Доклади на Българската академия на науките
Comptes rendus de l'Académie bulgare des Sciences
Tome 76, No 7, 2023

MEDICINE
Oral medicine

COMPARATIVE ANALYSIS OF THE TREATMENT RESULTS WITH DENT@LIGN DIGITAL ALIGNERS AND THE VIRTUAL TREATMENT PLAN

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Received on August 31, 2020
Presented by D. Damianov, Member of BAS, on September 29, 2020

Abstract

The aim of the present study is to evaluate the results of the treatment with DENT@LIGN digital aligners by comparative analysis between printed virtual 3D motivational models, obtained from the virtual treatment plan, and conventional plaster casts, from the end of orthodontic treatment.

We measured and evaluated 136 (69 from the upper and 67 from the lower dental arch) conventional plaster casts of 72 patients and 3D printed virtual motivational models of the same patients. The obtained data was evaluated statistically.

The results from the comparative analysis showed high coincidence of the treatment results with DENT@LIGN digital aligners and the virtual treatment plan. The data showed insignificant differences between conventional plaster casts and 3D digital models in the measured parameters.

This gave us the reason to believe that the virtual treatment planning and motivational models correspond to the achieved clinical results and are an overall reliable method for treatment planning.

Key words: aligners, orthodontics, virtual treatment plan

Introduction. Digital technologies are present in every aspect of the orthodontic treatment. In addition to the storage of patients' information, today a virtual treatment plan (setup) and a transfer of this plan is performed with

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DOI:10.7546/CRABS.2023.07.16

digitally assisted appliance production. Nowadays we could use virtual 3D models and CAD/CAM technology for the production of aligners, trays for indirect positioning of braces, individually made braces and archwires bent by a robot [1–3].

Treatment planning with virtual setup allows us to be more accurate in the prognosis and to plan the necessary procedures, such as the amount of IPR. We have the opportunity to see the models corresponding to the final result of the treatment even before it has started.

We call the 3D models, that represent the end of the treatment "motivational models". They are created with the help of the ZUB Studio software tool and the virtual setup. The inclusion of motivational models in the motivation protocol of patients in need of orthodontic treatment is an innovative method that increases the ratio of initial examinations/started treatments and makes patients more cooperative during long-term orthodontic treatment [4].

If the information obtained from the motivational models corresponds to the clinical results at the end of the treatment, that would give us additional certainty for the treatment with aligners [5].

The aim of this study is to evaluate the results of the treatment with DENT@LIGN digital aligners by comparative analysis between 3D printed virtual motivational models, obtained by virtual setup, and conventional plaster casts from the end of orthodontic treatment.

Materials and methods. One hundred and thirty-six (69 from the upper and 67 from the lower jaw) conventional plaster casts from the end of the orthodontic treatment of 72 patients and 3D printed virtual motivational models of the same patients, showing the digitally planned end of the virtual setup, were measured and evaluated.

The plaster casts were obtained from an accurate impression of the upper and lower jaw with silicone material. The models were checked for inaccuracies of the surface of the teeth and the soft tissues. The tested plaster casts separately and in occlusion were scanned with a 3Shape Trios 3D scanner. The scanner was calibrated before use. 3D data is generated and used to create CAD models. The latter are saved in 3D format as STL (Standard Tessellation Language) files. The models were manipulated using CAD packages for digital simulation of a treatment planning. The initial digitized models and the models showing the virtual result after making a setup are recorded and systematized by date and type according to the methodology "ONE PATIENT – ONE FILE" in Zub Studio. Zub Studio is a software product that allows application for operating systems MAC, LINUX, Windows XP, 7, 8, 10 versions with an interface in Bulgarian. After confirmation from the clinician and the patient of the virtualized visualization simulation, showing the displacements of the teeth in the dental arches and occlusion and size and location of interproximal enamel reduction, the digital models are saved in file format in Zub Studio and/or sent to a printer device.

The comparative analysis included measurements of the anterior length of

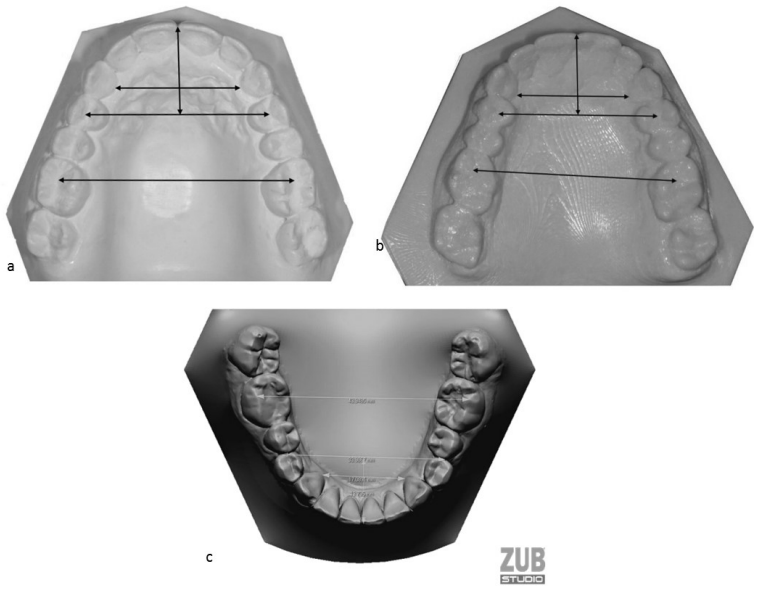


Fig. 1. Zub Studio – measurements of set parameters from the model analysis on: a) plaster cast, b) 3D printed motivational model, and c) control on 3D digital model

the dental arch in the upper and lower jaw (Lo and Lu), intercanine width (CC) [6], interpremolar width (PP) and intermolar width (MM) [7] made on conventional plaster casts from the end of the orthodontic treatment (S) and 3D printed motivational models (DLNM), obtained from the same stage of treatment.

The measurements were made with a caliper, to the nearest decimal.

For the reliability of the test, a re-measurement of 20 plaster and virtual casts was performed a week later.

The comparative analysis was statistically evaluated.

Results. The results of the treatment with DENT@LIGN digital aligners, evaluated on a conventional plaster cast from the end of the orthodontic treatment and 3D printed motivational models, showing the digitally planned end of the treatment from the virtual setup, is illustrated in Table 1 and Fig. 1. The result of the analysis shows the extent to which the actual treatment coincides with the virtually planned one.

The analysis was performed separately for the upper and lower jaw and included a total of 8 comparisons.

The two evaluation methods were compared using the Bland–Altman plot. The difference between the virtual and the conventional plaster cast was interpreted as a positive bias, if the average measurement made on the virtual model was bigger than that of the conventional plaster cast. If a lower measurement was made on the virtual model than the corresponding on the conventianal one,

the difference is interpreted as a negative bias. Of great importance for the study is the degree of difference between the motivational model, demonstrating the completed treatment and the conventional plaster cast from the end of the accomplished orthodontic treatment with DLN.

The mean value of the difference between the two measurement methods was compared to zero by t-test for one sample. If the difference did not differ significantly from zero, we assumed that the accuracy of the values when measuring the two models was very similar without significant difference.

The results include mean and standard deviations of the values, the difference in the mean values, the standard deviation of the difference, the 95% confidence interval, the discrepancy between the two measurements in percentage and the statistical significance of the difference compared to zero (Table 1).

T a b l e 1

Comparative analysis of the parameters of the virtually planned with the actual accomplished treatment

Comparison		±SD	Difference		Discrepancy %	P
			± SD	95% CI		
Upper jaw						
1	Lo-DLNM	16.93±1.2	+0.06±0.54	−0.07–0.19	+0.3%	0.375
	Lo-S-plaster	16.87±1.1				
2	CC-DLNM	24.88±1.7	+0.26±1.7	−0.17–0.69	+1.3%	0.236
	CC-S-plaster	24.62±1.9				
3	PP-DLNM	35.79±2.3	−0.03 ± 0.37	−0.12–−0.5	−0.1%	0.478
	PP-S-plaster	35.82±2.5				
4	MM-DLNM	45.78±2.9	−0.02 ± 1.2	−0.33–0.29	−0.04%	0.923
	MM-S-plaster	45.80±2.8				
Lower jaw						
5	Lu-DLNM	14.68±0.93	0	0	0%	1.00
	Lu-S-plaster	14.68±0.93				
6	CC-DLNM	19.58±1.3	−0.02 ± 0.10	−.04–0.005	−0.09%	0.124
	CC-S-plaster	19.60±1.3				
7	PP-DLNM	36.06±1.7	0	0	0%	1.00
	PP-S-plaster	36.06±1.7				
8	MM-DLNM	46.45±2.9	+0.48 ± 3.8	−0.53–1.49	−1.03%	0.347
	MM-S-plaster	45.97±3.1				

+ = the average measurements of the virtual model are higher than the real one; − = the average measurements of the virtual model are lower than the real one.
Legend: DLNM – DENT@LIGN digital motivational model
S – treated, with completed orthodontic treatment
Plaster – a conventional plaster cast

A graphical illustration of the comparative analysis between the measurements is presented in the Bland–Altman graph (Fig. 2). The solid horizontal line in the middle of the graph corresponds to the established difference between the values of the digital and conventional plaster casts, while the dashed line marks

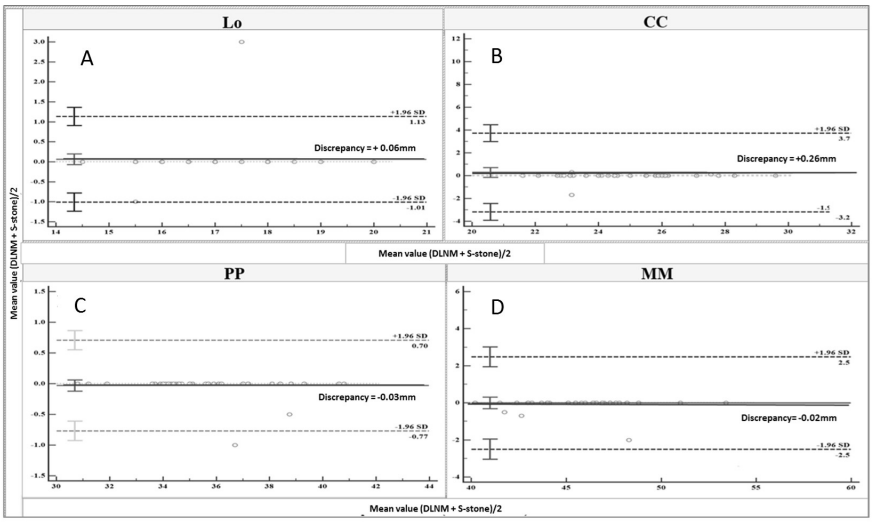


Fig. 2. Bland–Altman graphs of the comparative analysis between the values of the measurements on the conventional plaster from the actual accomplished treatment and the virtually planned one in the upper jaw

the hypothetical zero difference between them.

Panel A showed a high degree of correlation between the virtually planned and accomplished results of the upper dental arch anterior length, with a minimum difference of 0.06 mm, which did not differ significantly from zero ($p = 0.375$). Expressed in percentages, the virtually planned treatment differed from the accomplished one by only 0.3%.

A similar trend was observed for the intercanine width in the upper jaw (**panel B**), with a minimum difference of 0.26 mm ($p = 0.236$), constituting a 1.6% deviation of the virtually planned from the actually accomplished treatment. In both measurements, the difference was positive, which meant that the planned treatment is set at minimum higher values than the achieved.

The next two measurements, including interpremolar and intermolar width, show negative correlation of the difference between the virtual and material plaster casts. The premolar width showed a difference of -0.03 mm, which did not differ significantly from zero ($p = 0.478$) and showed only 0.1% difference between the virtually planned treatment and the real one (**panel C**).

For the molar width, the difference between the virtually planned and real results is only -0.02 mm, a value close to zero ($p = 0.923$) and a discrepancy of -0.04% (**panel D**). In the lower jaw, an even higher degree of coherence is observed between the virtually planned and actually achieved results (Fig. 3).

The virtually planned and actually achieved treatment of the anterior length of the lower dental arch showed a 100% match, with exactly the same average values of 14.68 ± 0.93 mm (**panel A**).

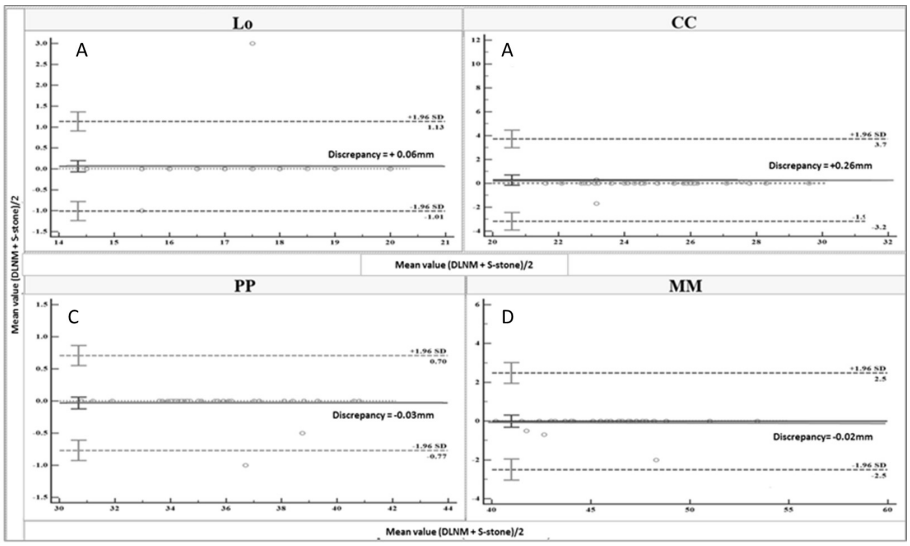


Fig. 3. Bland–Altman graphs of the comparative analysis between the values of the measurements on the conventional plaster from the actual accomplished treatment and the virtually planned one in the lower jaw

The difference in the measurement of the intercanine width in the upper jaw (**panel B**) was −0.02 mm ($p = 0.124$), with a minimum discrepancy of −0.09% of the planned from the actually achieved treatment of CC. The difference was negative, which meant that in the planned treatment there were some lower values than those in the actually achieved treatment.

For the interpremolar width, a complete overlap (100%) was reported between the virtually planned and the actually achieved treatment, with an average value of 36.06 ± 1.7 mm (**panel C**).

The intermolar width showed a difference of 0.48 ± 3.8 mm between the virtually planned and actual results, but without a significant difference from zero ($p = 0.347$), with a deviation of 1.03% (**panel D**). A positive difference means that some of the planned values are higher than the actually achieved ones.

Discussion. The obtained results from the comparative analysis of the motivational models with the planned virtual treatment showed a high degree of coincidence for the conventional plaster casts and the clinically accomplished orthodontic treatment. The data showed insignificant differences between conventional plaster casts and 3D digital models in the measured parameters. This gave us reason to summarize that the planned virtual treatment showed a great coincidence with the clinically achieved orthodontic treatment with a degree of consistency for the individual parameters between 98.7% and 100%. In general, the matches in the lower jaw were of a higher degree, where 100% match of the parameters (Lu and PP) were achieved. According to a number of authors such

differences are negligible [1,5,8–10]. Luu et al. [9] after numerous measurements of the teeth width, found absolute differences of less than 0.1 mm and differences of up to 0.2 mm when measuring the overjet, overbite, intercanine and intermolar distances. Comparisons were made between conventional plaster casts and laser-derived virtual models. The digitalization of the plaster casts is a step towards increasing efficiency and precision in the field of dental medicine. The development and refinement of 3D printing technology allows the production of 3D information with an accuracy of 0.1 mm [11,12].

The accuracy of the digital models, proved by the obtained comparative results, compared with the identical conventional plaster ones, allows shortening of the technological stages, including taking impressions, and also producing the physical models can be dropped out from the treatment protocol. 3Shape Trios scanners show average deviations for scanning the entire upper dental arch of 80 ± 18 µm and up to 500 µm in the distal segments, less than 0.14 mm for each of the three dimensions when measuring individual teeth, regardless of their position [13,14]. The translational and rotational deviations obtained in the measurements of individual teeth and the whole dental arches are minimal and can be considered negligible both in diagnostic and clinical aspect for the production of orthodontic appliances [1,10,13,15].

An advantage of the Zub Studio software tool is that it allows files from different systems to be combined into a single file to be superimposed. This feature distinguishes it from most known software products, which recognize limited files from a particular brand of scanner and/or software, and this creates inconvenience in practice, as the clinician is dependent on the terms of a particular brand. Zub Studio allows independent diagnosis, manipulation, monitoring of treatment progress and archiving in the clinic of the dentist by himself or by his team.

Conclusion. The obtained results showed a great extent of coincidence of the motivational models and the planned virtual treatment with the conventional plaster casts from the clinically achieved orthodontic treatment. That gives us reason to believe that the virtual setup and motivational models correspond exactly to the achieved clinical results and are a reliable method of treatment planning and motivation of patients with the software tool Zub Studio.

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