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Accuracy of Dolphin software assisted prediction of soft tissue changes post orthodontic treatment- A retrospective study

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Introduction

Orthodontic treatment most commonly deals with improvement in facial esthetics, especially in orofacial deformities such as bimaxillary protrusion, or class II div 1 malocclusion[1,2].One of the primary aims of orthodontic treatment is the improvement of facial and soft tissue profiles, which usually includes the extraction of premolars and retraction of incisors, reducing lip protrusion[3]

Orthodontic literature can be categorized into two major schools of thought. Several authors believe that orthodontic treatment has a significantimpact on the soft-tissue profile[2,3] while others note a stableresponse of these tissues to tooth movements[4].

For planning of orthodontic treatment an accurate prediction of soft tissue changes is very helpful. Many authors have proposed utilizing soft tissue cephalometric analysis as a reliable guide for occlusal treatment and attendant soft tissue changes[5].Arnett and Bergman presented the Facial Keys to Orthodontic Diagnosis and Treatment Planning as a three dimensional clinical blueprint for soft tissue analysis and treatment planning[6].

Accurately predicting orthodontic treatment outcome is of utmost importancein treating dentofacial deformities. These forecasts are intended to threefold: 1) To guide thetreatment to the desired result; 2) To give the patienta reasonable preview of the outcome; and 3) To act as a means of communication tool between the orthodontist and patient. Therefore,visualized treatment objectives are valuable analytical resources for visualizing goals before, during,and at the end of treatment. This visualizedtreatment objective (VTO) usually involves manualsurgical simulation depending on cephalometric tracings[Z.]

Computer-assisted imaging devices are now used in the preparation of orthognathic surgical cases due to technical advancements. There are many techniques in general use which perform a cephalometric analysis on a digitized cephalometric radiograph. Measurements can be taken rapidly and treatment plans can be developed using computer-assisted systems[7,8].

Various softwares such as Dolphin Imaging, Dentofacial Planner Plus, Orthoplan, Quick Ceph Image, and Vistadent were implemented to visually simulate and predict orthodontic treatment outcomes. These softwares are increasingly becoming popular in clinical evaluation, treatment planning, and decision making[5].

The Dolphin Imaging System (Dolphin Imaging, Canoga Park, CA) is a common software program for creating surgical VTOs. The accuracy of Dolphin VTO prediction in soft tissue changes in previous studies was focused on orthognathic treatment with or without orthodontic treatment. The accuracy of computer-assisted VTO prediction in soft tissue changes after orthodontic treatment using Dolphin Imaging software is still being debated.[5]

Present study was undertaken with an aim to evaluate the accuracy of Dolphin VTO prediction in soft tissue changes post orthodontic treatment by comparing the predicted values with actual values.

Materials And Methods

This study was designed as a retrospective observational study. Lateral cephalograms of orthodontically treated patients were taken from department of orthodontics and dentofacial orthopedics, B. V. D. U. D. C. and H., Sangli. The determination of sample size was based on a previous study by setting type I error at 0.05 and type II error at 0.20 (80% power) with 95% confidence interval and 5% marginal error. After applying inclusion and exclusion criteria, 28 treated orthodontic patients were included in the study. The study was approved by the ethical committee of B. V. D. U. D. C. and H., Sangli.

This retrospective study included good quality lateral cephalometric radiographs of non-growing young adults with age group of18-40yrs (Cervical maturation stage 5); pre-treatment and post- treatment lateral cephalometric radiographs of orthodontic patients with skeletal Class I jaw bases and bimaxillary dentoalveolar protrusion treated by extraction of all first premolars; pre-treatment and post- treatment lateral cephalometric radiographs of orthodontic patients with Class II division 1 malocclusion and tooth size arch discrepancy with mild crowding (<3 mm) treated by extraction of upper first premolars;.

Lateral cephalometric radiographs containing artifacts with strained lips; congenitally missing teeth (excluding third molars) were not included in this study. Also, lateral cephalogram with history of craniofacial trauma, syndrome or deformity and temporomandibular disorders; patient treated with functional appliances or headgear therapy and orthognathic surgery with or without orthodontic treatment; and tooth-size-arch-length discrepancies with spacing and moderate and severe crowding (>3mm) were excluded.

All selected cephalometric radiographs were taken in the patient's natural head position, with the teeth in centric occlusion and the lips lightly closed, using the same cephalometer. Dolphin Imaging software version 11.9 was used for cephalometric tracing, analysis, and VTO prediction. 28 patients were divided into 2 groups; Group I: Orthodontically treated patients with bimaxillary protrusion followed by first premolar extraction. Group II: Orthodontically treated patients with class II division 1 malocclusion followed by upper first premolar extraction.

The pre- and post-treatment cephalometric radiographs of each participant were imported, traced, and superimposed using the Frankfort horizontal plane as the reference plane (Figure 1a and 1b). Each group was further divided into 3 sub-groups. Sub-group A: Post treatment manual tracing (Figure 2 a and 2b); Sub-group B: Post treatment digital tracing (Figure 3); Sub-group C: Predicted values of pre- treatment digital tracing (Figure 4). Soft tissue profiles were evaluated before and after treatment, using thesagittal and vertical measurements described by Holdaway[9].

The pre- treatment lateral cephalometric radiographs for each patient were imported into Dolphin software to generate a VTO-predicted treatment outcome. Followed by post treatment lateral cephalometric radiographs were also imported into Dolphin software to compared with predicted treatment outcome. The horizontal and vertical displacement distances (mm) and angulation changes (°) of the actual post-treatment and VTO expected treatment outcomes were automatically reported using the Dolphin Imaging Software (the Holdaway analysis parameters; Table 1).

The actual post-treatment cephalometric tracing (red lines) was superimposed on the VTO-predicted profile cephalometric tracing (blue lines) to produce the cephalometric superimposition showing the discrepancy between the actual changes and the VTO-predicted results (Figure 5). Intraclass correlation coefficients (ICC) were used to evaluate intraoperator and interoperator reliabilities. Three cephalometric radiographs were randomly selected and retraced by two independent orthodontist. Each investigator repeated the measurements after two weeks.

The differences between the predicted and actual values of the soft tissue changes were calculated to evaluate exact estimation between them. The positive sign of the value of the difference revealed an overestimation of the VTO-predicted changes relative to the actual changes, with a more forward and upward predicted displacement of the predicted outcome relative to the actual post treatment outcome. Whereas, the negative sign of the value of the difference revealed an underestimation of the VTO-predicted changes relative to the actual changes, with a more backward and downward predicted displacement of the predicted outcome relative to the actual post treatment outcome.

Statistical analysis

Data was analyzed using SPSS statistical software (version 22).ANOVA test and Post Hoc test were used to check the significant difference in Means of predicted and actual treatment outcomes of the parameters used in the Holdaway soft tissue analysis with p values of less than 0.05 were considered statistically significant.

Results

Table 2 shows that there was a statistically significant differencebetween the predicted values and the actual values in 3 parameters of the Holdaway soft tissue analysis. Skeletal profile convexity in bimaxillary protrusion with higher values in Group IC and least in Group IA. The difference between the predicted and actual values in Group IC and Group IA was 1.52mm with P value 0.013; Lower lip sulcus depth in bimaxillary protrusion with higher values in Group IC and least in Group I A. The difference between the predicted and actual values in Group IC and Group IA was 1.73mm with P value 0.004; Nasal Prominence in Class II division 1 malocclusion with higher values in Group II C and least in Group II B. The difference between the predicted and actual values in Group IIC and Group IIB was 1.58mm with P value 0.043. Other soft tissue parameters shows non-significant difference between the predicted values and the actual values with p>0.05.

Table 2 also displays the negative sign of value of the difference which suggests an underestimation of the VTO-predicted changes relative to the actual changes, with a more backward and downward predicted displacement of the predicted outcome relative to the actual post treatment outcome (In Group I: Upper lip sulcus depth, nasal prominence, Soft tissue subnasale to H-line; In Group II: Lower lip sulcus depth, soft tissue subnasale to H-line, upper lip thickness).The other remaining valuesshow positive sign of the difference revealing an overestimation of the VTO-predicted changes relative to the actual changes, with a more forward and upward predicted displacement of the predicted outcome relative to the actual post treatment outcome.

Post Hoc Test suggests significant difference between: 1. Skeletal profile convexity in bimaxillary protrusion between Group IA vs. Group IC with 0.010; 2. Lower lip sulcus depth in bimaxillary protrusion between Group IA vs.GroupIC with 0.007 and Group IB vs.Group IC with 0.012; 3. Nasal prominence in Class II div 1 malocclusion between Group IIB vs. Group IIC with 0.047.

Discussion

The therapeutic demands made in orthodontics are not just limited to the re-establishment of a stable, functional occlusion but, also extend to the improvement of facial esthetics[3].

In the present study, we evaluated the accuracy of the Dolphin VTO in predicting the treatment result of soft tissue responses to orthodontic treatment in patients with bimaxillary protrusion and class II division 1 malocclusion and found that the prediction in 3 Holdaway parameters (i.e., Skeletal profile convexity, lower lip sulcus depth, and nasal prominence) was significantly different from the actual changes. The Dolphin Imaging VTO calculates predictions with two separate linear parameters based on the direction of movement in the X- or Y-axis. This study revealed that Dolphin Imaging had varying degrees of accuracy at each soft tissue landmark in both the horizontal and the vertical axis. Gosset et al[7] showed that dolphin had an even distribution of both over estimation and underestimation among tested landmarks. In present study, we found that Dolphin predictions tend to overestimate the amount of soft tissue retraction in bimaxillary cases and class II division 1 malocclusion.

Cephalometric surgical predictions are an integral part of orthognathic treatment plans. The accuracy of some of these methodshas been verified in previous studies.Z.O. Pektas et al[10]revealed that all predetermined soft tissue landmarks, computer-based predictions were more accurate in the sagittal plane than in the vertical plane.Contradictory to thisLu et al[11] found that in the vertical plane, software predictions of surgical profile changes were more accurate than in the sagittal plane. M. I. Shafi et al[12] and Magro-Filho O[13] used dolphin software to predict orthognathic surgery outcomes and concluded that, 3D soft tissue predictions were clinically satisfactory and obtained a profile accurately.

A number of studies about orthognathic treatment have reported that the Dolphin VTO did not show a directional bias in the prediction[14]. This is in agreement with present study that shows the distribution of the underestimation and overestimation of values similar in both horizontal and vertical planes. Robert J. Peterman et al[14]found that the maxilla region's landmarks (tip of nose, subnasale, ST A and upper lip) were more likely to be underestimated, and the in the horizontal plane mandibular landmarks (lower lip, ST Pg, ST Mn, and ST Gn) were more likely to be overestimated; almost all of the soft tissue landmarks were inferiorly predicted in the vertical plane.

In present study, the most accurately predicted landmark was the soft tissue point A in Group I and lower lip sulcus depth in Group II, whereas the least accurate prediction was found in the landmarks around the lower lip sulcus depth in Group I and upper lip sulcus depth in Group II. Some studies have found that Dolphin VTO demonstrated good predictive and comparative outcomes that are equally precise[5,15,16].G. Power et al.[15] and Xu Zhang et al[5] found that predictions which were directed to tip of the nose and subnasale revealed that these sites were most reliable than that software could predict. Whereas the least accurate predicted landmark was the lower lip, measured in the sagittal plane. This is also in agreement with the previous studies, which found that the landmarks of ST Pg,ST Me and ST Gnhad the least predictive accuracy[14,16,17].

However, despite the many benefits of these systems, it is important to remember that the presentation of these predictions to patients should be done with caution in order to avoid creating unrealistic treatment expectations.[11] Philips et al[18,11] reported patients who received the video-image case presentation had a higher self-image expectation when compared to a standard case presentation group.

Conclusion

The Dolphin VTO prediction in soft tissue changes after the orthodontic treatment in patients with bimaxillary protrusion and class II division 1 malocclusion is quite accurate for all other parameters except skeletal convexity, lower lip sulcus depth, and nasal prominence in patients with bimaxillary protrusion and class II div 1 malocclusion treated by fixed orthodontic treatment. Thus, the dolphin VTO prediction may be used for demonstration and communication with a patient or consulting practitioner, but not for precise orthodontic treatment planning.

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Legend Figures and Tables

Figure 1: Pre-treatment and Post-treatment lateral cephalometric radiographs

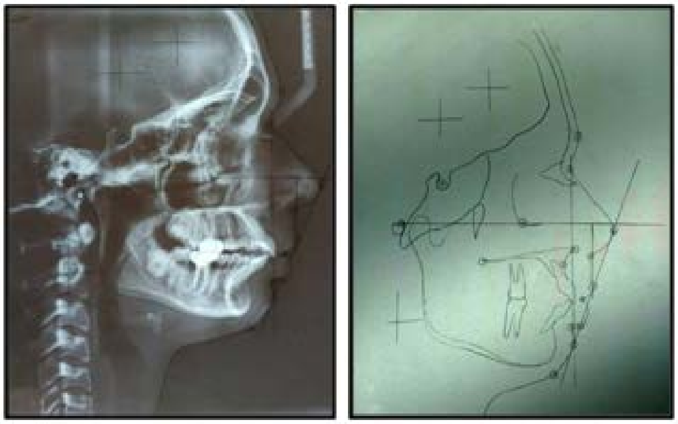

Figure 2: Post treatment manual tracing

Figure 3: Post treatment digital tracing

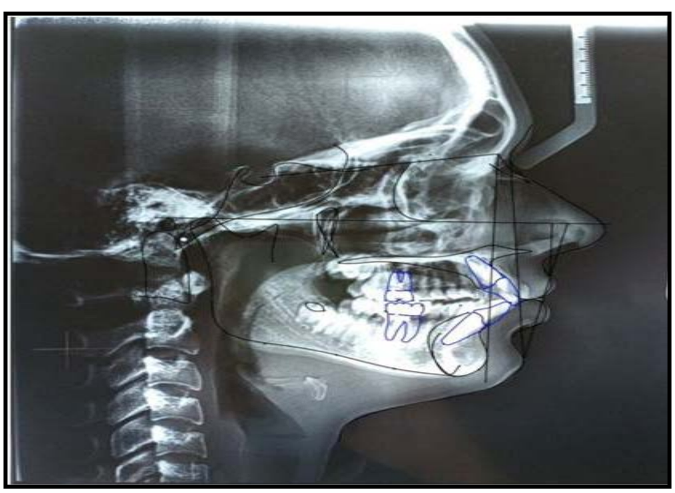

Figure 4: Predicted values of Pre-Treatment digital tracing

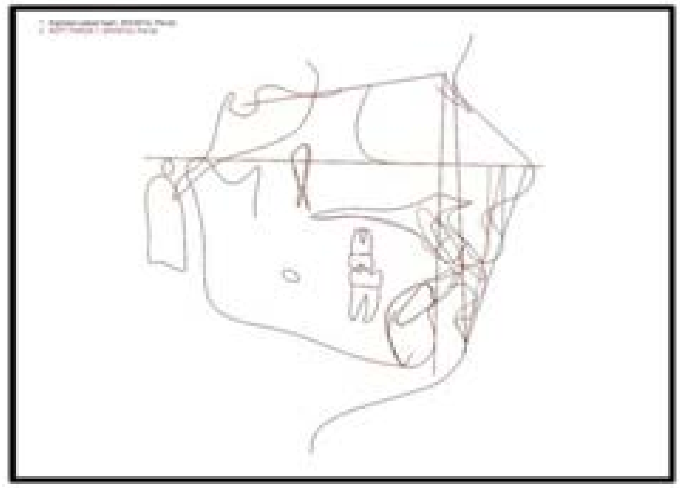

Figure 5: Cephalometric superimposition

Landmarks	
Tip of the nose	The junction of the inferior margin of the nasal ridge and the columella (the furthest point from the plane of the face)
Subnasale	The point where the columella merges with the upper lip
ST A	The most concavity point of the upper lip between subnasale and labrale superius
ST B	The most concavity point of the lower lip between labrale inferius and ST Pg
Upper lip	The border between skin and mucosa of the upper lip
Lower lip	The median point in the lower margin of the lower membranous lip
ST Pg	The most anterior point on the chin
ST Mn	The most inferior point on the chin
ST Gn	Midpoint between ST Pg and ST Mn

Table 1: Holdaway analysis: Landmarks and Parameters

Hold away soft tissue analysis	
Soft tissue chin thickness (mm)	The distance between the hard and soft tissue facial planes at the level of suprapogonion
Skeletal profile convexity (mm)	The dimension between point A and facial line;
H-angle (°)	The angle formed between the soft tissue facial plane line and the H-line
Lower lip to H-line (mm)	The measurement of the lower lip to the H-line
Nose prominence (mm)	The dimension between the tip of the nose and a perpendicular line drawn to the Frankfort plane from the vermillion
Soft tissue facial angle (°)	The downward and inner angle formed at a point where the sella-nasion line crosses the soft tissue and a line combining the supra pogonion with Frankfort horizontal plane
Soft tissue subnasale to H-line (mm)	The measurement from subnasale to the H-line
Upper lip sulcus depth (mm)	The measurement between the upper lip sulcus and a perpendicular line drawn from the vermillion to the vermillion to the Frankfort plane
Lower lip sulcus depth (mm)	The measurement at the point of greatest convexity between the vermillion border of the lower lip and the H-line
Upper lip thickness (mm)	The dimension between the vermillion point and the labial surface of the maxillary incisor
Basic upper lip thickness (mm)	The dimension measured approximately 3 mm below Point A and the drape of the upper lip
H-line (mm)	Tangent drawn from the tip of the chin to the upper lip

Table 2: Statistical inter group comparison of soft tissue values between the 3 grou

Parameter	Actual post treatment values with manual tracing	Actual post treatment values with digital tracing mean ±SEM	Predicted value values mean ± SEM	Difference between predicted and actual values	95% Confidence Interval for Mean		F value	p value
					Lower	Upper		
Soft tissue chin thickness Group I	11.114286	11.778571	12.614286	0.84	11.238918	12.432510	2.292	0.114
Soft tissue chin thickness Group II	11.271429	11.442857	12.007143	0.56	12.194542	12.194542	0.510	0.604
Skeletal profile convexity Group I	1.985714	2.578571	3.500000	0.93	2.247384	3.128806	4.839	0.013
Skeletal profile convexity Group II	2.478571	2.785714	3.696429	0.91	2.491753	3.482057	2.373	0.106
H angle Group I	14.378571	13.792857	14.378571	0.58	13.176382	14.414094	1.216	0.308
H angle Group II	15.142857	14.595714	14.600000	0.1	13.924893	15.847488	0.105	0.901
Lower Lip Sulcus Depth Group I	2.764286	2.871429	4.492857	1.62	2.876845	3.875536	6.483	0.004
Lower Lip Sulcus Depth Group II	4.592857	4.542857	4.414286	-0.13	3.887601	5.145733	0.028	0.973
Lower lip to H-line Group I	1.800	1.671	1.714	0.043	1.435	2.023	0.064	0.938
Lower lip to H-line	1.828571	2.292857	2.312857	0.02	1.679680	2.563177	0.440	0.647

Group II								
Upper Lip Sulcus Depth Group I	2.164	2.086	2.021	-0.065	1.766	2.415	0.063	0.939
Upper Lip Sulcus Depth Group II	4.007143	3.028571	3.200000	0.18	3.036934	3.786876	2.883	0.068
Nasal Prominence Group I	14.021429	13.442857	12.557143	-0.89	12.795793	13.885160	2.699	0.080
Nasal Prominence Group II	12.542857	11.271429	12.850000	1.58	11.663407	12.779450	3.419	0.043
Soft Tissue Facial Angle Group I	87.214	88.593	89.121	0.53	87.062	89.557	0.841	0.439
Soft Tissue Facial Angle Group II	89.000000	89.442857	89.452857	0.01	88.064181	90.492962	0.052	0.950
Soft Tissue sub nasal to H- line Group I	2.335714	2.242857	2.178571	-0.07	1.982619	2.522143	0.112	0.895
Soft Tissue sub nasal to H- line Group II	3.471429	3.428571	2.828571	-0.6	2.738822	3.746892	0.681	0.512
Upper lip thickness Group I	13.27142	12.917143	12.983571	0.07	12.599780	13.514982	0.222	0.802
Upper lip thickness Group II	14.571429	14.250000	13.600000	-0.65	13.680575	14.600378	1.622	0.211
Basic upper lip thickness Group I	12.929	12.350	13.143	0.793	12.282	13.333	0.821	0.447
Basic upper lip thickness Group I	13.428571	13.092857	13.585714	0.495	12.825651	13.912444	0.282	0.756