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Comparison of adverse effects and treatment duration between lingual orthodontics and clear aligners: A systematic review

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Abstract
Background: Lingual orthodontic appliances and clear aligner therapy have been the treatment of choice for patients with primary concern of aesthetics throughout the treatment. There are no systematic reviews comparing the adverse effects and treatment duration of the two aesthetic options available in orthodontic therapy.
Aim: The aim of this study was to systematically review the evidence available regarding the adverse effects and treatment duration of Lingual Orthodontic treatment and that of Clear aligner therapy
Materials and Methods: Data was collected from the year 2010 to 2020 that satisfied the inclusion and exclusion criteria, it was analysed for characteristics and quality assessment for the same was carried out.
Results: The most common adverse effects of lingual orthodontic appliances include tongue pain, chewing difficulties, and speech difficulties. In contrast, for clear aligner therapy, the most common adverse effects turned out to be poor occlusal contacts and root resorption. Whereas, treatment duration depends on the complexity of the case
Conclusion: The data available is not enough to compare adverse effects and treatment duration of lingual orthodontic appliances and clear aligner therapy. Further studies are required to assess the same.

Keywords: adverse effects, clear aligners, clear aligner therapy, lingual orthodontics, systematic review, treatment duration

Introduction

Orthodontic appliances can be broadly classified into fixed and removable orthodontic appliances. Fixed appliances have been an integral part of modern orthodontics for a long time. The traditional method of placing orthodontic brackets for fixed orthodontic appliances was on the labial surface of the teeth.

As the number of adult patients seeking orthodontic treatment increased, demand for treatment options offering higher aesthetics also increased. Advances in technology and its application in the field of dentistry have resulted in the emergence of newer, more aesthetic orthodontic treatment alternatives that have shown exemplary results without compromising the aesthetics and hence, the quality of life of the patient and improves self-esteem throughout the treatment duration.[1] This led to the introduction of various aesthetic options, including aesthetic brackets and archwires, brackets bonded to the lingual or palatal surfaces of teeth (Lingual orthodontic appliances) (Fig. 1a), and clear aligners (Fig. 1b) [2].

Lingual appliances were introduced by Fujita [3] in 1979, and there have been various advances in their design, manufacturing, and mechanotherapy. Lingual Orthodontics is an aesthetic fixed orthodontic treatment alternative that is challenging for both the orthodontist and the patients.

Dr. C. Kurz and his team at Ormco Company has developed seven generations of lingual brackets, from the first generation developed in the year 1976 to the present generation developed in 1990 [4].

There are various adverse effects of lingual orthodontic appliances that may affect the treatment objectives and outcomes due to reduced patient compliance.

These include difficulty maintaining oral hygiene, increased pain, tongue ulcers, and speech and eating difficulty.

Align Technologies Inc. first introduced Invisalign in 1998, a Clear Aligner Therapy (CAT) for orthodontic use. This is an improvised form of Tooth Positioner introduced in 1946 by Dr. Harold Kesling. Clear aligners were initially used to treat minor irregularities; however, later, certain clear aligners were introduced to correct complex malocclusions as well [5].

All the clear aligner technologies make use of transparent thermoformed removable aligners that cover many or all teeth to treat a variety of malocclusions [6].

Using clear aligners can have adverse effects as well. These may include[7] root resorption, poor occlusal contacts by the end of the treatment, some amount of speech impairment, and increased treatment time since clear aligner treatment entirely relies on patient compliance.

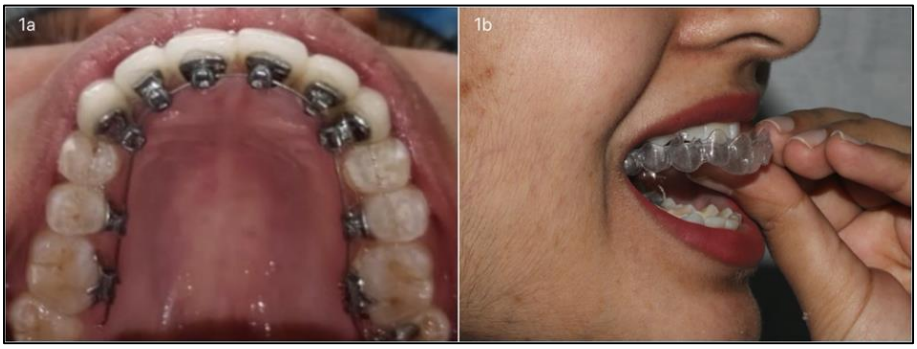

Fig 1: Invisible Orthodontic Appliances, **Fig. 1a.** Lingual Orthodontics. **Fig. 1b.** Clear Aligners

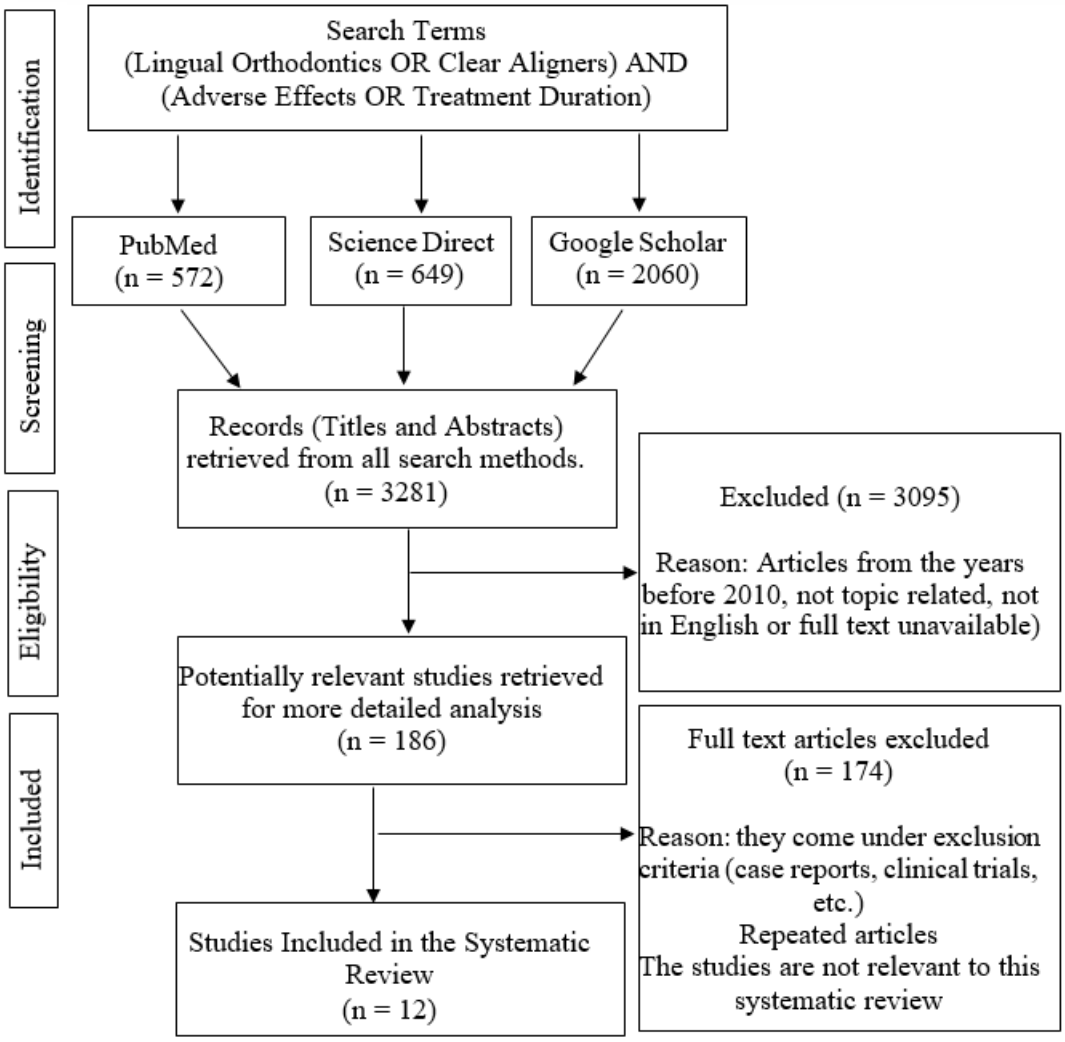

Fig. 2: PRISMA Flow Diagram

Aim and Objective

The aim of this study was to systematically review the evidence available regarding the adverse effects and treatment duration of Lingual Orthodontic treatment and that of Clear aligner therapy, with the primary objective being a comparison of adverse effects of lingual orthodontics with those of clear aligner therapy and the secondary objective being a comparison of treatment duration of lingual orthodontics and clear aligner therapy.

Materials and Methods

Eligibility criteria for study selection

Studies with their sample as an adult or adolescent patients undergoing lingual orthodontic treatment or clear aligner therapy were selected. Randomized clinical trials, Controlled clinical trials, and retrospective studies of lingual orthodontics and clear aligner therapy were included in this systematic review. Correction of malaligned teeth with lingual orthodontics was assessed as active intervention, and those treated with clear aligners were taken as control. Adverse effects caused due to lingual orthodontics and clear aligner therapy were recorded as primary outcomes, and treatment durations of lingual orthodontics and clear aligner therapy were measured as the secondary outcome.

The settings of this systematic review were based on the PRISMA guidelines, and the main question was formulated with the help of PICO format [8].

- Population: Subjects with malaligned teeth who require aesthetic orthodontic treatment
- Intervention: Correction of malaligned teeth with lingual orthodontics
- Comparison: Correction of malaligned teeth with Clear aligner
- Outcome: Adverse Effects and Treatment Duration

Data Collection

The literature was systematically searched for articles published from 2010 to 2020 in PubMed, Science Direct, and Google Scholar databases. A search of the keywords (Lingual Orthodontics OR Clear Aligners) AND (Adverse Effects OR Treatment Duration) was conducted, and relevant studies were identified by manually cross-referencing the search results. Same articles indexed in more than one database were counted only once in the systematic review.

Initially, the articles were selected based on title and abstracts. The selected articles were thoroughly analyzed as per the inclusion and exclusion criteria, applied for the final selection of the articles.

All systematic reviews, meta-analysis, randomized controlled trials, controlled clinical trials, and retrospective studies**,** from the year 2010 to 2020**,** published in the English language**,** with full text available online, were included in the study. Case reports/series, laboratory studies, descriptive studies, epidemiologic studies, books, documents, expert opinions, reviews, clinical trials, and clinical studies with no relevance to adverse effects or treatment duration concerning lingual orthodontics or clear aligners were excluded.

The selection process was independently conducted by two researchers, and their results were compared to identify discrepancies. Inter-examiner conflicts were resolved by discussion of each article to reach a consensus regarding all selection criteria.

At first, all the searched articles were screened according to their title, and potentially irrelevant articles were excluded. The abstracts were analyzed according to the eligibility criteria. Those articles whose abstract did not provide enough information to make a decision were thoroughly researched before inclusion. Full-text of selected articles was precisely reviewed for final selection. The reviewers contacted the authors of those articles where insufficient data was observed. A data extraction form was designed, which was filled by two reviewers independently.

The quality of each article was scored using an adapted version of 3 methods previously used by Fudalej and Antoszewska [9], Cozza *et al* [10], and Chen *et al* [11]. The following characteristics were evaluated: Study design, Sample size, Sample description, Error analysis, and Statistical Analysis. Each characteristic received a score according to the criteria described in Table I. The quality of each study was categorized as High (7-9 points), Medium (4-6 points), or Low (0-3 points). The data from the selected articles were divided into two groups according to the type of appliance used: Lingual Orthodontic Appliance or Clear Aligners.

Table 1: Methodologic quality scoring protocol (maximum score: 9 points)

Study design	3 points: randomized clinical trial 2 points: if randomization process is not well described, or if it was a controlled prospective study 1 point: an uncontrolled prospective study 0 point: retrospective study or not mentioned
Sample size	1 point: larger than or equal to 15 subjects or prior estimate of sample size 0 point: less than 15 subjects and no prior estimate of sample size
Sample description	2 points: description of all 3 items (age, sex, appliance) 1 point: only 2 items described 0 point: only 1 item described
Error analysis	1 point: error analysis value cited 0 point: error analysis value not cited, or error analysis not Performed
Statistical analysis	2 points: adequate 1 point: partially adequate 0 point: no statistical tests were conducted

Results

After the electronic database search on January 10, 2021, 572 studies were retrieved from PubMed, 649 from Science Direct, 2060 from Google Scholar. After application of the initial inclusion and exclusion criteria, 186 articles were retrieved for full-text review. Hence, 12 studies were included in this systematic review. The PRISMA Flow Diagram (Fig.2) schematically represents the stages of article selection.

From the remaining articles, we independently extracted the following data: Author names, Year of Publication, Type of appliances, Sample Size, Mean Age of groups, adverse effects, and treatment duration. (Table II).

Table 2: Characteristics of Included Studies

S. No.	Study	Appliance	Sample Size	Average Age (Years)	Adverse Effects	Treatment Duration (Months)
1	Rena Cooper-Kazaz *et al*. (2012)[12]	Lingual(L)/ Clear aligners(CA)	19/21	34 (L)/29.4 (CA)	Pain, Psychological impact	N/A
2	Ariane Hohoff *et al*. (2003) [13]	Lingual	22	34.7	Pain, hygiene, function	N/A
3	Abby K Y Wu, *et al*. (2010) [14	Lingual	30	21.63	Pain	N/A
4	Tarek Z Khattab, *et al*. (2013) [15]	Lingual	17	20.6	Speech difficulty	N/A
5	Garret Djeu *et al*. (2005) [16]	Clear Aligner	48	N/A	Poor occlusal contacts	N/A
6	Chiara Pavoni *et al*. (2011) [17]	Clear Aligners	20	18.4	Poor occlusal contacts	22
7	Weihong Li *et al*. (2019) [18]	Clear Aligners	76	35.2	Poor occlusal contacts	31.5
8	Jiafeng Gu *et al*. (2017) [19]	Clear Aligners	48	26.0	Final alignment	13.35
9	Valentina Lanteri *et al*. (2018) [20]	Clear Aligners	100	28	Final alignment	N/A
10	Miethke and Brauner (2007) [21]	Lingual Clear Aligners	30 30	39.6	Periodontal health	N/A
11	Michael Knosel *et al*. (2014) [22]	Lingual	376	17.3	N/A	21.7
12	Courtney Aman *et al*. (2018) [23]	Clear Aligners	160	N/A	Root resorption	N/A

Quality Assessment

After quality assessment, seven studies were classified as high quality, and five as medium quality. (Table III).

Table 3: Assessment of the Quality of the Studies

No.	Study	Study Design 0-3	Sample Size 0-1	Selection Description 0-2	Method Error Analysis 0-1	Adequacy of Statistical Analysis 0-2	Quality Score 0-9	Judged Quality Standard
1	Rena Cooper-Kazaz *et al*. (2012) [12]	2	1	2	0	1	6	Medium
2	Ariane Hohoff *et al*. (2003) [13]	2	1	2	0	2	7	High
3	Abby K Y Wu, *et al*. (2010) [14]	2	1	2	0	1	6	Medium
4	Tarek Z Khattab, *et al*. (2013) [15]	3	1	2	1	2	9	High
5	Garret Djeu *et al*. (2005) [16]	2	1	1	0	2	6	Medium
6	Chiara Pavoni *et al*. (2011) [17]	2	1	1	1	2	7	High
7	Weihong Li *et al*. (2019) [18]	3	1	2	1	2	9	High
8	Jiafeng Gu *et al*. (2017) [19]	3	1	2	0	2	8	High
9	Valentina Lanteri *et al*. (2018) [20]	2	1	2	0	2	7	High
10	Miethke and Brauner (2007) [21]	2	1	2	0	1	6	Medium
11	Michael Knosel *et al*. (2014) [22]	3	1	2	0	2	8	High
12	Courtney Aman *et al*. (2018) [23]	2	1	1	0	2	6	Medium

It was observed that there isn't enough evidence available to compare the various parameters regarding lingual orthodontic appliances and clear aligner therapy.

Most of the studies performed have considered only one of the appliances and assessed the adverse effects and treatment duration for the same.

The most common adverse effects of Lingual orthodontic appliances include tongue pain, chewing difficulties, and speech difficulties. In contrast, for clear aligner therapy, the most common adverse effects turned out to be poor occlusal contacts and root resorption.

Different studies showed different time durations for treatment with lingual orthodontic appliances and those with clear aligner therapy. Most of them concluded that it depended on the severity of malocclusions and patient cooperation.

According to the criteria for quality analysis, the authors obtained only 4 studies [15, 18-19, 22] that were randomized clinical trials with the randomization process described in detail. The authors of all the 12 studies [12-23] performed sample-size calculation or had sample sizes larger than or equal to 15 patients. 9 studies [12-15, 18-22] gave proper sample description including age, sex, appliance used, etc. The authors of 3 studies [15, 17-18] performed and described the method error results. Some studies stated that the error of the method was performed but did not present the results, and the authors of 3 studies [12, 14, 21] performed only a descriptive analysis

Discussion

Since the introduction of aesthetic orthodontic treatment alternatives like ceramic brackets, lingual orthodontics, and clear aligner therapy, patients have opted these over the conventional metal brackets placed on the buccal surface of the teeth. The primary reason for this change was the increasing concern about facial aesthetics, not only after treatment but also during treatment.

Lingual orthodontics has various advantages, as advocated by clinicians and manufacturers, including reduced visibility, reduced damage to labial surfaces of teeth from bonding, debonding and adhesive removal, and decreased damage to facial gingival tissues. The bite plane effect of brackets will allow the intrusion of incisors and limited extrusion of molars [24], the position of lingual brackets places the slot near to the center of resistance of the incisor teeth, hence, reduced undesired tooth movement and more predictable bodily tooth movements during space closure and bite opening is possible [25], lower chances of white spot lesions and caries, reduced inter-bracket distance requiring lighter forces, and lesser anchorage loss.

Some of the disadvantages pointed out for the same include practical difficulties in the placement and handling of these appliances, the technique is more demanding and sensitive, difficulty in the correction of rotations, compromised oral hygiene, higher laboratory cost [26], and longer chairside time along with discomfort to the orthodontist and the patients [27].

Clear aligner therapy gained rapid technological changes that led to the improvement of aligner materials, appliance design, and manufacture. The rapid evolution of clear aligners has made it difficult to scientifically assess the efficiency of these over long periods.

Various advantages of clear aligners include [7] higher aesthetics, no lacerations, gives the patient confidence to smile, technically much easier than other forms of fixed appliances, better oral hygiene maintenance, shorter dental appointments, treatment duration is more precise, and less frequent visits to the dental clinic as the patients can change the aligners every few weeks on their own.

Similarly, there are certain disadvantages to clear aligner therapy as well. These include [28] patient cooperation and motivation is required as they are removable in nature, the patient must wear it for at least 22 hours a day to obtain the desired results, clear aligners need to be removed every time during meals, it is known to cause root resorption and excessive bone enlargement which can lead to increased treatment time and deteriorate the quality of treatment, and it is expensive.

Table IV enumerates the type of cases that can be treated using lingual mechanotherapy [29] and clear aligner therapy [30].

Table 4: Ideal Cases for Lingual Mechanotherapy[29] and Clear Aligner Therapy [30]

S. No.	Type of Cases	Lingual Orthodontics	Clear Aligner Therapy
1.	Non-extraction Cases	Deep bite, Class I with mild crowding, good facial pattern	Mild crowding
		Deep bite, Class I with generalized spacing, good facial pattern	Generalized spacing
		Deep bite, mild Class II, good facial pattern	Mild Class II, good facial pattern
		Class II Div. 2 with retruded mandible	Mild deep bite
		Cases requiring expansion	Mild to moderate proclination of anteriors
		Cases of midline diastema	Cases with midline diastema
2	Extraction Cases	Class II, upper first premolar and lower second premolar extractions.	Extraction cases that do not require excessive space closure
		Extractions of upper first premolars only.	Minimum anchorage cases
		Mild protrusion of maxilla and mandible with four first premolar extractions, wherein anchorage demand is minimum.	
3.	Difficult Cases	Surgical cases.	Extraction cases
		Class III tendencies.	Posterior crossbite cases
		Class II, four first premolar extractions.	Cases with mild class III tendencies
		Mesiofacial patterns and/or average mandibular plane angles.	High angle cases
		Cases requiring multiple restorations.	
4.	Contraindicated cases	Acute temporomandibular joint dysfunction.	Surgical cases
		Mutilated posterior occlusions.	Severe antero-posterior discrepancies
		High angle/dolichofacial patterns.	Critical anchorage cases
		Extensive prosthesis with anterior.	Severe crowding cases
		Short clinical crowns.	Retrognathic mandible
		Critical anchorage case.	Anterior open bite
		Severe Class II discrepancies.	Posterior open bite
		Compromised oral hygiene or periodontal involvement.	Severe deep bite
		Extremely apprehensive patients	Anterior crossbite
			Facial asymmetries

The purpose of this systematic review was to compare the adverse effects and treatment duration of lingual orthodontic treatment and clear aligner therapy.

It is essential to evaluate the quality of the articles in a systematic review and allow the inclusion of better quality articles to decrease the heterogeneity among them, thus, presenting more reliable data. This systematic review has included reports that show clinical, methodological, and statistical heterogeneity to make the results and conclusion more reliable. In health field investigations that involve the treatment of patients, significant degrees of clinical, methodological, and statistical heterogeneity are required because of the nature of these studies and the different variables involved. The entire systematic review project must address this issue [31].

The most common adverse effects of lingual appliances are pain, poor oral hygiene, poor periodontal health, poor function, and speech difficulty during the treatment. The most common adverse effects of clear aligners include poor occlusal contacts, poor final alignment, root resorption, and poor periodontal health.

There are various adverse effects of lingual appliances as well as Clear Aligner Therapy, as advocated by multiple authors. The most commonly studied adverse effect for lingual appliances was "pain," Rena Cooper-Kazaz *et al.* [12] and Ariane Hohoff *et al.* [13] assessed pain using questionnaires as the preferred method, and Abby K Y Wu *et al.* [14] used VAS to assess pain. Haefeli M, Elfering A [32]. Evaluated different pain assessment methods and concluded that VAS helps evaluate pain intensity, pain effects, and pain-related disability, while questionnaires help in a detailed and more comprehensive evaluation of pain and factors influencing pain perception.

Other adverse effects included poor oral hygiene that was assessed using questionnaires; poor periodontal health, which was evaluated using the gingival index, plaque index, and sulcus probing depth; and speech and masticatory difficulty, assessed using spectrographic analysis and questionnaire, respectively.

The most common adverse effects that authors assessed for Clear Aligner Therapy included poor occlusal contacts, which were evaluated by Garret Djeu *et al* [16] and Weihong Li *et al.* [18] using ABO Model Grading System, and Chiara Pavoni *et al* [17] used dento-alveolar measurements on the

casts. Final alignment after Clear Aligner Therapy was assessed by Jiafeng Gu *et al* [19] and Valentina Lanteri *et al*. [20] using Peer Assessment Rating Index. Both the methods have advantages and disadvantages of their own. Buchanan *et al* [33] stated that PAR had limitations as it cannot adequately record features such as posterior alignment, incisor torque, and changes in arch dimensions. Yang-Powers *et al* [34] pointed out that ABO objective grading system did not consider the severity of original malocclusion or the difficulty of treatment and only defined treatment outcome. However, the change obtained from the pre-treatment stage to the post-treatment stage is an important aspect to evaluate the efficacy and effectiveness of orthodontic treatment [35].

Other adverse effects for clear aligners that were assessed included root resorption and periodontal health, which were evaluated using pre-treatment and post-treatment CBCT by Courtney Aman *et al* [23] and gingival index, plaque index, and sulcus probing depth by Miethke and Brauner [21], respectively.

Tarek Z. Khattab [15] conducted a randomized controlled trial to assess speech performance and oral impairments with lingual and labial orthodontic appliances in the first stage of fixed treatment. Speech performance was tested using spectrographic analysis of fricative /s/ sound before (T0), immediately after (T1), one month after (T2), and three months after (T3) bracket placement. The levels of oral impairment were assessed using standardized questionnaires. The results of this questionnaire-based analysis show that chewing difficulty was the most severe problem encountered by patients with lingual appliances, particularly in the immediate period following bracket placement. These findings do not concur with those of Caniklioglu and Ozturk [36] and Wu *et al* [37], who reported speech difficulty as the most severe problem with lingual appliances. Their findings also do not resemble those of Fillion [38] and Fritz *et al* [39], who showed that tongue discomfort was the most common and severe problem in lingual patients.

Wu AK *et al* [37] assessed pain due to labial and lingual appliances using a visual analog scale with 0 being least painful and 10 being most painful. They concluded that patients with lingual appliances experienced more intense pain and speech difficulty. The onset of pain was earlier in patients with lingual appliances than in those with labial appliances.

Hohoff A. *et al* [13] assessed oral comfort, function, and hygiene in patients with lingual brackets using a questionnaire with five possible answers with their quantitative rating as "No, not at all" = 1; "Slightly" = 2; "Yes, with reserve" = 3; "Yes, indeed, I can confirm this without reserve" = 4. And "No evaluation possible" = 0 at three-time intervals, before placement of appliance (T0), 24 hours after the placement of appliance (T1), and three months after placement of appliance (T3). They concluded that oral hygiene was most problematic for patients who opted for fixed lingual appliances.

Pavoni C. *et al* [17] made dento-alveolar measurements on the maxillary dental casts and concluded that Invisalign treatment has also had success with straightening arches by de-rotating the teeth, leveling arches, and easily tip crowns but cannot tip roots because of lack of control of tooth movement.

Djeu *et al* [16] found that Invisalign patients were relatively older than fixed appliances patients in his study "Outcome assessment of Invisalign and traditional orthodontic treatment compared with the American Board of Orthodontics objective grading system. He concluded that according to the OGS, Invisalign did not treat malocclusions as well as braces in this sample. Large anteroposterior discrepancies and occlusal contacts were not corrected efficiently by Invisalign. The ability to close spaces and correct anterior rotations and marginal ridge heights were some of the strengths of Invisalign.

Gu *et al* [19] evaluated Invisalign treatment effectiveness and efficiency compared with conventional fixed appliances using the Peer Assessment Rating index and concluded that both Invisalign and fixed appliances improved the occlusion. Invisalign patients finished treatment faster than those with fixed appliances. However, it appears that Invisalign may not be as effective as fixed appliances in achieving a precise treatment goal. They also concluded that treatment with Invisalign was finished on average 30% (5.7 months) faster than treatment with fixed appliances.

Rossini *et al* [40], in a systematic review titled periodontal health during clear Aligners treatment, concluded that periodontal health indices were significantly improved during Clear Aligner Therapy. Karkhanechi *et al* [41], in a study titled Periodontal status of adult patients treated with fixed buccal appliances and removable aligners over one year of active orthodontic therapy, concluded that treatment with fixed orthodontic appliances is associated with decreased periodontal status and increased levels of periodontopathic bacteria in comparison to treatment with removable aligners over the 12-month study duration.

Meithke and Brauner [21] assessed periodontal status using Gingival Index (GI) by Löe & Silness and the Papillary Bleeding Index (PBI) by Saxer & Mühlemann. Modified Plaque Index (PI) by Silness & Löe recorded plaque accumulation. The examination was completed with a measurement of the sulcus probing depth (SPD). They concluded that since all the teeth and parts of the keratinized gingiva are covered nearly all day during Invisalign treatment, the periodontal risk is lower than that associated with fixed lingual appliances. This may be due to the fact that aligners are removable, permitting unhindered oral hygiene. In contrast, the lingual tooth surfaces are very difficult to clean when fitted with a fixed appliance.

Aman *et al* [23] retrospectively studied the pre-treatment and post-treatment CBCT data of patients who had clear aligner therapy in their study titled apical root resorption during orthodontic treatment with clear aligners: A retrospective study using cone-beam computed tomography concluded that comprehensive treatment with clear aligners resulted in minimal root resorption. Sex, malocclusion, crowding, and post-treatment approximation to the cortical plates significantly affected the percentage of change in root length. Post-treatment approximation of root apices to the palatal cortical plate showed the strongest association for increased orthodontically induced inflammatory root resorption.

Conclusion

Even though there is inadequate evidence regarding the comparison of adverse effects and treatment durations of lingual orthodontic appliances and clear aligner therapy, various studies suggest that both forms of invisible orthodontic appliances have pros and cons of their own.

Where lingual orthodontic appliances are more prone to cause tongue pain, eating difficulties, and speech difficulties, clear aligner therapy causes comparatively more severe root

resorption and poor occlusal contacts by the end of the treatment.

When it comes to treatment duration, both the treatment modalities require a similar amount of time to correct similar malocclusions, but clear aligner therapy is dependent more on patient compliance.

Further studies are required to compare invisible orthodontic techniques for various parameters like efficacy, treatment duration, adverse effects, etc.

Conflict of Interest

The authors declare that there is no conflict of interest regarding this paper.

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