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Clinical evaluation of the tooth movement in aligner orthodontic treatment with and without acceleration devices: Part 1

Key words *aligner, dental movement acceleration, tooth movement*

Objective: *The purpose of this study was to evaluate the efficacy of AcceleDent and Orthopulse in accelerating the orthodontic tooth movement of aligner treatment.*

Materials and methods: *In total, 30 patients without skeletal malocclusion were randomly assigned to three groups: the 7 days group – patients were instructed to change aligners every 7 days, without any accelerating devices; the AcceleDent group – patients were instructed to change aligners every 6 days, with the AcceleDent accelerating device; and the Orthopulse group – patients were instructed to change aligners every 5 days, with the Orthopulse accelerating device. Dental information was collected upon pretreatment, aligner 10 and aligner 20 by iTero scanner as T0, T1 and T2; treatment expected dental information was collected upon aligner 10 and aligner 20 by Clincheck as T1' and T2'. Data was imported and analysed by Geomagic qualify 2013, according to the peer assessment rating (PAR) method.*

Results: *No statistical difference was found among those groups in both the maxillary and mandibular arches. The Orthopulse group had the highest tooth moving efficiency among the three groups for its shortest wearing duration and the least difference was between iTero scanner information and Clincheck Software Information, although the difference is not statistically significant.*

Conclusion: *AcceleDent and Orthopulse accelerating devices did not show an observable effect with statistical significance.*

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Introduction

Orthodontic treatments with aligners, the steadily improving possibilities in computer image processing technology and the combination of both with the three-dimensional moulding technology in the late 1990s have gradually been accepted by more and more orthodontic doctors worldwide[1]. It is also a hotspot for orthodontic doctors to accelerate tooth movement, improve efficiency and shorten treatment time.

At present, there are many kinds of methods to accelerate tooth movement, which can be classified into four categories: the operation method, physical method, medicine, and the gene method. As for the molecular mechanism of the accelerated tooth movement, no matter which method is adopted, it is achieved by influencing a certain part of the metabolic pathway of periodontal tissues, thereby affecting the bone formation and bone fracture function, accelerating bone remodelling, so as to accelerate the speed of tooth movement[2]. Among various methods, laser and vibration treatments by physical method are safe, non-invasive, relatively low cost and easy to use, and have been widely used in traditional fixed orthodontic treatment. However, little research has been carried out on the application of orthodontic tooth accelerating devices in the invisible orthodontic treatment at home and abroad. In the present study, two common kinds of orthodontic tooth movement devices AcceleDent (OrthoAccel Technologies, USA) and Orthopulse (Biolux Research, Canada) were selected to compare the clinical effect of both in accelerating tooth movement in the invisible orthodontic treatment.

Materials and methods

There were 30 cases of adult patients with invisible orthodontic treatment. Orthodontic treatment plans were made according to a routine clinical examination, cephalometric analysis, orthopantomography, and model analysis. The same dental practitioner planned the staging in all cases. The staging was usual staging suggested by Align Technology, and not limited to certain teeth. Distalization was performed in the upper arch to gain space for alignment and few fillings; in the lower anterior region IPR was added to align and avoid excessive protrusion or expansion and therefore to avoid potential risk of decalcification.
Inclusion criteria were:

1. Patients with permanent dentition, without previous history of denture restoration, without the habit of unilateral mastication;
2. Only with the removal of third molar orthodontic or non-extraction orthodontic treatment;
3. Patients with an invisible appliance only, but without other appliances;
4. Patients who had good oral hygiene habits, patients with normal root development, morphology, periodontal and alveolar bone;

Patients who were informed and agreed to enter the study. Exclusion criteria were: patients with bony deformity, who had previous history of surgery in the maxillofacial soft tissue, and who applied other appliances in the course of treatment.

Grouping (Fig 1)

In total, 30 cases were randomly assigned to the three groups as follows:

7 days

Participants were asked to change aligners every 7 days, without any accelerating appliances.

AcceleDent

Participants were asked to change aligners every 6 days, with the AcceleDent accelerating appliance.

Orthopulse

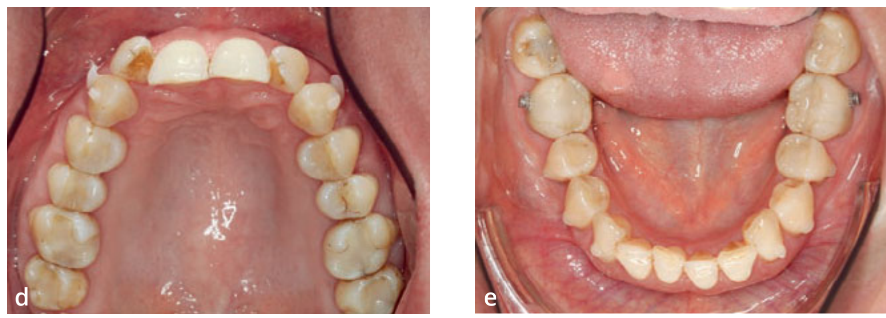
Participants were asked to change aligners every 5 days, with the Orthopulse accelerating appliance.

Data was collected at the following time points (Figs 2 – 9)

T0: The iTero scanner collected the pretreatment dental information.
T1: On aligner 10, the iTero scanner scanned the intraoral situation.
T1′: On aligner 10, the expected situation on Clincheck was collected.
T2: On aligner 20, iTero scanner scanned the intraoral situation.
T2′: On aligner 20, the expected situation on Clincheck was collected.

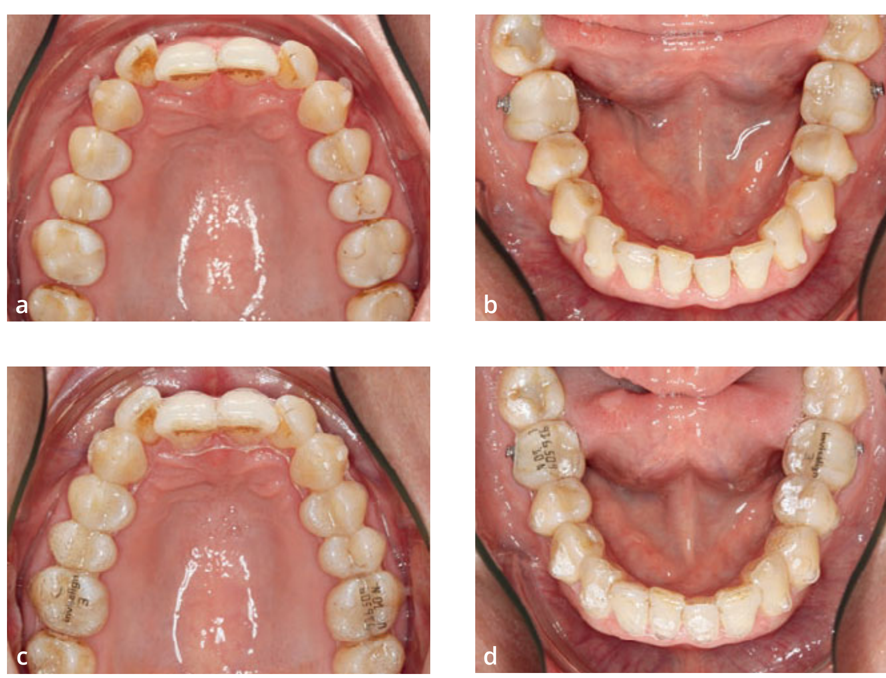
Measurements of the virtual dental models

All the digital dental models were standardised, denoised and added with base using a 3-shape analyser (3-shape, Denmark), and then imported and analysed by Geomagic qualify 2013 (Geomagic, USA). We set the occlusal plane through the mesial adjacent point of the upper central incisors and upper first molars, and then measured the shortest distance between adjacent points and the occlusal plane (mm), according to the peer assessment rating (PAR) method (Fig 10).



Figs 1a to e The patient's pretreatment dental information.

Figs 2a to c The patient's stage 10 dental information.



Figs 3a to d The patient's stage 10 dental information.

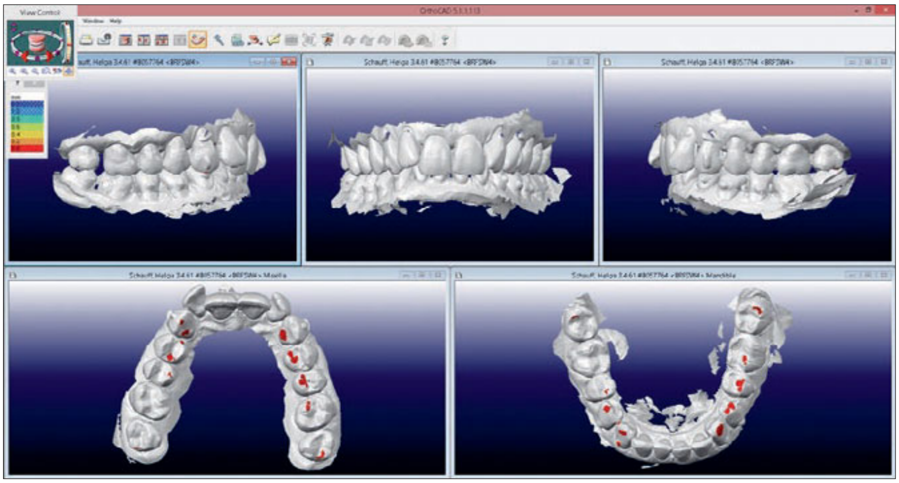


Fig 4 The patient's stage 10 dental information by the iTero scanner.

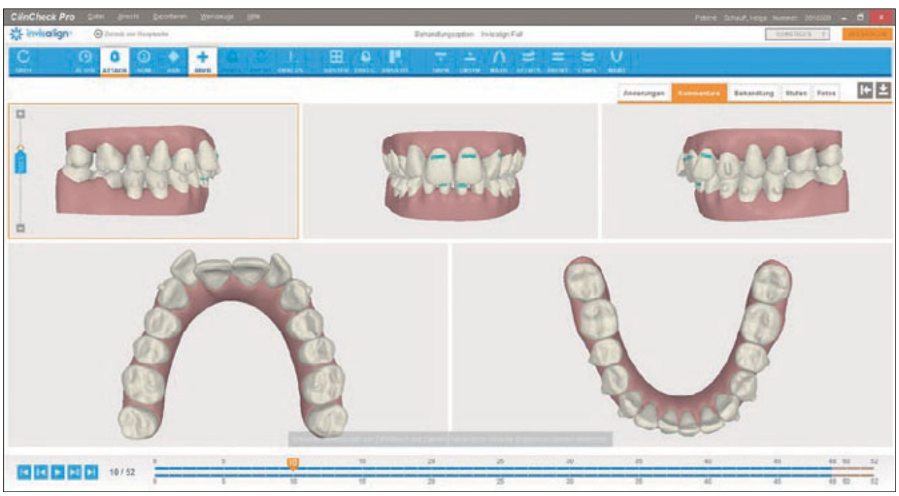


Fig 5 The patient's stage 10 dental information by Clincheck Software.

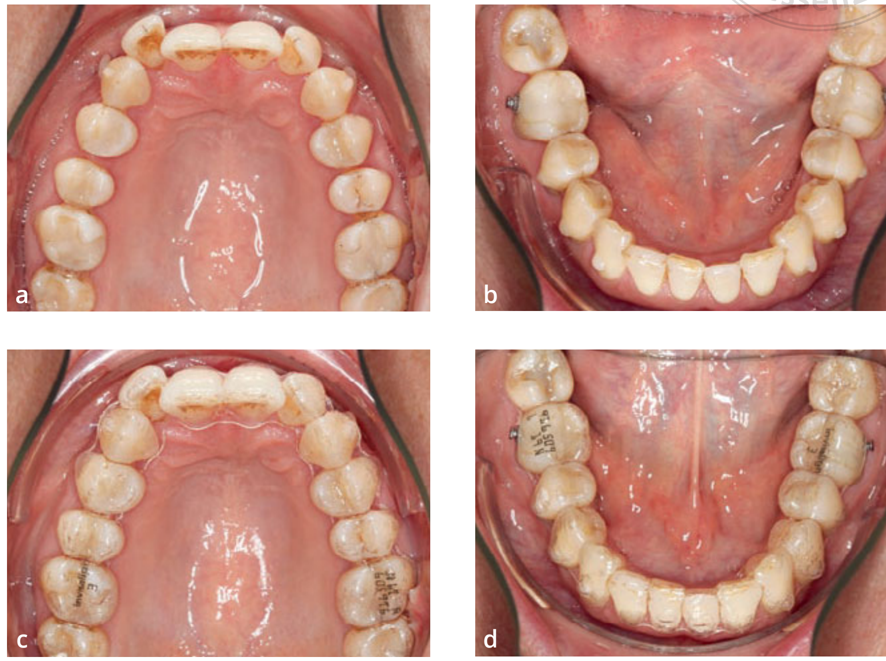
Figs 6a to c The patient's stage 20 dental information.

Irregularity index of all the time points, i.e. T0, T1, T1′, T2 and T2′, was calculated. The absolute value of difference between T1′ and T1, T2′ and T2 was recorded as shown in Figs 12a to 12c. The statistics data was analysed using one-way ANOVA with SPSS 23.0.

Results

Dental irregularity before treatment (Fig 11a)

Before treatment, the irregularity index of the maxillary arch was 8.02 ± 6.66, 4.35 ± 4.96, and 7.44 ± 6.50 for 7 days, for the AcceleDent and Orthopulse groups, respectively. In the mandibular arch, the index was 7.50 ± 6.52, 8.98 ± 7.90



Figs 7a to d The patient's stage 20 dental information.

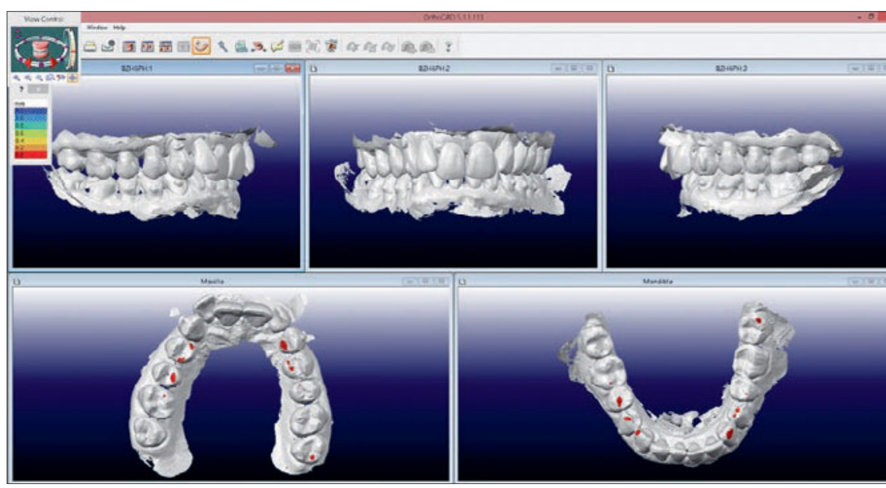


Fig 8 The patient's stage 10 dental information by iTero scanner.

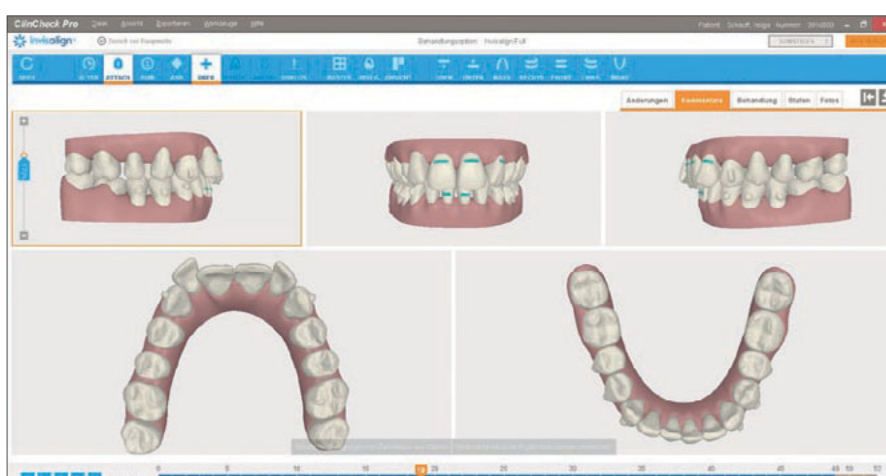


Fig 9 The patient's stage 10 dental information by the Clincheck Software.

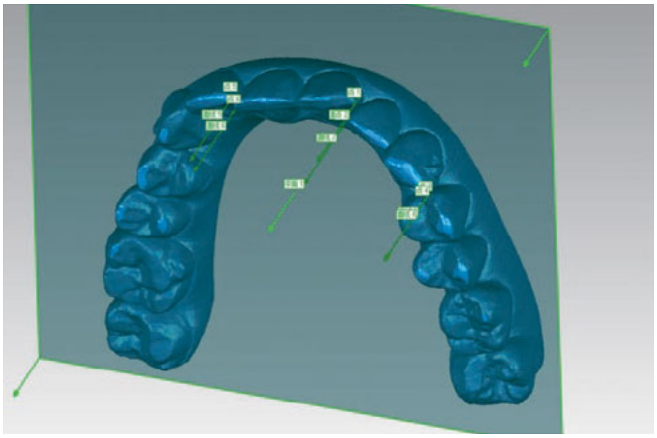


Fig 10 Measurement of the scanned model.

and 6.34 ± 4.51 respectively. No statistical difference was found among those groups.

Difference between expected and actual tooth movement (Fig 11b)

The absolute value of difference between T1' and T1, T2' and T2 revealed the difference between expected (Clincheck model) and actual (Scan model) tooth movement, and thus the tooth-moving efficiency on time points T1 and T2.

The difference between the scan model and the ClinCheck models of the maxillary arch through stages 1 to 10 was 2.14 ± 2.99, 1.52 ± 1.25 and 0.89 ± 0.90 for 7 days, AcceleDent and Orthopulse group, respectively. In the mandibular arch, the difference was 0.59 ± 0.84, 0.42 ± 0.38 and 1.06 ± 1.31 respectively. No statistical difference was found among those groups.

The difference between the scan and ClinCheck models of the maxillary arch through stages 11 to 20 was 1.8 ± 1.94, 1.07 ± 0.97 and 0.81 ± 1.36 for 7 days, for the AcceleDent and Orthopulse groups, respectively. In the mandibular arch, the difference was 1.21 ± 1.05, 0.87 ± 1.54 and 1.08 ± 1.70 respectively. No statistical difference was found among those groups (Fig 11c). Figures 12a to c show the individual irregularity index difference of the 7 days, AcceleDent and Orthopulse groups, respectively.

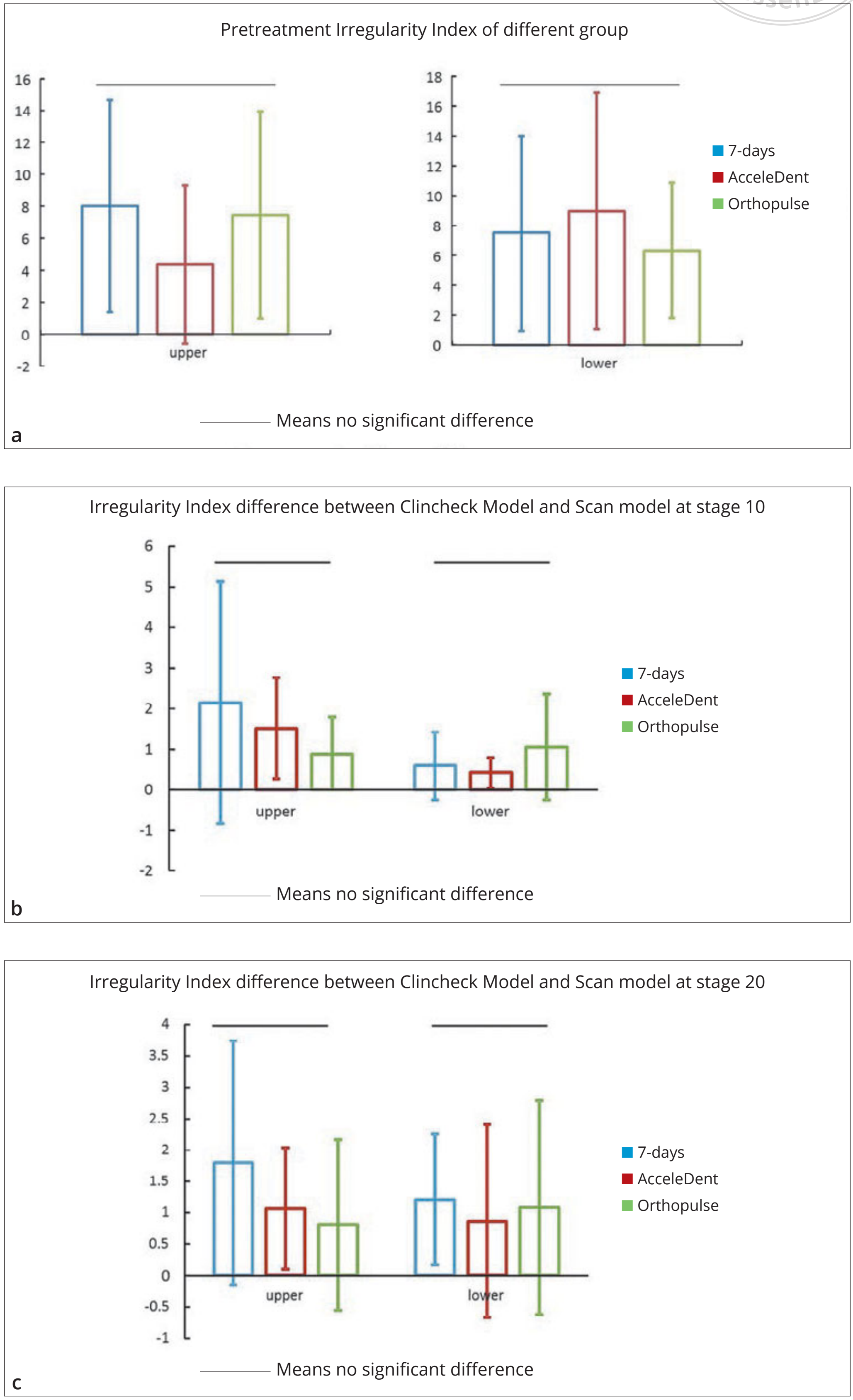
Discussion

Aligner treatment has many characteristics and advantages, and its indications are still expanding. It should be noted that in clinical practice, there will be some cases where the appliance might not perfectly fit the patients' teeth during treatment. The most common reason is that the real movement of the teeth is less than the amount of tooth movement planned in the Clincheck Software. In cases of lack of aligner fitting, changing treatment planning or adding additional features such as attachments might help to obtain better aligner fitting and therefore better results of planned movements. Meanwhile, even if the treatment process is going well, it is also expected to accelerate the orthodontic rate and shorten the course of treatment for both the orthodontist and the patient. Not only that, shortening the duration of treatment can also improve patient compliance[3], reduce pain[4], decrease the incidence of caries[5], benefit periodontal health[6] and depress the risk of root resorption[7].

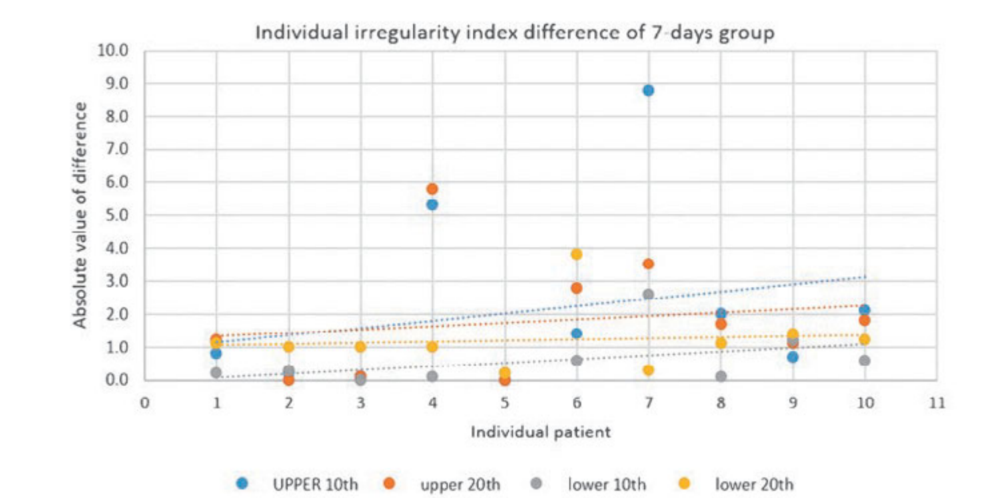
In the previous study of the therapeutic efficacy of invisible orthodontic correction, a method for direct measurement of model or model superposition is generally used to measure the changes of the maxillary and mandibular teeth. Model superposition often needs to establish a unified reference system, such as the designation of the posterior teeth without any movements[8], palatine folds[9], or reconstructed jaw with cone beam computed tomography (CBCT)[10], etc. However, there are some limitations with respect to previous approaches.

For example, in the case of posterior teeth movement, it cannot be used as a reference system; the overlap of palatal folds requires the acquisition of a complete palatal image and can only be applied to the maxillary model. Furthermore, CBCT requires an additional dose of irradiation and a more complex overlap process.

In this study, the use of the digital model of the PAR index in the measurement of the uneven index has certain advantages: Studies have shown that the PAR index can be used to evaluate the severity and changes of malocclusion, the outcome of orthodontic treatment, and the stability of curative effects[11]. Simultaneously, Mayers et al proposed that it is more effective and reliable to measure the PAR index with a digital dental model[12]. Significantly, the PAR index can only evaluate the tooth arrangement of the model, but cannot reflect the degree of deformity and improvement of the bone. However, in this study, only skeletal Class I cases were selected and cases with bone deformity were excluded. Therefore, the measurements of PAR index based on the digital dental model can well reflect the difference



Figs 11a to c a) Dental irregularity before treatment; b) The difference between expected and actual tooth movement of stage 10; c) The difference between the expected and actual tooth movement of stage 20.



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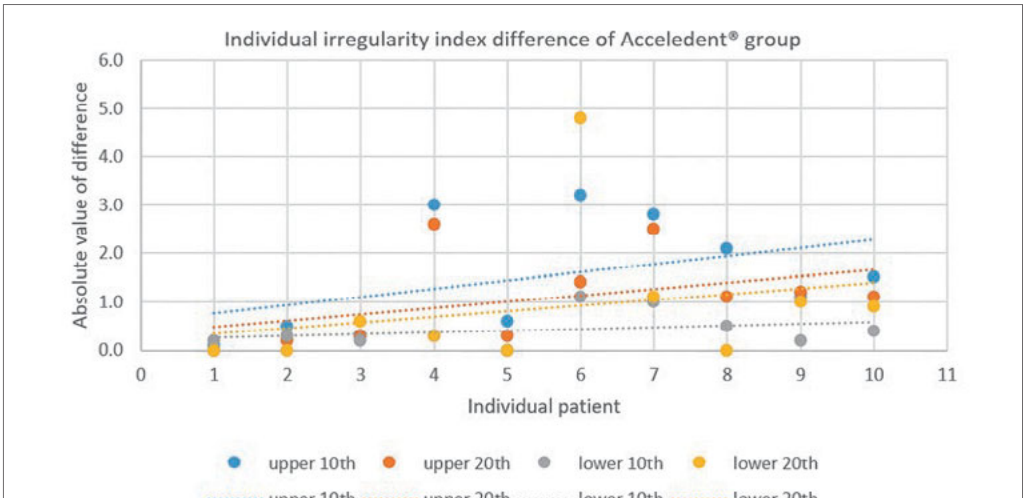

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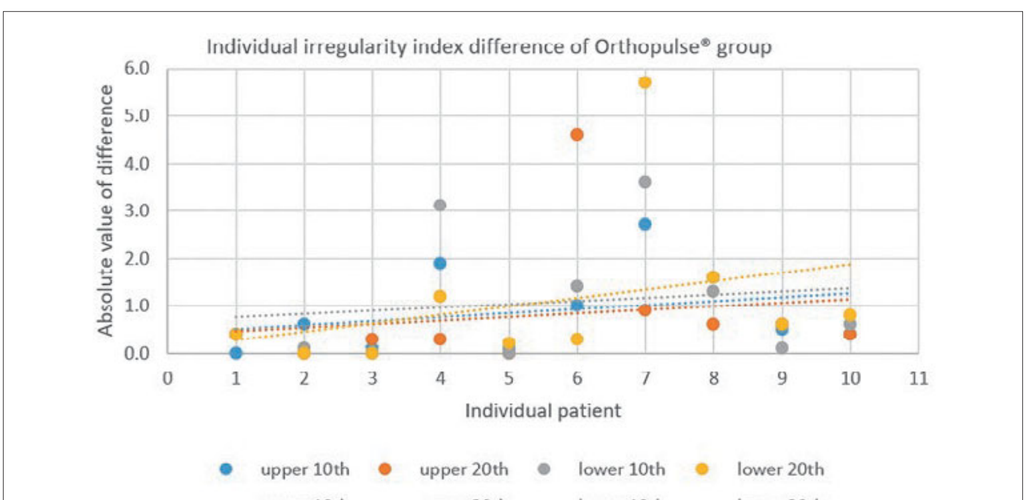

c

Figs 12a to c The individual irregularity index difference of the 7-days, AcceleDent and Orthopulse groups. Legend of x-axis: Individual patient (Patients 1 to 10); Legend of y-axis: The absolute value of difference between T1' and T1, T2' and T2 (stage 10, stage 20; maxillary and mandibular arch) – which revealed the difference between expected (ClinCheck Software model) and actual (Scan model) tooth movement.

of tooth movement in the treatment, and contribute to the reduction of patients' exposure dose without the performance of CBCT.

This study used the two kinds of orthodontic tooth movement device – AcceleDent and Orthopulse – respectively. In order to explore the clinical effect of both, this study measures the 7 days, AcceleDent, Orthopulse groups respectively before treatment and there is no statistical difference between the irregularity indexes among those groups before treatment. This proves that the case complexity of the three groups was generally identical.

The principle of the AcceleDent orthodontic tooth movement- accelerating device is low intensity pulse vibration. Scholars have proposed a possible mechanism related to the acceleration of tooth movement: it can act on the blood vessels to increase the synthesis of angiogenesis-related cytokines, increase blood flow, and improve blood supply[13], which can also increase the secretion of platelet-derived growth factor, induce the differentiation and maturation of osteoblasts, and indirectly affect osteoclasts.

Furthermore, by acting upon bone derived cell, it may stimulate the synthesis and secretion of a series of cytokines from bone derived cells; meanwhile, its micro-mechanical massage effect can also act on the cell membrane, causing the cell membrane permeability changes and ion channel changes in cell membrane, thereby activating cell mitosis, accelerate the process of bone remodelling[14]. At the same time, it can stimulate the proliferation and differentiation of bone-derived cells by enhancing the expression of some specific genes. In addition, acting on the enzymatic reaction, it can affect the bone remodelling by promoting the formation of calcified scaffolds and producing thermal effects. The internal mechanism of a series of dental acceleration devices designed based on the principle of vibration may also be related to the above four points, including an electric toothbrush[15]. Studies have shown that vibratory stimulation also has the effect of relieving pain after orthodontic treatment[16,17]. The principle of the Orthopulse orthodontic tooth movement accelerating device is low-level laser therapy (LLLT), which has a series of biological effects on cells and tissues. When exposed to LLLT, the red light or infrared light is absorbed by cytochrome C oxidase in the cell respiratory chain. In addition, the biological reaction is produced in the cell[18], which leads to the synthesis of substances such as ATP, RNA and proteins[19].

Previous studies have documented that a laser is used to accelerate the tooth movement by increasing the number and function of osteoblasts and osteoclasts, but the specific mechanism is not clear. The effect of LLLT is suggested to be correlated with its wavelength, pulse frequency, pulse width, peak power, irradiation distance, irradiation time, energy density and other relevant parameters in application. LLLT parameters setting are not the same in different studies; the results are not the same accordingly[20-21].

Currently, the clinical effect of the two kinds of orthodontic tooth movement devices in fixed appliances remains controversial[22-23].

From stages 1 to 10 and from 11 to 20, the difference between the expected and actual tooth movement of the maxillary arch in the Orthopulse group is smallest, while that of the 7 days group is largest. Although the wearing duration was shortest among the three groups, the tooth movement difference was the least for Orthopulse group, which means this group may have the highest tooth-moving efficiency, similar to Kau's study results[24]. A recent randomised controlled clinical trial found that LLLT in orthodontic treatment is an effective way to accelerate tooth movement[25]. Similarly, Woodhouse et al also pointed out that the application of fixed rectification Orthopulse of LLLT method can reduce the treatment time, but using the vibration method cannot significantly reduce fixed appliance treatment time[26]. However, the difference is not statistically significant, thus definite clinical implications cannot yet be proposed.

The difference between expected and actual tooth movement of the mandibular arch is less regular. From stages 1 to 10, the sequence from smallest to largest is AcceleDent, the 7 days group, and Orthopulse; however, from stages 11 to 20, the sequence is AcceleDent, Orthopulse and the 7 days group. The difference of average values among the three groups is less obvious than the maxillary arch, and again no statistical significance is found. This result may be attributed to the high bone density of the mandibular arch, and thus accelerating appliances cannot work at full capacity. It has been reported in other studies: Kau's study of AcceleDent found that for orthodontic treatment with the AcceleDent orthodontic tooth movement device, mandibular movement within 28 days was 2.1 mm and maxillary movement was 3 mm[27.]. Pavlin and others in the cases of tooth extraction in the application of orthodontic tooth movement speed device also found a similar situation[28], the speculation may be associated with the different structures of the maxilla and mandible. The reason and mechanism need to be further identified and discussed. It is well known that there is a great variation in rates of tooth movement between individuals, which may confound this study and others that aim to show a faster rate of tooth movement between study groups. Additional studies with larger patient data need to be performed to find further results in detail.

Conclusions

Neither the AcceleDent nor Orthopulse accelerating appliances showed an observable effect with statistical significance.

Acknowledgements

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