ASSESSMENT OF TOOTH MOVEMENT EFFICIENCY DURING CLASSICAL ORTHODONTIC AND CLEAR ALIGN THERAPY

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Abstract: The process of orthodontic tooth movement is initiated by applying forces to the teeth via particular appliances that orthodontists carefully choose, place, and activate based on the identified malocclusion. The response of the teeth and their supporting tissues to these forces involves a complex biological reaction, resulting in the movement of the teeth through the surrounding structures. Conventional orthodontic treatment utilizing fixed appliances facilitates tooth movement to treat different kinds of malocclusion by employing fixed components on the surfaces of teeth, including orthodontic bands, brackets, archwires, ligatures, and abutments. The popularity of aligners in orthodontic treatment has notably increased in recent years, especially among older individuals primary because of their aesthetic advantages, comfort, and the ease of maintaining oral hygiene compared to conventional fixed braces. Regarding the importance of this issue from a clinical perspective, and because this issue is underpinned by scientific literature, we have set the following aim for this study- to compare the movement of the crown and root of the tooth between the two studied groups (traditional braces therapy and aligner therapy) after a predetermined time frame from the beginning of treatment. To achieve the defined objectives, a clinical trial was conducted at the private dental office "ALJBI ORTODENT" in Tetovo. Total number of 360 teeth from 30 subjects suffering from primary crowding malocclusion were included in this study. The study population as categorized into two groups of 15 individuals each, as follows: (1)First group: 15 patients, a total of 180 teeth, from both genders, who will be treated with a fixed appliance, DentaurumRrooth 0.22. and (2) second group: 15 patients, a total of 180 teeth, of both genders, who will be treated using an aligner, Biolon 0.75.The post-treatment digital models and the final virtual treatment plan were exported from the software as STL files and subsequently imported into Geomagic Qualify® software for comparison of the final tooth positions. Variations were calculated and analyzed for statistical significance for each tooth in the mesial-distal dimensions. For $F=1.700$ and $p>0.05$ ($p=0.193$) there is no significant difference between the value of the mesial-distal direction of the teeth at the beginning of the study (To), one month after treatment (T1), three months after treatment (T3), treated with a fixed appliance and an aligner. Clear aligner therapy marks a notable progression in orthodontic care, providing benefits over conventional braces, including enhanced aesthetics, greater comfort, and improved oral hygiene. Research indicates that clear aligners are effective in addressing mild to moderate malocclusions, requiring fewer visits and shorter treatment times than traditional fixed appliances. Consequently, it is essential for clinicians to weigh the attributes of these two types of orthodontic devices when determining treatment options.
Keywords: Orthodontic 3D model; tooth movement; Orthodontic fixed appliances; Clear aligners; Geomagic software

1. INTRODUCTION

The process of orthodontic tooth movement is initiated by applying forces to the teeth via particular appliances that orthodontists carefully choose, place, and activate based on the identified malocclusion. The response of the teeth and their supporting tissues to these forces involves a complex biological reaction, resulting in the movement of the teeth through the surrounding structures.

By addressing and minimizing the unknown factors associated with treatment implementation, the variability in clinical outcomes can be reduced. On the other hand, the forces and moments produced during the various phases of orthodontic treatment are subject to controlled variables.

Conventional orthodontic treatment utilizing fixed appliances facilitates tooth movement to treat different kinds of malocclusion by employing fixed components on the surfaces of teeth, including orthodontic bands, brackets, archwires, ligatures, and abutments (Spirito et al. 2023). Consequently, comprehending the biomechanical principles and mechanisms involved in the activation of orthodontic appliances during each phase of tooth movement is crucial for optimizing the effectiveness of orthodontic treatment.

The popularity of aligners in orthodontic treatment has notably increased in recent years, especially among older individuals. This rise can be attributed to their aesthetic advantages, comfort, and the ease of maintaining oral hygiene compared to conventional fixed braces (Madariaga et al. 2020; Stefano et al. 2021). Today, aligners are effectively used to treat various types of malocclusions (Staderini et al. 2020; Dianiskova et al. 2022), thanks to

advancements in abutments, attachments, and aligning materials (Bucci et al. 2019; Stefano et al. 2019). These developments enable the performance of complex movements, including rotation and torque (D'Antò et al. 2022; Stefano et al. 2021).

The introduction of three-dimensional (3D) printing has brought about a significant transformation in dentistry, particularly in the orthodontic correction of malocclusion. While aligners appear to meet the criteria for an ideal orthodontic appliance, certain biomechanical limitations still need to be addressed (Patterson et al. 2021). The predictability of tooth movement is largely contingent upon various factors, including the types of teeth, the desired movements, and the characteristics of the arch, including its structure, thickness, and shape.

Furthermore, studies indicate that aligners provide benefits compared to fixed appliances, particularly in terms of segmented tooth movement and shorter treatment times (Buschang et al. 2014). Conversely, fixed appliances have shown greater efficacy in achieving proper occlusal contacts and managing tooth torque and rotation (Ke et al.2019). Nevertheless, advancements in technology have enabled the treatment of various complex malocclusions using aligners (D'Antò et al. 2023).

According to Smith et al. (2022), in non-extraction patients, only 0.4 of the prescribed movement for each mandibular incisor root tip was clinically achieved with the Invisalign system. Ren et al. (2022) also reported similar findings in a study involving patients who underwent double maxillary extraction of first premolar. Dai et al. (2024) conducted research on patients who had four first premolars extracted and were treated with aligners, revealing that deficits in crown movement resulted in more significant mesial tipping of the maxillary first molars and distal tipping of the maxillary canines than what was anticipated by the clinician's verification software.

The efficiency of tooth movement significantly impacts the establishment of treatment goals, the duration of treatment, and the associated costs. Erroneous predictions may necessitate extended treatment periods, lead to patient dissatisfaction, and increase the risk of relapse. Therefore, it is essential to evaluate the accuracy of tooth movement predictions and the effectiveness of clear aligners in achieving major tooth and root movements when compared to fixed orthodontic treatments.

The results some research indicated that treatment with clear aligners was more effective in terms of duration than treatment with braces. This conclusion is corroborated by Zheng et al. (2017) who found that clear aligners significantly reduced treatment duration compared to braces. It is important to emphasize that the effects are biggest at the biggening of the treatment (first six months).

According to Kravitz et al. (2009), patients experiencing simple malocclusions require an extra 4.8 months of treatment with aligners in comparison to conventional brackets, although the treatment and occlusal results after six months are similar. The study concluded that the device demonstrated the highest precision in achieving lingual displacement, averaging 47.1% accuracy, while egression and mesiodistal tilt were the least precise, with accuracies of 29.6% and 26.9%, respectively. The authors attribute this limitation to the fact that Invisalign® cannot provide a vertical pulling force on teeth.

Also, according to Simon et al.(2014) reported that a distalization of the upper teeth of at least 1.5 mm led to a highly accurate bodily movement of the teeth. The authors also discovered that the accuracy of this movement was increased when it was facilitated by tooth attachment.AlMogbel et al,(2023) noted that if the maximum activation over a two-week period is lowered from 0.5 mm to 0.25 mm or less, it is likely that precision and treatment efficacity will be enhanced

With regard to the importance of this issue from a clinical perspective, and because this issue is underpinned by scientific literature, the aim for this sudy was to compare the movement of the crown and root of the tooth between the two studied groups (traditional braces therapy and aligner therapy) after a predetermined time frame from the beginning of treatment.

2. MATERIAL AND METHOD

To achieve the defined objectives, a clinical trial was conducted at the private dental office specialized for orthodontics "ALJBI ORTODENT" in Tetovo, North Macedonia. Total number of 360 teeth from 30 subjects suffering from primary crowding malocclusion were included in this study. The study population, was aged from 14 to 16 years, include both males and females and categorized into two groups of 15 individuals each, as follows:

- First group: 15 patients, atotal of 180 teeth, from both genders, who will be treated with a fixed appliance, DentaurumRrooth 0.22.
- Second group: 15 patients, a total of 180 teeth, of both genders, who will be treated using an aligner, Biolon 0.75.

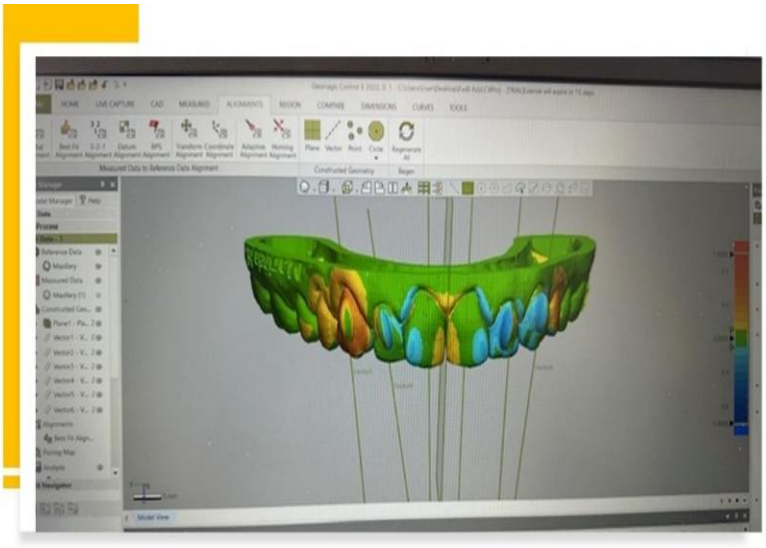
The following procedures and methodologies were implemented for all participants involved in the study:

- Collection of a comprehensive personal history;
- Clinical examination;
- Evaluation of a digital CT scan of the dental structures;

- Determining the necessity for orthodontic treatment based on the aesthetic criteria of the Index of Orthodontic Treatment Need (IOTN), as outlined by Bruck and Show (1989) and later modified by Richmond (1990) for an objective assessment of orthodontic treatment requirements. This index is also utilized to evaluate patient eligibility for orthodontic treatment within public health contexts (Sharma et al., 2012).
- Development of digital and final models for a virtual treatment plan.
- The post-treatment digital models and the final virtual treatment plan were exported from the software as STL files and subsequently imported into Geomagic Qualify® software for comparison of the final tooth positions. Variations were calculated and analyzed for statistical significance for each tooth in the mesial-distal dimensions.
- Laboratory protocol – order: selection and modification of various parameters.
- Digital protocol – treatment plan and design: Subsequently, the data from the scanned master model, which is cast in plaster from the patient's impression, will be transformed into an STL file.
- Installation of a fixed orthodontic appliance of the Dentaurum Rroth 0.22 type.
- Installation of an aligner (straightener) of the Biolon 0.75 type.
- Follow-up examinations were conducted in the first month, followed by assessments in the third and sixth months.

Planning, measurements, and simulations are executed on a detailed 3D representation of the teeth, which is initially generated from digital models created by scanning plaster models or through direct intraoral scans. Both intraoral scans and those captured by technical scanners are utilized (refer to Fig. No. 1). Serial 3D models acquired at different time points can be registered and consolidated into a single international coordinate system, facilitating the measurement of tooth mobility. The impact of therapeutic interventions over time has been assessed using various techniques and software tools designed for the digital 3D registration of virtual models and the quantification of tooth movement.

Figure No. 1. Illustrates the analysis of dimensional discrepancies by comparing a scanned object to a reference model. The extent of these deviations is depicted through a color gradient on the right, transitioning from blue to red. A negative deviation, characterized by distal movement, is represented in blue, indicating either an excess or a deficiency of material in the current model. Conversely, a positive deviation, denoting mesial movement, is shown in red. Deviations marked in green are considered negligible or absent, indicating proximity to the nominal tolerance.



Source: authors

3. RESULTS

Table No. 1. and Fig. No.1. show descriptive statistics of the values (limit values) of the mesial-distal direction in 48 teeth at the beginning of the study (To), one month after treatment (T1), three months after treatment (T3), treated

with a fixed appliance (0) and an aligner (1).For F=1.700 and p>0.05 (p=0.193) there is no significant difference between the value of the mesial-distal direction of the teeth at the beginning of the study, one month after treatment, three months after treatment, treated with a fixed appliance and an aligner.

In the Post Hoc Tests / Bonferroni test / analysis of the relation R1*Group; LS Meansfor p>0.05, no significant difference was determined in the displacement of teeth treated with a fixed appliance and aligner, between the values determined at the beginning of the study (T0), one month after treatment (T1), three months after treatment (T3).In Post Hoc Tests / Bonferroni test / analysis of the relation R1*Tooth*Group; LS Means / (Table No. 2.) a significant difference in tooth displacement was registered:

- The value of the mesial-distal direction of displacement during orthodontic treatment with an aligner for tooth 12 after three months of treatment (T3) -0.05 for p<0.001 (p=0.0005) is significantly greater than the initial value of the mesial-distal direction (To) -12.66.
- The value of the mesial-distal direction of displacement during orthodontic treatment with an aligner for tooth 12 after three months of treatment (T3) -0.05 for p<0.001 (p=0.0007) is significantly greater than the value of the mesial-distal direction after 1 month of treatment (T1) -12.41.Among the remaining teeth in the relation R1*Tooth*Group for p>0.05 there is no significant difference in the values of the mesial-distal direction.

Table No. 1. Descriptive statistics of the values (limit values) of the mesial-distal direction in 48 teeth at the beginning of the study (To), one month after treatment (T1), three months after treatment (T3), treated with a fixed appliance (0) and an aligner (1)

R1*group; LS Means;
Current effect: F(2, 48)=1,7006, p=,19339
Effective hypothesis decomposition

Cell No	Група	R1	DV_1 Mean	DV_1 Std.Err.	DV_1 -95,00%	DV_1 +95,00%	N
1	0	T0M-D direction	-5,10167	1,759301	-8,73269	-1,47065	24
2	0	T1 M-D direction	-4,73292	1,763317	-8,37222	-1,09361	24
3	0	T3 M-D direction	-5,17167	1,904962	-9,10331	-1,24002	24
4	1	ToM-D direction	-0,41167	1,759301	-4,04269	3,21935	24
5	1	T1 M-D direction	-0,38042	1,763317	-4,01972	3,25889	24
6	1	T3 M-D direction	0,67208	1,904962	-3,25956	4,60373	24

* fixed orthodontic appliance (0), Aligners (1)

Figure No. 2. Values (limit values) of the mesial-distal direction in 48 teeth at the beginning of the study (To), one month after treatment (T1), three months after treatment (T3), treated with a fixed appliance (0) and an aligner (1)

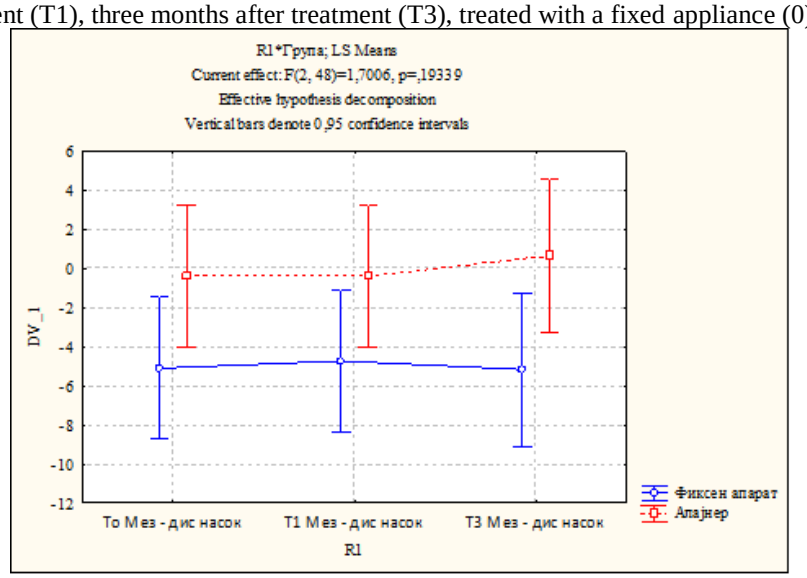


Table No. 2. Post Hoc Tests / Bonferroni test

Bonferroni test; variable DV_1; Probabilities for Post Hoc Tests Error: Between; Within; Pooled MS = 78,666, df = 25,838								
Cell No	Група	R1	{1} -5,10	{2} -4,73	{3} -5,17	{4} -0,41	{5} -0,38	{6} 0,67
1	0	T0 M-D direction		1,000000	1,000000	1,000000	1,000000	0,492498
2	0	T1 M-D direction	1,000000		1,000000	1,000000	1,000000	0,669071
3	0	T3 M-D direction	1,000000	1,000000		1,000000	1,000000	1,000000
4	1	To M-D direction	1,000000	1,000000	1,000000		1,000000	1,000000
5	1	T1 M-D direction	1,000000	1,000000	1,000000	1,000000		1,000000
6	1	T3 M-D direction	0,492498	0,669071	1,000000	1,000000	1,000000	

* Fixed orthodontic appliance (0), Aligners (1)

4. DISCUSSION

Orthodontic tooth movement is achieved by applying forces to the teeth through specific appliances that orthodontists select, position, and activate according to the malocclusion type. The teeth and their surrounding supportive tissues respond to these forces with a complex biological reaction, leading to the movement of the teeth through the supporting structures. By reducing the unknown factors involved in treatment implementation, the variability of clinical outcomes can be minimized. In contrast, the forces and moments generated during different phases of orthodontic treatment are governed by controlled variables.

Most fixed appliances are designed to deliver continuous forces. Continuous force is defined as a force that is sustained within certain intervals, ensuring that its intensity does not drop below the threshold necessary to stimulate cellular activity (including apposition and resorption) during orthodontic treatment. These forces are gentle, enabling consistent and uniform movement of the teeth over prolonged periods.

Aligners have gained popularity not only for their aesthetic appeal but also for their ability to enhance oral hygiene compared to traditional fixed orthodontic appliances. Nevertheless, from a biomechanical perspective, the two treatment modalities are not yet equivalent (D'Alessandro et al., 2020). Aligner therapy, which involves custom-made and removable appliances, is increasingly adopted in clinical settings as a more aesthetically pleasing and comfortable alternative to multi-attachment systems (Macri et al., 2023). Over time, there has been a shift towards more aesthetically pleasing orthodontic appliances, driven by technological advancements and a growing number of adults seeking orthodontic care.

Borda et al. conducted a study in 2020 to compare the efficacy and efficiency of clear aligners with fixed appliances in treating mild malocclusions in adolescents. The research analyzed retrospective data from a private practice, which included 26 patients in each treatment group, either receiving Invisalign or Damon braces. The findings revealed that the aligner group had significantly fewer discrepancies from the ideal treatment outcome (CRE: 30.1 vs. 37.0; $P < .01$). Furthermore, aligner patients attended fewer appointments (13.7 compared to 19.3; $P < .0001$), had a reduced number of emergency visits (0.8 vs. 3.6; $P < .0001$), and completed their treatment in a shorter time frame (16.9 months vs. 23.4 months; $P < .0001$). Thus, while clear aligners were found to be equally effective as fixed appliances for mild malocclusions, they offered enhanced efficiency in the treatment process.

According to the results from this study, there is no significant difference between the value of the mesial-distal direction of the teeth at the beginning of the study, one month after treatment, three months after treatment treated with a fixed appliance and an aligners. This findings are similar to the data presented by numerous studies did not found the statistically significant difference between two appliances (Li et al, 2015; Hennessy et al, 2016; Gu et al, 2017; Laneti et al, 2018). Other studies verified that clear aligners could not treat malocclusion as well as braces. (Djeu et al, 2005; Kuncio et al, 2007; Pavoni et al, 2011; Grünheid et al, 2016)

Nonetheless, additional studies are necessary to fully assess their effects on oral health, particularly in more complicated cases, and to analyze the clinical efficacy of various aligner brands.

5. CONCLUSIONS

Clear aligner therapy marks a notable progression in orthodontic care, providing benefits over conventional braces, including enhanced aesthetics, greater comfort, and improved oral hygiene. Research indicates that clear aligners are effective in addressing mild to moderate malocclusions, requiring fewer visits and shorter treatment times than

traditional fixed appliances. Consequently, it is essential for clinicians to weigh the attributes of these two types of orthodontic devices when determining treatment options.

BIBLIOGRAPHY

AlMogbel, A. (2023). Clear Aligner Therapy: Up to date review article. *Journal of orthodontic science*, *12*(1), 37.

Borda, A. F., Garfinkle, J. S., Covell Jr, D. A., Wang, M., Doyle, L., Sedgley, C. M. (2020). Outcome assessment of orthodontic clear aligner vs fixed appliance treatment in a teenage population with mild malocclusions. *The Angle Orthodontist*, *90*(4), 485-490.

Bucci R., Rongo R., Levatè C., Michelotti A., Barone S., Razionale A.V., D'Antò V.(2019). Thickness of Orthodontic Clear Aligners after Thermoforming and after 10 Days of Intraoral Exposure: A Prospective Clinical Study. Prog Orthod 9;20(1):36.

Buschang, P.H. Shaw, S.G., Ross, M. Crosby, D., Campbell, P.M. (2014) Comparative Time Efficiency of Aligner Therapy and Conventional Edgewise Braces. Angle Orthod., 84, 391–396.

D'Alessandro Ch A., D'Anto V., Razionale V.A., Alessandri-Bonetti G., (2020). Integrating CBCT and Virtual Models for Root Movement with Clear Aligners. www.jco-online.com

D'Antò V., Bucci R., De Simone V., Ghislanzoni H L., Michelotti A., Rongo R.(2022). Evaluation of Tooth Movement Accuracy with Aligners: A Prospective Study. Materials (Basel) 4;15(7):2646.

D'Antò, V.; Valletta, R.; De Simone, V.; Pisano, M.; Stefano M., (2023) Clear Aligners Treatment of Class III Subdivision with an Extraction of a Lower Bicuspid. Int J Environ Res Public Health. 20(4): 3550.

Dai, F., Sang, Y., Zeng, J., Wang, H., Pan, Y., Zhao, J., Xu, T., Shu, G. (2024). How accurate is predicted root movement achieved in four first-premolar extraction cases with Invisalign?. *Orthodontics & craniofacial research*, *27*(6), 985–995. https://doi.org/10.1111/ocr.12842

Dianiskova S., Rongo R., Buono R., Franchi L., Michelotti A., D'Antò V.(2022). Treatment of mild Class II malocclusion in growing patients with clear aligners versus fixed multibracket therapy: A retrospective study. OrthodCraniofac Res 25(1):96-102.

Djeu, G., Shelton, C., Maganzini, A. (2005). Outcome assessment of Invisalign and traditional orthodontic treatment compared with the American Board of Orthodontics objective grading system. *American journal of orthodontics and dentofacial orthopedics*, *128*(3), 292-298.

Grünheid, T., Gaalaas, S., Hamdan, H., Larson, B. E. (2016). Effect of clear aligner therapy on the buccolingual inclination of mandibular canines and the intercanine distance. *The Angle Orthodontist*, *86*(1), 10-16.

Gu, J., Tang, J. S., Skulski, B., Fields Jr, H. W., Beck, F. M., Firestone, A. R., ... Deguchi, T. (2017). Evaluation of Invisalign treatment effectiveness and efficiency compared with conventional fixed appliances using the Peer Assessment Rating index. *American Journal of Orthodontics and Dentofacial Orthopedics*, *151*(2), 259-266.

Hennessy, J., Garvey, T., Al-Awadhi, E. A. (2016). A randomized clinical trial comparing mandibular incisor proclination produced by fixed labial appliances and clear aligners. *The Angle Orthodontist*, *86*(5),706-712.

Ke, Y. Zhu, Y. Zhu, M. (2019). A Comparison of Treatment Effectiveness between Clear Aligner and Fixed Appliance Therapies. BMC Oral Health 23;19(1):24.

Kravitz, N. D., Kusnoto, B., BeGole, E., Obrez, A., Agran, B. (2009). How well does Invisalign work? A prospective clinical study evaluating the efficacy of tooth movement with Invisalign. *American Journal of Orthodontics and Dentofacial Orthopedics*, *135*(1), 27-35.

Kuncio, D., Maganzini, A., Shelton, C., Freeman, K. (2007). Invisalign and traditional orthodontic treatment postretention outcomes compared using the American Board of Orthodontics objective grading system. *The Angle Orthodontist*, *77*(5), 864-869.

Lanteri, V., Farronato, G., Lanteri, C., Caravita, R., Cossellu, G. (2018). The efficacy of orthodontic treatments for anterior crowding with Invisalign compared with fixed appliances using the Peer Assessment Rating Index. *Quintessence International*, *49*(7).

Li, W., Wang, S., Zhang, Y. (2015). The effectiveness of the Invisalign appliance in extraction cases using the the ABO model grading system: a multicenter randomized controlled trial. *International journal of clinical and experimental medicine*, *8*(5), 8276.

Macrì, M., Medori, S., Varvara, G., Festa, F. (2023). A digital 3D retrospective study evaluating the efficacy of root control during orthodontic treatment with clear aligners. *Applied Sciences*, *13*(3), 1540.

Madariaga A.C.P., Bucci R., Rongo R., Simeon V., D'Antò V., Valletta R.(2020). Impact of Fixed Orthodontic Appliance and Clear Aligners on the Periodontal Health: A Prospective Clinical Study. Dent J (Basel) 2;8(1):4.

Patterson D. B., Foley F. P., Ueno H., Mason A. Sh., Schneider P P., Kim B K. (2021). Class II malocclusion correction with Invisalign: Is it possible? Am J Orthod Dentofacial Orthop 159(1):e41-e48.

Pavoni, C., Lione, R., Laganà, G., Cozza, P. (2011). Self-ligating versus Invisalign: analysis of dento-alveolar effects. *Annali di stomatologia*, *2*(1-2), 23.

Ren, L., Liu, L., Wu, Z., Shan, D., Pu, L., Gao, Y., ... Lai, W. (2022). The predictability of orthodontic tooth movements through clear aligner among first-premolar extraction patients: a multivariate analysis. *Progress in Orthodontics*, *23*(1), 52.

Simon, M., Keilig, L., Schwarze, J., Jung, B. A., Bourauel, C. (2014). Treatment outcome and efficacy of an aligner technique–regarding incisor torque, premolar derotation and molar distalization. *BMC oral health*, *14*, 1-7.

Smith, J. M., Weir, T., Kaang, A., Farella, M. (2022). Predictability of lower incisor tip using clear aligner therapy. *Progress in orthodontics*, *23*(1), 37.

Spirito F Di.,D'Ambrosio F., Cannatà D., D'Antò V., Giordano F. and Stefano M., (2023). Impact of Clear Aligners versus Fixed Appliances on Periodontal Status of Patients Undergoing Orthodontic Treatment: A Systematic Review of Systematic Reviews. Healthcare .; 11(9): 1340.

Staderini E., Patini R., Meuli S., Camodeca A., Guglielmi F., Gallenzi P.(2020). Indication of clear aligners in the early treatment of anterior crossbite: A case series. Dental Press J Orthod 25(4):33-43.

Stefano M., Amato A. Faccioni P., Landolo A., Amato M.,Rongo R.,(2021). The perception of COVID-19 among Italian dental patients: An orthodontic point of view. Prog Orthod 7;22(1):11.

Stefano M., Martini M., Bordegoni M., Razionale A.V.(2021). Predictability of Root Movements Using Virtual Root Setup in a Patient with Periodontal Disease Treated with Clear Aligners. Open Dent. J. 15:605–611.

Stefano M., Rongo R., Bucci R., RazionaleV A., Valletta R., D'Antò V., (2019).In vitro cytotoxicity of different thermoplastic materials for clear aligners. Angle Orthod. ;89:942–945.

Zheng, M., Liu, R., Ni, Z., Yu, Z. (2017). Efficiency, effectiveness and treatment stability of clear aligners: A systematic review and meta-analysis. *Orthodontics & craniofacial research*, *20*(3), 127-133.