2012;60:218-23.
59. Hannequin R, Ouadi E, Racy E, Moreau N. Clinical follow-up of corticotomy-accelerated Invisalign orthodontic treatment with Dental Monitoring. Am J Orthod Dentofacial Orthop 2020;158:878-88.
60. Hennessy J, Al-Awadhi EA. Clear aligners generations and orthodontic tooth movement. J Orthod 2016;43:1-9.
61. Chang CH, Lin LY, Roberts WE. Orthodontic bone screws: A quick update and its promising future. Orthod Craniofac Res 2021;24 Suppl 1:75-82.
62. Ojima K, Dan C, Watanabe H, Kumagai Y, Nanda R. Accelerated extraction treatment with the Invisalign system and photobiomodulation. J Clin Orthod 2020;54:151-8.
63. Mheissen S, Khan H, Aldandan M. Limited evidence on differences between fixed appliances and clear aligners regarding pain level. Evid Based Dent 2020;21:144-5.
64. Lee JW, Lee SJ, Lee CK, Kim BO. Orthodontic treatment for maxillary anterior pathologic tooth migration by periodontitis using clear aligner. J Periodontal Implant Sci 2011;41:44-50.
65. El-Bialy T. The effect of high-frequency vibration on tooth movement and alveolar bone in non-growing skeletal Class II high angle orthodontic patients: Case series. Dent J (Basel) 2020;8:110.
66. Lombardo L, Martini M, Cervinara F, Spedicato GA, Oliverio T, Siciliani G. Comparative SEM analysis of nine F22 aligner cleaning strategies. Prog Orthod 2017;18:26.
67. Joffe L. Invisalign: Early experiences. J Orthod 2003;30:348-52.
68. Peck S. Easy street, is that the right place for us? Angle Orthod 2021;91:138-9.
69. Zhu Y, Li X, Lai W. Treatment of severe anterior crowding with the invisalign g6 first-premolar extraction solution. J Clin Orthod 2019;53:459-69.
70. Ojima K, Dan C, Kumagai Y, Watanabe H, Nanda R. Correction of severe crowding in teenage patients using the Invisalign system. J Clin Orthod 2020;54:383-91.
71. Giancotti A, Mozzicato P, Mampieri G. Thermoformed retainer: An effective option for long-term stability. Case Rep Dent 2020;2020:8861653.
72. Sheridan JJ. The readers' corner. Invisalign. J Clin Orthod 2014;48:371-4.
73. Chang J, Steinbacher D, Nanda R, Uribe F. "Surgery-First" Approach with Invisalign therapy to correct a Class II malocclusion and severe mandibular retrognathism. J Clin Orthod 2019;53:397-404.
74. Wheeler TT. Invisalign material studies. Am J Orthod Dentofacial Orthop 2004;125:19A.
75. Keser EI, Dibart S. Piezocision-assisted Invisalign treatment. Compend Contin Educ Dent 2011;32:46-8, 50-1.
76. Tartaglia GM, Mapelli A, Maspero C, Santaniello T, Serafin M, Farronato M, *et al*. Direct 3D printing of clear orthodontic aligners: Current state and future possibilities. Materials (Basel) 2021;14:1799.
77. Huang AT, Huang D. Space management with Invisalign for interdisciplinary orthodontic treatment. J Clin Orthod 2018;52:219-26.
78. Malik OH, McMullin A, Waring DT. Invisible orthodontics part 1: Invisalign. Dent Update 2013;40:203-4, 207-10, 213-5.
79. Bous RM, Kochenour N, Valiathan M. A novel method for fabricating nasoalveolar molding appliances for infants with cleft lip and palate using 3-dimensional workflow and clear aligners. Am J Orthod Dentofacial Orthop 2020;158:452-8.
80. Schwartz B. Invisalign and aesthetic dentistry. N Y State Dent J 2012;78:36-7.
81. Cetta CN. Virtually eliminating undercuts in Invisalign's ClinCheck. J Clin Orthod 2018;52:51-2.
82. Park JH, Kim TW. Anterior crossbite correction with a series of clear removable appliances: A case report. J Esthet Restor Dent 2009;21:149-59.
83. Wong BH. Invisalign A to Z. Am J Orthod Dentofacial Orthop 2002;121:540-1.
84. Waring D, McMullin A, Malik OH. Invisible orthodontics part 3: Aesthetic orthodontic brackets. Dent Update 2013;40:555-6, 559-61, 563.
85. Reinhardt S. 10 Tips and tricks to finish your invisalign-cases with success. Int J Orthod Milwaukee 2016;27:69-79.
86. Kau CH, Wang Z, Wang J, Krishnan DG. Contemporary management of an orthodontic-orthognathic patient with limited time availability in an orthodontic office setting: Case report. J Orthod 2020;47:257-64.
87. Bawaskar NS. Anterior crossbite and crowding correction with a series of clear aligners involving lower incisor extraction: "The Clear Way" case report. Int J Orthod Milwaukee 2015;26:29-33.
88. Eckhart JE. Sequential MARA-Invisalign treatment. J Clin Orthod 2009;43:439-48.
89. Chami VO, Nunes L, Capelli Júnior J. Expression of cytokines in gingival crevicular fluid associated with tooth movement induced by aligners: A pilot study. Dental Press J Orthod 2018;23:41-6.
90. Owen AH 3rd. Accelerated Invisalign treatment. J Clin Orthod 2001;35:381-5.
91. Cassetta M, Guarnieri R, Altieri F. The combined use of clear aligners and computer-guided piezocision: A case report with a 2-year follow-up. Int J Comput Dent 2020;23:57-71.
92. Ellis CP. Invisalign and changing relationships. Am J Orthod Dentofacial Orthop 2004;126:20A-21A.
93. Greco M, Rossini G, Rombolà A. Simplifying the approach of open bite treatment with aligners and selective micro-osteoperforations: An adult case report. Int Orthod 2021;19:159-69.
94. Miller DB. Invisalign in TMD treatment. Int J Orthod Milwaukee 2009;20:15-9.
95. El-Bialy T. The use of high frequency vibration and clear aligners in management of an adult patient with Class III skeletal malocclusion with open bite and severe bimaxillary protrusion: Case Report. Dent J (Basel) 2020;8:75.
96. Melkos AB. Advances in digital technology and orthodontics: A reference to the Invisalign method. Med Sci Monit 2005;11:I39-42.
97. Putrino A, Barbato E, Galluccio G. Clear aligners: Between evolution and efficiency-a scoping review. Int J Environ Res Public Health 2021;18:2870.
98. Whitehouse JA. Everyday uses of adult orthodontics. Dent Today 2004;23:116, 118, 120.

99. Ojima K, Dan C, Nishiyama R, Ohtsuka S, Schupp W. Accelerated extraction treatment with Invisalign. J Clin Orthod 2014;48:487-99.
100. Eliades T, Bourauel C. Intraoral aging of orthodontic materials: The picture we miss and its clinical relevance. Am J Orthod Dentofacial Orthop 2005;127:403-12.
101. Turpin DL. Clinical trials needed to answer questions about Invisalign. Am J Orthod Dentofacial Orthop 2005;127:157-8.
102. Voudouris JC, Poulos JJ, Schismenos C, Argyropoulos C. Invisalign mandibular advancers and tetrahedron 3D facial analysis in dentofacial orthopedics: 10 rules. J Clin Orthod 2018;52:134-47.
103. Wu D. Oral epithelial cell reaction and Invisalign treatment. Am J Orthod Dentofacial Orthop 2014;145:551.
104. Pagani R, Signorino F, Poli PP, Manzini P, Panisi I. The use of Invisalign® system in the management of the orthodontic treatment before and after Class III surgical approach. Case Rep Dent 2016;2016:9231219.
105. Levrini L, Tettamanti L, Macchi A, Tagliabue A, Caprioglio A. Invisalign teen for thumb-sucking management. A case report. Eur J Paediatr Dent 2012;13:155-8.
106. Awosika O, Kao S, Rengifo-Pardo M, Ehrlich A. Angioedema, stomatitis, and urticaria caused by contact allergy to invisalign. Dermatitis 2017;28:323-4.
107. Fry B. Complex orthodontic treatment using a new protocol for the invisalign appliance. J Clin Orthod 2017;51:610-4.
108. Ojima K, Dan C, Kumagai Y, Schupp W. Invisalign treatment accelerated by photobiomodulation. J Clin Orthod 2016;50:309-17.
109. Beers AC, Choi W, Pavlovskaia E. Computer-assisted treatment planning and analysis. Orthod Craniofac Res 2003;6 Suppl 1:117-25.
110. Jyothikiran H, Shanthara JR, Subbiah P, Thomas M. Craniofacial imaging in orthodontics-past present and future. Int J Orthod Milwaukee 2014;25:21-6.
111. Lou T, Caminiti M. Orthognathic surgery combined with clear aligner therapy. J Clin Orthod 2021;55:44-58.
112. Zawawi KH. Orthodontic treatment of a mandibular incisor extraction case with invisalign. Case Rep Dent 2014;2014:657657.
113. Ellis D. Letter about Invisalign practices-important! J Okla Dent Assoc 2012;103:26.
114. Johal A, Bondemark L. Clear aligner orthodontic treatment: Angle Society of Europe consensus viewpoint. J Orthod 2021;48:300-4.
115. Antelo OM, Meira TM, Miyoshi CS, Allahham A, Tanaka OM. Single lower incisor extractions in adult Invisalign patients. J Clin Orthod 2018;52:419-26.
116. Park JH, Kim TW. Esthetic orthodontic correction of a canine crossbite. Int J Orthod Milwaukee 2010;21:25-31.
117. Levrini L, Tieghi G, Bini V. Invisalign clincheck and the aesthetic digital smile design protocol. J Clin Orthod 2015;49:518-24.
118. Needham R, Waring DT, Malik OH. Invisalign treatment of Class III malocclusion with lower-incisor extraction. J Clin Orthod 2015;49:429-41.
119. Smallwood TW. Invisalign and porecelain: The contemporary restorative powerhouse. Alpha Omegan 2009;102:148-51.
120. Christensen GJ. Orthodontics and the general practitioner. J Am Dent Assoc 2002;133:369-71.
121. Garino F, Garino GB, Castroflorio T. The iTero intraoral scanner in Invisalign treatment: A 2-year report. J Clin Orthod 2014;48:98-106.
122. Frongia G, Castroflorio T. Correction of severe tooth rotations using clear aligners: A case report. Aust Orthod J 2012;28:245-9.
123. Giancotti A, Greco M, Mampieri G. Extraction treatment using Invisalign technique. Prog Orthod 2006;7:32-43.
124. Kim TW, Park JH. Eruption guidance in the mixed dentition: A case report. J Clin Pediatr Dent 2008;32:331-9.
125. Garino F, Garino B. The iOC intraoral scanner and Invisalign: A new paradigm. J Clin Orthod 2012;46:115-21.
126. Feinberg KB, Souccar NM, Kau CH, Oster RA, Lawson NC. Translucency, stain resistance, and hardness of composites used for invisalign attachments. J Clin Orthod 2016;50:170-6.
127. Mampieri G, Giancotti A. Invisalign technique in the treatment of adults with pre-restorative concerns. Prog Orthod 2013;14:40.
128. Eissa O, Carlyle T, El-Bialy T. Evaluation of root length following treatment with clear aligners and two different fixed orthodontic appliances. A pilot study. J Orthod Sci 2018;7:11.
129. Lin JC, Tsai SJ, Liou EJ, Bowman SJ. Treatment of challenging malocclusions with Invisalign and miniscrew anchorage. J Clin Orthod 2014;48:23-36.
130. Giancotti A, Mampieri G. Unilateral canine cross bite correction in adults using the Invisalign method: A case report. Orthodontics (Chic) 2012;13:122-7.
131. Ali SA, Miethke HR. Invisalign, an innovative invisible orthodontic appliance to correct malocclusions: Advantages and limitations. Dent Update 2012;39:254-6, 258-60.
132. Brezniak N, Wasserstein A. Root resorption following treatment with aligners. Angle Orthod 2008;78:1119-24.
133. Torres FC, Jóias RP, Cepera F, Paranhos LR, Sanders D. A clinical case treated with clear aligners. Int J Orthod Milwaukee 2011;22:11-5.
134. Abraham KK, James AR, Thenumkal E, Emmatty T. Correction of anterior cross bite using modified transparent aligners: An esthetic approach. Contemp Clin Dent 2016;7:394-7.
135. Womack WR, Day RH. Surgical-orthodontic treatment using the Invisalign system. J Clin Orthod 2008;42:237-45.
136. Giancotti A, Germano F, Muzzi F, Greco M. A miniscrew-supported intrusion auxiliary for open-bite treatment with Invisalign. J Clin Orthod 2014;48:348-58.
137. Vlaskalic V, Boyd RL. Clinical evolution of the Invisalign appliance. J Calif Dent Assoc 2002;30:769-76.
138. Rocke PA. A simple technique for placing Invisalign attachments. J Clin Orthod 2008;42:594.
139. Schupp W, Haubrich J, Neumann I. Invisalign(®) treatment of patients with craniomandibular disorders. Int Orthod 2010;8:253-67.
140. Schupp W, Haubrich J, Neumann I. Class II correction with the Invisalign system. J Clin Orthod 2010;44:28-35.
141. Barlattani A Jr., Mampieri G, Ottria L, Bollero P. Invisalign treatment in periodondal patient: Case report. Oral Implantol (Rome) 2009;2:35-9.
142. Aulakh R. The anterior ratio: The missing link between orthodontics and aesthetic dentistry. Case Rep Dent 2013;2013:470637.
143. Norris RA, Brandt DJ, Crawford CH, Fallah M. Restorative and Invisalign: A new approach. J Esthet Restor Dent

2002;14:217-24.
144. Giancotti A, Garino F, Mampieri G. Lower incisor extraction treatment with the Invisalign® technique: Three case reports. J Orthod 2015;42:33-44.
145. Cassetta M, Altieri F, Barbato E. The combined use of corticotomy and clear aligners: A case report. Angle Orthod 2016;86:862-70.
146. Fischer K. Invisalign treatment of dental Class II malocclusions without auxiliaries. J Clin Orthod 2010;44:665-72.
147. Ruiz JL, Finger WJ, Sasazaki H, Komatsu M. Removal of Invisalign retention attachments: A new minimally invasive method. Compend Contin Educ Dent 2009;30:634-6, 638, 640 passim.
148. Schupp W, Haubrich J, Neumann I. Treatment of anterior open bite with the Invisalign system. J Clin Orthod 2010;44:501-7.
149. Wheeler T. Invisalign clinical trials needed. Am J Orthod Dentofacial Orthop 2005;127:527.
150. Kumar M, Goyal M, Kaur A. Has Invisalign improved? Am J Orthod Dentofacial Orthop 2021;159:e73.
151. Hönn M, Göz G. A premolar extraction case using the Invisalign system. J Orofac Orthop 2006;67:385-94.
152. Lombardo L, Palone M, Maino G, Paoletto E, Carlucci A, Siciliani G. Class II subdivision with skeletal transverse maxillary deficit treated by single-sitting bone-borne appliance. Angle Orthod 2021;91:129-37.
153. Uribe F, Cutrera A, Nanda R. A segmented appliance for space closure followed by Invisalign and fixed appliances. Orthodontics (Chic) 2011;12:386-95.
154. Dickerson TE. Invisalign with photobiomodulation: Optimizing tooth movement and treatment efficacy with a novel self-assessment algorithm. J Clin Orthod 2017;51:157-65.
155. Miller RJ, Duong TT, Derakhshan M. Lower incisor extraction treatment with the Invisalign system. J Clin Orthod 2002;36:95-102.
156. Levrini L, Sacerdote P, Moretti S, Panzi S, Caprioglio A. Changes of substance P in the crevicular fluid in relation to orthodontic movement preliminary investigation. ScientificWorldJournal 2013;2013:896874.
157. Long HA. Invisalign therapy in teeth with clinically short roots. J N J Dent Assoc 2012;83:33.
158. Maganzini AL. Outcome assessment of Invisalign and traditional orthodontic treatment and subsequent commentaries. Am J Orthod Dentofacial Orthop 2006;129:456.
159. Giancotti A, Di Girolamo R. Treatment of severe maxillary crowding using Invisalign and fixed appliances. J Clin Orthod 2009;43:583-9.
160. Patient's page. Thinking about Invisalign? J Okla Dent Assoc 2013;104:9.
161. Giancotti A, Mampieri G, Greco M. Correction of deep bite in adults using the Invisalign system. J Clin Orthod 2008;42:719-26.
162. Sheridan JJ. The Readers' Corner. 2. What percentage of your patients are being treated with Invisalign appliances? J Clin Orthod 2004;38:544-5.
163. Galluccio G. Is the use of clear aligners a real critical change in oral health prevention and treatment? Clin Ter 2021;172:113-5.
164. Chenin DA, Trosien AH, Fong PF, Miller RA, Lee RS. Orthodontic treatment with a series of removable appliances. J Am Dent Assoc 2003;134:1232-9.
165. Crosby D, Lee J. A patient-classification system for Invisalign cases. J Clin Orthod 2009;43:502-6.
166. Womack WR. Four-premolar extraction treatment with Invisalign. J Clin Orthod 2006;40:493-500.
167. Boyd RL. Complex orthodontic treatment using a new protocol for the Invisalign appliance. J Clin Orthod 2007;41:525-47.
168. Boyd RL. Surgical-orthodontic treatment of two skeletal Class III patients with Invisalign and fixed appliances. J Clin Orthod 2005;39:245-58.
169. Sousa Dias N, Tsingene F. SAEF-smile's aesthetic evaluation form: A useful tool to improve communications between clinicians and patients during multidisciplinary treatment. Eur J Esthet Dent 2011;6:160-76.
170. Cai Y, Liu J, Liao W. Observations on the effect of Invisalign correction. Am J Orthod Dentofacial Orthop 2021;159:556.
171. Giancotti A, Farina A. Treatment of collapsed arches using the Invisalign system. J Clin Orthod 2010;44:416-25.
172. Vlaskalic V, Boyd R. Orthodontic treatment of a mildly crowded malocclusion using the Invisalign System. Aust Orthod J 2001;17:41-6.
173. Marcuzzi E, Galassini G, Procopio O, Castaldo A, Contardo L. Surgical-Invisalign treatment of a patient with Class III malocclusion and multiple missing teeth. J Clin Orthod 2010;44:377-84.
174. Bradley TG. Changes in orthodontic treatment modalities in the past 20 years: Exploring the link between technology and scientific evidence. J Ir Dent Assoc 2013;59:91-4.
175. McFarland B. CEREC and Invisalign: How the technologies complement each other. Dent Today 2007;26:104, 106-7.
176. Corsair AJ. Restoration of a smile using Invisalign and soft-tissue grafting. Dent Today 2007;26:100, 102.
177. Sterental R. A new helping-hand concept for Invisalign users. Dent Today 2008;27:118, 120-1.
178. Turatti G, Womack R, Bracco P. Incisor intrusion with Invisalign treatment of an adult periodontal patient. J Clin Orthod 2006;40:171-4.
179. Hamula W, Brewka RE. The Invisalign office. J Clin Orthod 2005;39:259-63.
180. Bishop A, Womack WR, Derakhshan M. An esthetic and removable orthodontic treatment option for patients: Invisalign. Dent Assist 2002;71:14-7.
181. Giancotti A, Ronchin M. Pre-restorative treatment with the Invisalign system. J Clin Orthod 2006;40:679-82.
182. McKenna S. Invisalign: Technology or mythology? J Mass Dent Soc 2001;50:8-9.
183. Barzilay V, Dayan W. Clear-aligner treatment of overerupted upper molars. J Clin Orthod 2016;50:48-53.
184. Salomone A, Turatti G. Etching mask for Invisalign attachments. J Clin Orthod 2020;54:173-4.
185. Lin F, Yao L, Bhikoo C, Guo J. Impact of fixed orthodontic appliance or clear-aligner on daily performance, in adult patients with moderate need for treatment. Patient Prefer Adherence 2016;10:1639-45.
186. Pithon MM, Baião FC, Sant Anna LI, Paranhos LR, Cople Maia L. Assessment of the effectiveness of invisible aligners compared with conventional appliance in aesthetic and functional orthodontic treatment: A systematic review. J Investig Clin Dent 2019;10:e12455.

187. Bollen AM, Huang G, King G, Hujoel P, Ma T. Activation time and material stiffness of sequential removable orthodontic appliances. Part 1: Ability to complete treatment. Am J Orthod Dentofacial Orthop 2003;124:496-501.
188. Meier B, Wiemer KB, Miethke RR. Invisalign-patient profiling. Analysis of a prospective survey. J Orofac Orthop 2003;64:352-8.
189. Shalish M, Cooper-Kazaz R, Ivgi I, Canetti L, Tsur B, Bachar E, *et al.* Adult patients' adjustability to orthodontic appliances. Part I: A comparison between Labial, Lingual, and Invisalign™. Eur J Orthod 2012;34:724-30.
190. Miller RJ, Kuo E, Choi W. Validation of align technology's Treat III digital model superimposition tool and its case application. Orthod Craniofac Res 2003;6 Suppl 1:143-9.
191. Djeu G, Shelton C, Maganzini A. Outcome assessment of Invisalign and traditional orthodontic treatment compared with the American Board of Orthodontics objective grading system. Am J Orthod Dentofacial Orthop 2005;128:292-8.
192. Duong T, Kuo E. Finishing with Invisalign. Prog Orthod 2006;7:44-55.
193. Miller KB, McGorray SP, Womack R, Quintero JC, Perelmuter M, Gibson J, *et al.* A comparison of treatment impacts between Invisalign aligner and fixed appliance therapy during the first week of treatment. Am J Orthod Dentofacial Orthop 2007;131:9.e1-9.
194. Kuncio D, Maganzini A, Shelton C, Freeman K. Invisalign and traditional orthodontic treatment postretention outcomes compared using the American Board of Orthodontics objective grading system. Angle Orthod 2007;77:864-9.
195. Kravitz ND, Kusnoto B, BeGole E, Obrez A, Agran B. How well does Invisalign work? A prospective clinical study evaluating the efficacy of tooth movement with Invisalign. Am J Orthod Dentofacial Orthop 2009;135:27-35.
196. Schaefer I, Braumann B. Halitosis, oral health and quality of life during treatment with Invisalign(®) and the effect of a low-dose chlorhexidine solution. J Orofac Orthop 2010;71:430-41.
197. Krieger E, Seiferth J, Saric I, Jung BA, Wehrbein H. Accuracy of Invisalign® treatments in the anterior tooth region. First results. J Orofac Orthop 2011;72:141-9.
198. Pavoni C, Lione R, Laganà G, Cozza P. Self-ligating versus Invisalign: Analysis of dento-alveolar effects. Ann Stomatol (Roma) 2011;2:23-7.
199. Krieger E, Seiferth J, Marinello I, Jung BA, Wriedt S, Jacobs C, *et al.* Invisalign® treatment in the anterior region: Were the predicted tooth movements achieved? J Orofac Orthop 2012;73:365-76.
200. Simon M, Keilig L, Schwarze J, Jung BA, Bourauel C. Treatment outcome and efficacy of an aligner technique-regarding incisor torque, premolar derotation and molar distalization. BMC Oral Health 2014;14:68.
201. Ercoli F, Tepedino M, Parziale V, Luzi C. A comparative study of two different clear aligner systems. Prog Orthod 2014;15:31.
202. Li W, Wang S, Zhang Y. The effectiveness of the Invisalign appliance in extraction cases using the the ABO model grading system: A multicenter randomized controlled trial. Int J Clin Exp Med 2015;8:8276-82.
203. Grünheid T, Gaalaas S, Hamdan H, Larson BE. Effect of clear aligner therapy on the buccolingual inclination of mandibular canines and the intercanine distance. Angle Orthod 2016;86:10-6.
204. Duncan LO, Piedade L, Lekic M, Cunha RS, Wiltshire WA. Changes in mandibular incisor position and arch form resulting from Invisalign correction of the crowded dentition treated nonextraction. Angle Orthod 2016;86:577-83.
205. Best AD, Shroff B, Carrico CK, Lindauer SJ. Treatment management between orthodontists and general practitioners performing clear aligner therapy. Angle Orthod 2017;87:432-9.
206. Hennessy J, Garvey T, Al-Awadhi EA. A randomized clinical trial comparing mandibular incisor proclination produced by fixed labial appliances and clear aligners. Angle Orthod 2016;86:706-12.
207. Ravera S, Castroflorio T, Garino F, Daher S, Cugliari G, Deregibus A. Maxillary molar distalization with aligners in adult patients: A multicenter retrospective study. Prog Orthod 2016;17:12.
208. Weir T. Invisalign treatment of lower incisor extraction cases. Aust Orthod J 2016;32:82-7.
209. Moshiri S, Araújo EA, McCray JF, Thiesen G, Kim KB. Cephalometric evaluation of adult anterior open bite non-extraction treatment with Invisalign. Dental Press J Orthod 2017;22:30-8.
210. Houle JP, Piedade L, Todescan R Jr., Pinheiro FH. The predictability of transverse changes with Invisalign. Angle Orthod 2017;87:19-24.
211. Gu J, Tang JS, Skulski B, Fields HW Jr., Beck FM, Firestone AR, *et al.* Evaluation of Invisalign treatment effectiveness and efficiency compared with conventional fixed appliances using the Peer assessment rating index. Am J Orthod Dentofacial Orthop 2017;151:259-66.
212. White DW, Julien KC, Jacob H, Campbell PM, Buschang PH. Discomfort associated with Invisalign and traditional brackets: A randomized, prospective trial. Angle Orthod 2017;87:801-8.
213. Grünheid T, Loh C, Larson BE. How accurate is Invisalign in nonextraction cases? Are predicted tooth positions achieved? Angle Orthod 2017;87:809-15.
214. Shin K. The Invisalign appliance could be an effective modality for treating overbite malocclusions within a mild to moderate range. J Evid Based Dent Pract 2017;17:278-80.
215. Solano-Mendoza B, Sonnemberg B, Solano-Reina E, Iglesias-Linares A. How effective is the Invisalign® system in expansion movement with Ex30' aligners? Clin Oral Investig 2017;21:1475-84.
216. Khosravi R, Cohanim B, Hujoel P, Daher S, Neal M, Liu W, *et al.* Management of overbite with the Invisalign appliance. Am J Orthod Dentofacial Orthop 2017;151:691-9.e2.
217. Pacheco-Pereira C, Brandelli J, Flores-Mir C. Patient satisfaction and quality of life changes after Invisalign treatment. Am J Orthod Dentofacial Orthop 2018;153:834-41.
218. Garnett BS, Mahood K, Nguyen M, Al-Khateeb A, Liu S, Boyd R, *et al.* Cephalometric comparison of adult anterior open bite treatment using clear aligners and fixed appliances. Angle Orthod 2019;89:3-9.
219. Crouse JM. Patient compliance with removable clear aligner therapy. J Clin Orthod 2018;52:710-3.
220. Charalampakis O, Iliadi A, Ueno H, Oliver DR, Kim KB. Accuracy of clear aligners: A retrospective study of patients

who needed refinement. Am J Orthod Dentofacial Orthop 2018;154:47-54.
221. Lanteri V, Farronato G, Lanteri C, Caravita R, Cossellu G. The efficacy of orthodontic treatments for anterior crowding with Invisalign compared with fixed appliances using the Peer Assessment Rating Index. Quintessence Int 2018;49:581-7.
222. Tepedino M, Paoloni V, Cozza P, Chimenti C. Movement of anterior teeth using clear aligners: A three-dimensional, retrospective evaluation. Prog Orthod 2018;19:9.
223. Sfondrini MF, Gandini P, Castroflorio T, Garino F, Mergati L, D'Anca K, *et al.* Buccolingual inclination control of upper central incisors of aligners: A comparison with conventional and self-ligating brackets. Biomed Res Int 2018;2018:9341821.
224. Flores-Mir C, Brandelli J, Pacheco-Pereira C. Patient satisfaction and quality of life status after 2 treatment modalities: Invisalign and conventional fixed appliances. Am J Orthod Dentofacial Orthop 2018;154:639-44.
225. Ko HC, Liu W, Hou D, Torkan S, Spiekerman C, Huang GJ. Recommendations for clear aligner therapy using digital or plaster study casts. Prog Orthod 2018;19:22.
226. Kankam H, Madari S, Sawh-Martinez R, Bruckman KC, Steinbacher DM. Comparing outcomes in orthognathic surgery using clear aligners versus conventional fixed appliances. J Craniofac Surg 2019;30:1488-91.
227. Christou T, Abarca R, Christou V, Kau CH. Smile outcome comparison of Invisalign and traditional fixed-appliance treatment: A case-control study. Am J Orthod Dentofacial Orthop 2020;157:357-64.
228. Caruso S, Nota A, Ehsani S, Maddalone E, Ojima K, Tecco S. Impact of molar teeth distalization with clear aligners on occlusal vertical dimension: A retrospective study. BMC Oral Health 2019;19:182.
229. Dai FF, Xu TM, Shu G. Comparison of achieved and predicted tooth movement of maxillary first molars and central incisors: First premolar extraction treatment with Invisalign. Angle Orthod 2019;89:679-87.
230. Izhar A, Singh G, Goyal V, Singh R, Gupta N, Pahuja P. Comparative assessment of clinical and predicted treatment outcomes of clear aligner treatment: An *in vivo* study. Turk J Orthod 2019;32:229-35.
231. Alajmi S, Shaban A, Al-Azemi R. Comparison of short-term oral impacts experienced by patients treated with invisalign or conventional fixed orthodontic appliances. Med Princ Pract 2020;29:382-8.
232. De Felice ME, Nucci L, Fiori A, Flores-Mir C, Perillo L, Grassia V. Accuracy of interproximal enamel reduction during clear aligner treatment. Prog Orthod 2020;21:28.
233. Haouili N, Kravitz ND, Vaid NR, Ferguson DJ, Makki L. Has Invisalign improved? A prospective follow-up study on the efficacy of tooth movement with Invisalign. Am J Orthod Dentofacial Orthop 2020;158:420-5.
234. Long H, Wu Z, Yan X, Wang Q, Liu L, Wang Y, *et al.* An objective system for appraising clear aligner treatment difficulty: Clear aligner treatment complexity assessment tool (CAT-CAT). BMC Oral Health 2020;20:312.
235. Harris K, Ojima K, Dan C, Upadhyay M, Alshehri A, Kuo CL, *et al.* Evaluation of open bite closure using clear aligners: A retrospective study. Prog Orthod 2020;21:23.
236. Borda AF, Garfinkle JS, Covell DA, Wang M, Doyle L, Sedgley CM. Outcome assessment of orthodontic clear aligner vs fixed appliance treatment in a teenage population with mild malocclusions. Angle Orthod 2020;90:485-90.
237. Zhou N, Guo J. Efficiency of upper arch expansion with the Invisalign system. Angle Orthod 2020;90:23-30.
238. Morales-Burruezo I, Gandía-Franco JL, Cobo J, Vela-Hernández A, Bellot-Arcís C. Arch expansion with the Invisalign system: Efficacy and predictability. PLoS One 2020;15:e0242979.
239. Lucchese A, Nocini R, Tacchino U, Ghislanzoni LH, Bertossi D, Ricciardi G, *et al.* Invisalign appliance: Aesthetic and efficiency. Minerva Stomatol 2020;69:329-34.
240. Deregibus A, Tallone L, Rossini G, Parrini S, Piancino M, Castroflorio T. Morphometric analysis of dental arch form changes in Class II patients treated with clear aligners. J Orofac Orthop 2020;81:229-38.
241. Amodeo G, Meuli S, Carboni A, Brugnami F, Marrocco S, Orsini R, *et al.* Surgery first and Invisalign system: Combined digital approach. J Craniofac Surg 2020;31:1681-6.
242. Hansa I, Semaan SJ, Vaid NR. Clinical outcomes and patient perspectives of dental Monitoring® GoLive® with Invisalign®-a retrospective cohort study. Prog Orthod 2020;21:16.
243. Gaffuri F, Cossellu G, Lanteri V, Brotto E, Farronato M. Comparative effectiveness of Invisalign and fixed appliances in first-premolar extraction cases. J Clin Orthod 2020;52:294-301.
244. Al-Nadawi M, Kravitz ND, Hansa I, Makki L, Ferguson DJ, Vaid NR. Effect of clear aligner wear protocol on the efficacy of tooth movement. Angle Orthod 2021;91:157-63.
245. Lione R, Paoloni V, Bartolommei L, Gazzani F, Meuli S, Pavoni C, *et al.* Maxillary arch development with Invisalign system. Angle Orthod 2021;91:433-40.
246. Kalemaj Z, Levrini L. Quantitative evaluation of implemented interproximal enamel reduction during aligner therapy. Angle Orthod 2021;91:61-6.
247. Al-Balaa M, Li H, Ma Mohamed A, Xia L, Liu W, Chen Y, *et al.* Predicted and actual outcome of anterior intrusion with Invisalign assessed with cone-beam computed tomography. Am J Orthod Dentofacial Orthop 2021;159:e275-80.
248. Jiang T, Wang JK, Jiang YY, Hu Z, Tang GH. How well do integrated 3D models predict alveolar defects after treatment with clear aligners? Angle Orthod 2021;91:313-9.
249. Jiang T, Jiang YN, Chu FT, Lu PJ, Tang GH. A cone-beam computed tomographic study evaluating the efficacy of incisor movement with clear aligners: Assessment of incisor pure tipping, controlled tipping, translation, and torque. Am J Orthod Dentofacial Orthop 2021;159:635-43.
250. Laganà G, Malara A, Lione R, Danesi C, Meuli S, Cozza P. Enamel interproximal reduction during treatment with clear aligners: Digital planning versus OrthoCAD analysis. BMC Oral Health 2021;21:199.
251. Dianiskova S, Rongo R, Buono R, Franchi L, Michelotti A, D'Antò V. Treatment of mild Class II malocclusion in growing patients with clear aligners versus fixed multibracket therapy: A retrospective study. Orthod Craniofac Res 2022;25:96-102.
252. Caruso S, Nota A, Caruso S, Severino M, Gatto R, Meuli S, *et al.* Mandibular advancement with clear aligners in the treatment of skeletal Class II. A retrospective controlled study.

Eur J Paediatr Dent 2021;22:26-30.
253. Patterson BD, Foley PF, Ueno H, Mason SA, Schneider PP, Kim KB. Class II malocclusion correction with Invisalign: Is it possible? Am J Orthod Dentofacial Orthop 2021;159:e41-8.
254. Riede U, Wai S, Neururer S, Reistenhofer B, Riede G, Besser K, *et al.* Maxillary expansion or contraction and occlusal contact adjustment: Effectiveness of current aligner treatment. Clin Oral Investig 2021;25:4671-9.
255. Henick D, Dayan W, Dunford R, Warunek S, Al-Jewair T. Effects of Invisalign (G5) with virtual bite ramps for skeletal deep overbite malocclusion correction in adults. Angle Orthod 2021;91:164-70.
256. Graf I, Puppe C, Schwarze J, Höfer K, Christ H, Braumann B. Evaluation of effectiveness and stability of aligner treatments using the Peer Assessment Rating Index. J Orofac Orthop 2021;82:23-31.
257. Miethke RR, Vogt S. A comparison of the periodontal health of patients during treatment with the Invisalign system and with fixed orthodontic appliances. J Orofac Orthop 2005;66:219-29.
258. Miethke RR, Brauner K. A Comparison of the periodontal health of patients during treatment with the Invisalign system and with fixed lingual appliances. J Orofac Orthop 2007;68:223-31.
259. Eliades T, Pratsinis H, Athanasiou AE, Eliades G, Kletsas D. Cytotoxicity and estrogenicity of Invisalign appliances. Am J Orthod Dentofacial Orthop 2009;136:100-3.
260. Sombuntham NP, Songwattana S, Atthakorn P, Jungudomjaroen S, Panyarachun B. Early tooth movement with a clear plastic appliance in rats. Am J Orthod Dentofacial Orthop 2009;136:75-82.
261. Low B, Lee W, Seneviratne CJ, Samaranayake LP, Hägg U. Ultrastructure and morphology of biofilms on thermoplastic orthodontic appliances in 'fast' and 'slow' plaque formers. Eur J Orthod 2011;33:577-83.
262. Krieger E, Drechsler T, Schmidtmann I, Jacobs C, Haag S, Wehrbein H. Apical root resorption during orthodontic treatment with aligners? A retrospective radiometric study. Head Face Med 2013;9:21.
263. Fujiyama K, Honjo T, Suzuki M, Matsuoka S, Deguchi T. Analysis of pain level in cases treated with Invisalign aligner: Comparison with fixed edgewise appliance therapy. Prog Orthod 2014;15:64.
264. Premaraj T, Simet S, Beatty M, Premaraj S. Oral epithelial cell reaction after exposure to Invisalign plastic material. Am J Orthod Dentofacial Orthop 2014;145:64-71.
265. Han JY. A comparative study of combined periodontal and orthodontic treatment with fixed appliances and clear aligners in patients with periodontitis. J Periodontal Implant Sci 2015;45:193-204.
266. Azaripour A, Weusmann J, Mahmoodi B, Peppas D, Gerhold-Ay A, Van Noorden CJ, *et al.* Braces versus Invisalign®: Gingival parameters and patients' satisfaction during treatment: A cross-sectional study. BMC Oral Health 2015;15:69.
267. Abbate GM, Caria MP, Montanari P, Mannu C, Orrù G, Caprioglio A, *et al.* Periodontal health in teenagers treated with removable aligners and fixed orthodontic appliances. J Orofac Orthop 2015;76:240-50.
268. Levrini L, Mangano A, Montanari P, Margherini S, Caprioglio A, Abbate GM. Periodontal health status in patients treated with the Invisalign(®) system and fixed orthodontic appliances: A 3 months clinical and microbiological evaluation. Eur J Dent 2015;9:404-10.
269. Hellak A, Schmidt N, Schauseil M, Stein S, Drechsler T, Korbmacher-Steiner HM. Influence of Invisalign treatment with interproximal enamel reduction (IER) on bone volume for adult crowding: A retrospective three-dimensional cone beam computed tomography study. BMC Oral Health 2016;16:83.
270. Levrini L, Mangano A, Margherini S, Tenconi C, Vigetti D, Muollo R, *et al.* ATP bioluminometers analysis on the surfaces of removable orthodontic aligners after the use of different cleaning methods. Int J Dent 2016;2016:5926941.
271. Allareddy V, Nalliah R, Lee MK, Rampa S, Allareddy V. Adverse clinical events reported during Invisalign treatment: Analysis of the MAUDE database. Am J Orthod Dentofacial Orthop 2017;152:706-10.
272. Gay G, Ravera S, Castroflorio T, Garino F, Rossini G, Parrini S, *et al.* Root resorption during orthodontic treatment with Invisalign®: A radiometric study. Prog Orthod 2017;18:12.
273. Castroflorio T, Gamerro EF, Caviglia GP, Deregibus A. Biochemical markers of bone metabolism during early orthodontic tooth movement with aligners. Angle Orthod 2017;87:74-81.
274. Iglesias-Linares A, Sonnenberg B, Solano B, Yañez-Vico RM, Solano E, Lindauer SJ, *et al.* Orthodontically induced external apical root resorption in patients treated with fixed appliances vs removable aligners. Angle Orthod 2017;87:3-10.
275. Hellak A, Schmidt N, Schauseil M, Stein S, Drechsler T, Korbmacher-Steiner HM. Influence on interradicular bone volume of Invisalign treatment for adult crowding with interproximal enamel reduction: A retrospective three-dimensional cone-beam computed tomography study. BMC Oral Health 2018;18:103.
276. Almasoud NN. Pain perception among patients treated with passive self-ligating fixed appliances and Invisalign(®) aligners during the first week of orthodontic treatment. Korean J Orthod 2018;48:326-32.
277. Aman C, Azevedo B, Bednar E, Chandiramami S, German D, Nicholson E, *et al.* Apical root resorption during orthodontic treatment with clear aligners: A retrospective study using cone-beam computed tomography. Am J Orthod Dentofacial Orthop 2018;153:842-51.
278. Yi J, Xiao J, Li Y, Li X, Zhao Z. External apical root resorption in non-extraction cases after clear aligner therapy or fixed orthodontic treatment. J Dent Sci 2018;13:48-53.
279. Katchooi M, Cohanim B, Tai S, Bayirli B, Spiekerman C, Huang G. Effect of supplemental vibration on orthodontic treatment with aligners: A randomized trial. Am J Orthod Dentofacial Orthop 2018;153:336-46.
280. Guo R, Zheng Y, Liu H, Li X, Jia L, Li W. Profiling of subgingival plaque biofilm microbiota in female adult patients with clear aligners: A three-month prospective study. PeerJ 2018;6:e4207.
281. Patini R, Gallenzi P, Meuli S, Paoloni V, Cordaro M. Clear aligners' effects on aesthetics: Evaluation of facial wrinkles. J Clin Exp Dent 2018;10:e696-701.
282. Parrini S, Comba B, Rossini G, Ravera S, Cugliari G, De Giorgi I, *et al.* Postural changes in orthodontic patients treated with clear aligners: A rasterstereographic study. J Electromyogr Kinesiol 2018;38:44-8.
283. Farouk K, Shipley T, El-Bialy T. Effect of the application

of high-frequency mechanical vibration on tooth length concurrent with orthodontic treatment using clear aligners: A retrospective study. J Orthod Sci 2018;7:20.
284. Pogal-Sussman-Gandia CB, Tabbaa S, Al-Jewair T. Effects of Invisalign(®) treatment on speech articulation. Int Orthod 2019;17:513-8.
285. Oliverio T, Cremonini F, Lombardo L, Siciliani G. Tooth whitening in association with clear aligner treatment. J Clin Orthod 2019;53:508-17.
286. Wang Q, Ma JB, Wang B, Zhang X, Yin YL, Bai H. Alterations of the oral microbiome in patients treated with the Invisalign system or with fixed appliances. Am J Orthod Dentofacial Orthop 2019;156:633-40.
287. Abu Alhaija ES, Al-Abdallah SY, Taha NA. A comparative study of initial changes in pulpal blood flow between clear aligners and fixed orthodontic appliances. Am J Orthod Dentofacial Orthop 2019;156:603-10.
288. Lombardo L, Palone M, Scapoli L, Siciliani G, Carinci F. Short-term variation in the subgingival microbiota in two groups of patients treated with clear aligners and vestibular fixed appliances: A longitudinal study. Orthod Craniofac Res 2021;24:251-60.
289. Antonio-Zancajo L, Montero J, Albaladejo A, Oteo-Calatayud MD, Alvarado-Lorenzo A. Pain and oral-health-related quality of life in orthodontic patients during initial therapy with conventional, low-friction, and lingual brackets and aligners (Invisalign): A prospective clinical study. J Clin Med 2020;9:2088.
290. Tran J, Lou T, Nebiolo B, Castroflorio T, Tassi A, Cioffi I. Impact of clear aligner therapy on tooth pain and masticatory muscle soreness. J Oral Rehabil 2020;47:1521-9.
291. Albhaisi Z, Al-Khateeb SN, Abu Alhaija ES. Enamel demineralization during clear aligner orthodontic treatment compared with fixed appliance therapy, evaluated with quantitative light-induced fluorescence: A randomized clinical trial. Am J Orthod Dentofacial Orthop 2020;157:594-601.
292. Mulla Issa FH, Mulla Issa ZHK, Rabah AF, Hu L. Periodontal parameters in adult patients with clear aligners orthodontics treatment versus three other types of brackets: A cross-sectional study. J Orthod Sci 2020;9:4.
293. Zhao R, Huang R, Long H, Li Y, Gao M, Lai W. The dynamics of the oral microbiome and oral health among patients receiving clear aligner orthodontic treatment. Oral Dis 2020;26:473-83.
294. Li Y, Deng S, Mei L, Li Z, Zhang X, Yang C, *et al.* Prevalence and severity of apical root resorption during orthodontic treatment with clear aligners and fixed appliances: A cone beam computed tomography study. Prog Orthod 2020;21:1.
295. Levrini L, Paracchini L, Bakaj R, Diaconu A, Cortese S. Dental bleaching during orthodontic treatment with aligners. Int J Esthet Dent 2020;15:44-54.
296. Al Nazeh AA, Alshahrani I, Badran SA, Almoammar S, Alshahrani A, Almomani BA, *et al.* Relationship between oral health impacts and personality profiles among orthodontic patients treated with Invisalign clear aligners. Sci Rep 2020;10:20459.
297. Meazzini MC, Tortora C, Mazzoleni F, Autelitano L. Comparison of pain perception in patients affected by cleft and cranio facial anomalies treated with traditional fixed appliances or invisalign. Cleft Palate Craniofac J 2020;57:35-42.
298. Barreda GJ, Dzierewianko EA, Mazza V, Muñoz KA, Piccoli GI, Romanelli HJ. Expansion treatment using Invisalign®: Periodontal health status and maxillary buccal bone changes. A clinical and tomographic evaluation. Acta Odontol Latinoam 2020;33:69-81.
299. Kaur H, El-Bialy T. Shortening of overall orthodontic treatment duration with low-intensity pulsed ultrasound (LIPUS). J Clin Med 2020;9:1303.
300. Xie Y, Zhang M, Zhang W, Liu X, Zheng W, Jiang X. Gold nanoclusters-coated orthodontic devices can inhibit the formation of *Streptococcus mutans* biofilm. ACS Biomater Sci Eng 2020;6:1239-46.
301. Zhang M, Liu X, Xie Y, Zhang Q, Zhang W, Jiang X, *et al.* Biological safe gold nanoparticle-modified dental aligner prevents the *Porphyromonas gingivalis* Biofilm formation. ACS Omega 2020;5:18685-92.
302. Xie Y, Zheng W, Jiang X. Near-infrared light-activated phototherapy by gold nanoclusters for dispersing biofilms. ACS Appl Mater Interfaces 2020;12:9041-9.
303. Nemec M, Bartholomaeus HM, M HB, Behm C, Ali Shokoohi-Tabrizi H, Jonke E, *et al.* Behaviour of human oral epithelial cells grown on Invisalign(®) SmartTrack(®) material. Materials (Basel) 2020;13:5311.
304. Gao M, Yan X, Zhao R, Shan Y, Chen Y, Jian F, *et al.* Comparison of pain perception, anxiety, and impacts on oral health-related quality of life between patients receiving clear aligners and fixed appliances during the initial stage of orthodontic treatment. Eur J Orthod 2021;43:353-9.
305. Wang J, Lamani E, Christou T, Li P, Kau CH. A randomized trial on the effects of root resorption after orthodontic treatment using pulsating force. BMC Oral Health 2020;20:238.
306. Lou T, Tran J, Castroflorio T, Tassi A, Cioffi I. Evaluation of masticatory muscle response to clear aligner therapy using ambulatory electromyographic recording. Am J Orthod Dentofacial Orthop 2021;159:e25-33.
307. Campos Zeffa A, Dias BG, Silva DC, Rotta LO, Jussiani EI, Andrello AC, *et al.* Influence of conventional or invisalign orthodontic treatment on mineral and trace element salivary levels: Longitudinal study with total reflection X-ray fluorescence. Biol Trace Elem Res 2021;199:2565-72.
308. Liu W, Shao J, Li S, Al-Balaa M, Xia L, Li H, *et al.* Volumetric cone-beam computed tomography evaluation and risk factor analysis of external apical root resorption with clear aligner therapy. Angle Orthod 2021;91:597-603.
309. Al-Dboush R, Esfahani AN, El-Bialy T. Impact of photobiomodulation and low-intensity pulsed ultrasound adjunctive interventions on orthodontic treatment duration during clear aligner therapy. Angle Orthod 2021;91:619-25.
310. Antonio-Zancajo L, Montero J, Garcovich D, Alvarado-Lorenzo M, Albaladejo A, Alvarado-Lorenzo A. Comparative analysis of periodontal pain according to the type of precision orthodontic appliances: Vestibular, lingual and aligners. A prospective clinical study. Biology (Basel) 2021;10:379.
311. Seleem D, Dadjoo S, Ha A, Santos C, Mirfarsi S, Matsumura-Lem K, *et al.* Effect of 10% Carbamide peroxide on tooth shade, plaque index and gingival index during Invisalign treatment. Dent J (Basel) 2021;9:48.

312. D'Antò V, Muraglie S, Castellano B, Candida E, Sfondrini MF, Scribante A, *et al.* Influence of dental composite viscosity in attachment reproduction: An experimental *in vitro* study. Materials (Basel) 2019;12:4001.
313. Skaik A, Wei XL, Abusamak I, Iddi I. Effects of time and clear aligner removal frequency on the force delivered by different polyethylene terephthalate glycol-modified materials determined with thin-film pressure sensors. Am J Orthod Dentofacial Orthop 2019;155:98-107.
314. Schuster S, Eliades G, Zinelis S, Eliades T, Bradley TG. Structural conformation and leaching from *in vitro* aged and retrieved Invisalign appliances. Am J Orthod Dentofacial Orthop 2004;126:725-8.
315. Gracco A, Mazzoli A, Favoni O, Conti C, Ferraris P, Tosi G, *et al.* Short-term chemical and physical changes in Invisalign appliances. Aust Orthod J 2009;25:34-40.
316. Schott TC, Göz G. Color fading of the blue compliance indicator encapsulated in removable clear Invisalign Teen® aligners. Angle Orthod 2011;81:185-91.
317. Lombardo L, Arreghini A, Maccarrone R, Bianchi A, Scalia S, Siciliani G. Optical properties of orthodontic aligners-spectrophotometry analysis of three types before and after aging. Prog Orthod 2015;16:41.
318. Alexandropoulos A, Al Jabbari YS, Zinelis S, Eliades T. Chemical and mechanical characteristics of contemporary thermoplastic orthodontic materials. Aust Orthod J 2015;31:165-70.
319. Liu CL, Sun WT, Liao W, Lu WX, Li QW, Jeong Y, *et al.* Colour stabilities of three types of orthodontic clear aligners exposed to staining agents. Int J Oral Sci 2016;8:246-53.
320. Gerard Bradley T, Teske L, Eliades G, Zinelis S, Eliades T. Do the mechanical and chemical properties of InvisalignTM appliances change after use? A retrieval analysis. Eur J Orthod 2016;38:27-31.
321. Bräscher AK, Zuran D, Feldmann RE Jr., Benrath J. Erratum to: Patient survey on Invisalign(®) treatment comparing the SmartTrack(®) material to the previously used aligner material. J Orofac Orthop 2017;78:511.
322. Condo' R, Pazzini L, Cerroni L, Pasquantonio G, Lagana' G, Pecora A, *et al.* Mechanical properties of "two generations" of teeth aligners: Change analysis during oral permanence. Dent Mater J 2018;37:835-42.
323. Agarwal M, Wible E, Ramir T, Altun S, Viana G, Evans C, *et al.* Long-term effects of seven cleaning methods on light transmittance, surface roughness, and flexural modulus of polyurethane retainer material. Angle Orthod 2018;88:355-62.
324. Wible E, Agarwal M, Altun S, Ramir T, Viana G, Evans C, *et al.* Long-term effects of different cleaning methods on copolyester retainer properties. Angle Orthod 2019;89:221-7.
325. Papadopoulou AK, Cantele A, Polychronis G, Zinelis S, Eliades T. Changes in roughness and mechanical properties of Invisalign(®) Appliances after one-and two-weeks use. Materials (Basel) 2019;12:2406.
326. Ihssen BA, Willmann JH, Nimer A, Drescher D. Effect of *in vitro* aging by water immersion and thermocycling on the mechanical properties of PETG aligner material. J Orofac Orthop 2019;80:292-303.
327. Lombardo L, Palone M, Longo M, Arveda N, Nacucchi M, De Pascalis F, *et al.* MicroCT X-ray comparison of aligner gap and thickness of six brands of aligners: An *in-vitro* study. Prog Orthod 2020;21:12.
328. Bernard G, Rompré P, Tavares JR, Montpetit A. Colorimetric and spectrophotometric measurements of orthodontic thermoplastic aligners exposed to various staining sources and cleaning methods. Head Face Med 2020;16:2.
329. Fang D, Li F, Zhang Y, Bai Y, Wu BM. Changes in mechanical properties, surface morphology, structure, and composition of Invisalign material in the oral environment. Am J Orthod Dentofacial Orthop 2020;157:745-53.
330. Tamburrino F, D'Antò V, Bucci R, Alessandri-Bonetti G, Barone S, Razionale AV. Mechanical properties of thermoplastic polymers for aligner manufacturing: *In vitro* study. Dent J (Basel) 2020;8:47.
331. McCarty MC, Chen SJ, English JD, Kasper F. Effect of print orientation and duration of ultraviolet curing on the dimensional accuracy of a 3-dimensionally printed orthodontic clear aligner design. Am J Orthod Dentofacial Orthop 2020;158:889-97.
332. Memè L, Notarstefano V, Sampalmieri F, Orilisi G, Quinzi V. ATR-FTIR analysis of orthodontic Invisalign(®) aligners subjected to various *in vitro* aging treatments. Materials (Basel) 2021;14:818.
333. Palone M, Longo M, Arveda N, Nacucchi M, Pascalis F, Spedicato GA, *et al.* Micro-computed tomography evaluation of general trends in aligner thickness and gap width after thermoforming procedures involving six commercial clear aligners: An *in vitro* study. Korean J Orthod 2021;51:135-41.
334. Isman O, Isman E. Identification of various orthodontic materials as foreign bodies via panoramic radiography, cone beam computed tomography, magnetic resonance imaging, and ultrasonography: An *in vitro* study. Oral Radiol 2021;37:524-30.
335. Mantovani E, Parrini S, Coda E, Cugliari G, Scotti N, Pasqualini D, *et al.* Micro computed tomography evaluation of Invisalign aligner thickness homogeneity. Angle Orthod 2021;91:343-8.
336. Nedwed V, Miethke RR. Motivation, acceptance and problems of Invisalign patients. J Orofac Orthop 2005;66:162-73.
337. Jeremiah HG, Bister D, Newton JT. Social perceptions of adults wearing orthodontic appliances: A cross-sectional study. Eur J Orthod 2011;33:476-82.
338. Cooper-Kazaz R, Ivgi I, Canetti L, Bachar E, Tsur B, Chaushu S, *et al.* The impact of personality on adult patients' adjustability to orthodontic appliances. Angle Orthod 2013;83:76-82.
339. Kuhlman DC, Lima TA, Duplat CB, Capelli J Junior. Esthetic perception of orthodontic appliances by Brazilian children and adolescents. Dental Press J Orthod 2016;21:58-66.
340. Arun M, Usman Q, Johal A. Orthodontic treatment modalities: A qualitative assessment of Internet information. J Orthod 2017;44:82-9.
341. Noll D, Mahon B, Shroff B, Carrico C, Lindauer SJ. Twitter analysis of the orthodontic patient experience with braces vs Invisalign. Angle Orthod 2017;87:377-83.
342. Livas C, Delli K, Pandis N. "My Invisalign experience": Content, metrics and comment sentiment analysis of the most popular patient testimonials on YouTube. Prog Orthod 2018;19:3.
343. Ustdal G, Guney AU. YouTube as a source of information about

orthodontic clear aligners. Angle Orthod 2020;90:419-24.
344. Bustati N, Rajeh N. The impact of COVID-19 pandemic on patients receiving orthodontic treatment: An online questionnaire cross-sectional study. J World Fed Orthod 2020;9:159-63.
345. Adobes-Martin M, Montoya-Morcillo ML, Zhou-Wu A, Garcovich D. Invisalign treatment from the patient perspective: A Twitter content analyses. J Clin Exp Dent 2021;13:e376-e82.
346. Zybutz T, Drummond R, Lekic M, Brownlee M. Investigation and comparison of patient experiences with removable functional appliances. Angle Orthod 2021;91:490-5.
347. Noble J, Hechter FJ, Karaiskos NE, Lekic N, Wiltshire WA. Future practice plans of orthodontic residents in the United States. Am J Orthod Dentofacial Orthop 2009;135:357-60.
348. Noble J, Karaiskos N, Wiltshire WA. Motivations and future plans of Canadian orthodontic residents. Am J Orthod Dentofacial Orthop 2009;136:644-50.
349. Vicéns J, Russo A. Comparative use of Invisalign by orthodontists and general practitioners. Angle Orthod 2010;80:425-34.
350. Al-Hamlan N, Al-Ruwaithi MM, Al-Shraim N, El-Metwaaly A. Motivations and future practice plans of orthodontic residents in Saudi Arabia. J Orthod Sci 2013;2:67-72.
351. Jauhar P, Mossey PA, Popat H, Seehra J, Fleming PS. A survey of undergraduate orthodontic teaching and factors affecting pursuit of postgraduate training. Br Dent J 2016;221:487-92.
352. Mackay MM, Fallah M, Danyal T. Acquisition of a digital intraoral scanning device: An examination of practice volume changes and the economic impact via an interrupted time series analysis. J Clin Dent 2017;28:S1-5.
353. Didier VF, Almeida-Pedrin RR, Pedron Oltramari PV, Freire Fernandes TM, Lima Dos Santos L, de Castro Ferreira Conti A. Influence of orthodontic appliance design on employment hiring preferences. Am J Orthod Dentofacial Orthop 2019;156:758-66.
354. d'Apuzzo F, Perillo L, Carrico CK, Castroflorio T, Grassia V, Lindauer SJ, *et al.* Clear aligner treatment: Different perspectives between orthodontists and general dentists. Prog Orthod 2019;20:10.
355. Batarse AP, English JD, Frey GN, Piazza JM, Akyalcin S. Referral patterns of pediatric dentists and general practitioners to orthodontists based on case complexity. Am J Orthod Dentofacial Orthop 2019;156:61-6.
356. Linjawi AI, Alsadat MA, Othman MA, Fakhry LM, Basalaim AS, Alansari RA, *et al.* Awareness, perception and readiness regarding clear aligner therapy among orthodontists and other dental specialists. J Biol Regul Homeost Agents 2020;34:1061-6.
357. Hellyer P. Poor information on clear aligner websites. Br Dent J 2021;230:397.
358. Bruni A, Serra FG, Gallo V, Deregibus A, Castroflorio T. The 50 most-cited articles on clear aligner treatment: A bibliometric and visualized analysis. Am J Orthod Dentofacial Orthop 2021;159:e343-62.
359. Kravitz ND, Kusnoto B, Agran B, Viana G. Influence of attachments and interproximal reduction on the accuracy of canine rotation with Invisalign. A prospective clinical study. Angle Orthod 2008;78:682-7.
360. Castroflorio T, Garino F, Lazzaro A, Debernardi C. Upper-incisor root control with Invisalign appliances. J Clin Orthod 2013;47:346-51.
361. Dasy H, Dasy A, Asatrian G, Rózsa N, Lee HF, Kwak JH. Effects of variable attachment shapes and aligner material on aligner retention. Angle Orthod 2015;85:934-40.
362. Simon M, Keilig L, Schwarze J, Jung BA, Bourauel C. Forces and moments generated by removable thermoplastic aligners: Incisor torque, premolar derotation, and molar distalization. Am J Orthod Dentofacial Orthop 2014;145:728-36.
363. Mantovani E, Castroflorio E, Rossini G, Garino F, Cugliari G, Deregibus A, *et al.* Scanning electron microscopy analysis of aligner fitting on anchorage attachments. J Orofac Orthop 2019;80:79-87.
364. Barreda GJ, Dzierewianko EA, Muñoz KA, Piccoli GI. Surface wear of resin composites used for Invisalign® attachments. Acta Odontol Latinoam 2017;30:90-5.
365. Thai JK, Araujo E, McCray J, Schneider PP, Kim KB. Esthetic perception of clear aligner therapy attachments using eye-tracking technology. Am J Orthod Dentofacial Orthop 2020;158:400-9.
366. Cortona A, Rossini G, Parrini S, Deregibus A, Castroflorio T. Clear aligner orthodontic therapy of rotated mandibular round-shaped teeth: A finite element study. Angle Orthod 2020;90:247-54.
367. Lin S, Huang L, Li J, Wen J, Mei L, Xu H, *et al.* Assessment of preparation time and 1-year Invisalign aligner attachment survival using flowable and packable composites. Angle Orthod 2021;91:583-9.
368. Yaosen C, Mohamed AM, Jinbo W, Ziwei Z, Al-Balaa M, Yan Y. Risk factors of composite attachment loss in orthodontic patients during orthodontic clear aligner therapy: A prospective study. Biomed Res Int 2021;2021:6620377.
369. Vardimon AD, Robbins D, Brosh T. *In-vivo* von Mises strains during Invisalign treatment. Am J Orthod Dentofacial Orthop 2010;138:399-409.
370. Mantovani E, Castroflorio E, Rossini G, Garino F, Cugliari G, Deregibus A, *et al.* Scanning electron microscopy evaluation of aligner fit on teeth. Angle Orthod 2018;88:596-601.
371. Son HJ, Lee KH, Sim JY, Kim HY, Kim JH, Kim WC. Pressure differences from clear aligner movements assessed by pressure sensors. Biomed Res Int 2020;2020:8376395.
372. Kim WH, Hong K, Lim D, Lee JH, Jung YJ, Kim B. Optimal position of attachment for removable thermoplastic aligner on the lower canine using finite element analysis. Materials (Basel) 2020;13:3369.
373. Jiang T, Wu RY, Wang JK, Wang HH, Tang GH. Clear aligners for maxillary anterior en masse retraction: A 3D finite element study. Sci Rep 2020;10:10156.
374. Ma Y, Li S. The optimal orthodontic displacement of clear aligner for mild, moderate and severe periodontal conditions: An *in vitro* study in a periodontally compromised individual using the finite element model. BMC Oral Health 2021;21:109.
375. Seo JH, Eghan-Acquah E, Kim MS, Lee JH, Jeong YH, Jung TG, *et al.* Comparative analysis of stress in the periodontal ligament and center of rotation in the tooth after orthodontic treatment depending on clear aligner thickness-finite element analysis study. Materials (Basel) 2021;14:324.

How to cite this article: Adel SM, Hansa I, Vaid NR. Clear aligner therapy in contemporary orthodontics: A scoping review of scholarly literature. APOS Trends Orthod. 2024;14:3-27. doi: 10.25259/APOS_215_2022