Original article

Implications of the occlusal vertical dimension in the aesthetics of the facial lower third: a clinical study

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Abstract. *Background and objective:* An adequate occlusal vertical dimension (OVD) can decrease the fillers needed and better control of the volumes and symmetry, providing enhanced balance and better cosmetic results to the human face. The study's objective was to show how an increase or decrease in the ideal measurement of the occlusal vertical dimension affects the aesthetics of the lower facial third, and how restoring it through oral rehabilitation prior to facial aesthetic treatments helps optimize cosmetic results. *Methods:* This was a single-center, comparative, non-randomized study including soft profile measurements using teleradiography to verify whether aesthetic standards were met before and after prosthetic rehabilitation, with other assessments based on frontal images of the patient's face. The need to decrease fillers was assessed through the photographs obtained and with the patient's input. A golden section gauge and an electronic vernier caliper were used to check the presence of a golden proportion before and after oral rehabilitation and restore the ideal occlusal vertical dimension. *Results:* The study enrolled 12 patients, divided into three age groups (Group 1: 41–50 years old; Group 2; 51–60 years and Group 3: 61–70 years old), with a mean sample age of 57.25 years (SD 9.85). A direct relationship was found between the occlusal vertical dimension and orofacial aesthetics, so an early intervention in the intraoral treatment optimized the subsequent facial treatment. *Conclusions:* Achieving optimal intraoral volume helps improve asymmetries resulting from edentulism while improving the vertical dimension of the lower third, in turn improving extraoral and facial patient management, minimizing the number of fillers, and avoiding more invasive surgical facial treatments. The study results highlighted the importance of establishing a collaboration between dentists and aesthetic medicine specialists.

Key words: vertical dimension, dental occlusion, dental aesthetics, golden proportion, lower facial third

Introduction

Dental aesthetics developed as a subfield of facial aesthetics[1] and eventually came to occupy a prominent place in the 90s[2]. It later rejoined the field of facial aesthetics (R.L. Lee, 2000)[3], and in the last decades, patients' aesthetic expectations and advances in technology have revolutionized the field[4–7]. The study of the occlusal vertical dimension (OVD) is essential to understand the aesthetic balance of the face and entails significant variations in facial compartments[8]. An adequate OVD results in a flat face[9], and its use in facial filler treatments helps achieve better cosmetic results and decreases the quantity of fillers used. The OVD leads to better volume and symmetry control[8]. Changing the OVD has been one of the most controversial issues in restorative dentistry. It may be indicated when dental-facial aesthetics need to be harmonized to provide space for planned restorations and improve occlusal relationships[10]. However, restoring the ideal OVD is a complex task that depends on objective and subjective factors, which have led to

multiple studies[11]. Subjective criteria can vary, and it would be interesting to record these assessments in a way that can be easily reproduced when attempting to achieve an optimal OVD. Through maintaining and increasing heights, volumes, and symmetry, which among other techniques, allow us to optimize the beauty of the lower facial third, we can decrease the number and invasiveness of aesthetic treatments to ensure the best result.

The study's objective was to show how an increase or decrease in the ideal measurement of the OVD affects the aesthetics of the lower facial third and how its restoration through an oral rehabilitation treatment, prior to facial aesthetic treatments, helps optimize cosmetic results.

Materials and methods

Study design and patients

A single-center, comparative, non-randomized study was conducted at the Clínica Dental Peralada (Peralada, Girona, Spain) from 2018 to May 2021, to see how restoring the OVD affects the aesthetics of the lower facial third.

The study followed the principles described in the revised Declaration of Helsinki and with Good Clinical Practice (GCP). Before starting the treatments, each patient signed an informed consent form to participate in the study.

Inclusion criteria: >18 years old, toothless (totally or partially), and having undergone dental prosthetic rehabilitation (fixed or removable prosthesis). Exclusion criteria: non- edentulous patients.

Patients were grouped based on age: Group 1, from 41 to 50 years old; Group 2, from 51 to 60; Group 3, from 61 to 70. Four patients were included in each group (two men and two women).

Study procedures

The patients' medical history was obtained, and several measurements were taken. The affected craniofacial structures were explored with two types of measurements: i) soft tissue measurements using a lateral teleradiography of the skull at rest with and without dental occlusion, and with and without dental rehabilitation, to verify whether profile aesthetic standards were met before and after prosthetic rehabilitation; ii) measurements with the three-point golden section gauge, a 20 cm millimetric metal ruler and the electronic vernier caliper, on frontal photographs of the patient to verify the presence of a golden proportion before and after oral rehabilitation; that is, to check whether the ideal OVD was restored; iii) overlapping of the Marquardt beauty mask on frontal photographs; iv) patient satisfaction survey.

Teleradiography measurements

Two lateral radiographs of the skull were obtained at rest with and without dental occlusion and with and without prosthetic rehabilitation. Radiographs were analyzed with a soft tissue cephalometric study using the Nemoceph software. A Planmeca - Proline XC digital unit was used with the following parameters: 68 KV voltage, 0.5 mA current, a 17-second exposure time, a dose area product (DAP) of 18.5 mGycm, and a 393 RX quality. The patient was positioned in a cephalostat to ensure that the photographs would be reproducible and to be able to conduct the follow-up. The magnification remained the same with each radiography (68 KV / 17 s). Patients were positioned with their lips at rest and their heads parallel to the ground, following the Frankfort plane. Following prosthetic rehabilitation, the teeth were placed in a maximum intercuspation position.

On each teleradiography, the anthropometric points related to the lower third were marked, and the distances between them were measured, following the protocols from a variety of authors[1,12–15]. With the obtained data, several measurements and analyses were performed (Table 1) using the Nemoceph software. The software analyzed displacement due to prosthetic rehabilitation and its effect on measuring specific anthropometric points to see whether the lost OVD was restored following the treatment (Table S1).

The assessment of the results of lateral skull teleradiographs, with and without teeth, was conducted in a blinded manner, without knowing the gender or age of the patient assessed.

Table 1. Analysis of horizontal measurements.

Distance a									
		chelion/chelion		**alar/alar**		**Quotient**		**% PHI deviation**	
		WOT	**WT**	**WOT**	**WT**	**WOT**	**WT**	**WOT**	**WT**
Group 1	Patient 1	37.80	38.69	27.47	27.68	1.38	1.40	-14.53	-13.18
	Patient 5	41.14	43.75	28.61	35.82	1.44	1.22	-10.69	-24.14
	Patient 6	53.73	47.56	48.52	44.80	1.11	1.06	-31.22	-34.06
	Patient 8	48.43	48.20	35.68	34.28	1.36	1.41	-15.69	-12.67
Group 2	Patient 7	52.60	47.68	48.65	45.24	1.08	1.05	-32.85	-34.54
	Patient 10	52.55	58.74	45.46	47.47	1.16	1.24	-28.20	-23.14
	Patient 9	34.62	37.23	25.05	24.85	1.38	1.50	-14.16	-6.94
	Patient 3	37.46	41.58	26.43	29.56	1.42	1.41	-11.97	-12.63
Group 3	Patient 2	47.16	44.64	36.10	33.96	1.31	1.31	-18.86	-18.35
	Patient 4	43.41	42.82	30.42	22.87	1.43	1.54	-11.37	-4.57
	Patient 11	42.21	55.42	34.07	39.67	1.24	1.40	-23.05	-13.23
	Patient 12	45.54	41.06	35.18	33.42	1.29	1.23	-19.60	-23.69
Distance b									
		exocation		**chelion/chelion**		**Quotient**		**% PHI deviation**	
		WOT	**WT**	**WOT**	**WT**	**WOT**	**WT**	**WOT**	**WT**
Group 1	Patient 1	74.10	72.40	37.80	38.69	1.96	1.87	21.76	16.23
	Patient 5	72.31	80.43	41.14	43.75	1.76	1.84	9.17	14.19
	Patient 6	97.49	95.31	53.73	47.56	1.81	2.00	12.70	24.47
	Patient 8	86.18	83.44	48.43	48.20	1.78	1.73	10.53	7.52
Group 2	Patient 7	97.49	94.36	52.60	47.68	1.85	1.98	15.12	22.92
	Patient 10	96.10	March 10 2001	52.55	58.74	1.83	1.75	13.59	8.92
	Patient 9	63.59	64.49	34.62	37.23	1.84	1.73	14.09	7.59
	Patient 3	70.59	74.10	37.46	41.58	1.88	1.78	17.04	10.69
Group 3	Patient 2	80.48	76.47	47.16	44.64	1.71	1.71	6.00	6.40
	Patient 4	74.81	69.24	43.41	42.82	1.72	1.62	7.04	0.43
	Patient 11	87.66	93.78	42.21	55.42	2.08	1.69	28.99	5.10
	Patient 12	96.36	92.99	45.54	41.06	2.12	2.26	31.42	40.67
Distance c									
		tragus/tragus		**chelion/chelion**		**Quotient**		**% PHI deviation**	
		WOT	**WT**	**WOT**	**WT**	**WOT**	**WT**	**WOT**	**WT**
Group 1	Patient 1	105.00	103.39	37.80	38.69	2.78	2.67	72.53	65.98
	Patient 5	109.88	127.19	41.14	43.75	2.67	2.91	65.89	80.57
	Patient 6	142.41	138.40	53.73	47.56	2.65	2.91	64.63	70.75
	Patient 8	134.52	129.68	48.43	48.20	2.78	2.69	72.52	67.9
Group 2	Patient 7	142.90	138.39	52.60	47.68	2.72	2.90	68.74	80.28
	Patient 10	145.06	154.76	52.55	58.74	2.76	2.63	71.45	63.64
	Patient 9	95.36	97.90	34.62	37.23	2.75	2.63	71.09	63.33
	Patient 3	89.30	96.94	37.46	41.58	2.38	2.33	48.07	44.81

Table 1 (*Contniued*)

Distance c									
		tragus/tragus		chelion/chelion		Quotient		% PHI deviation	
		WOT	WT	WOT	WT	WOT	WT	WOT	WT
Group 3	Patient 2	125.61	119.09	47.16	44.64	2.66	2.67	65.43	65.70
	Patient 4	121.65	110.87	43.41	42.82	2.80	2.59	74.06	60.82
	Patient 11	134.90	144.38	42.21	55.42	3.20	2.61	98.50	61.81
	Patient 12	149.88	142.07	45.54	41.06	3.29	3.46	104.42	114.91

Photograph-based comparative study

Four photographs were taken of each patient, oriented according to the Frankfort Horizontal Plane parallel to the ground (from the external auditory canal to the infraorbital point) to obtain the natural position of the head. Two frontal and two profile photographs were taken before and after prosthetic rehabilitation, with the lips resting, at 1.6 m from the photographer. As a background of the image, a matte dark blue curtain was positioned 0.8 m from the patient, following the law of golden proportion for picture taking. A Canon EOS 6D Mark II camera was used, equipped with Canon ZOOM LENS EF 24-105 mm 1:4 L ISII USM, flash Canon Twin lite MT-24 EX, and placed on a tripod. Images were enlarged and printed on 20x30 cm Kodak photographic paper with the image of the face as close to real size as possible.

In frontal photographs, before and after prosthetic rehabilitation, the horizontal and vertical facial golden proportions were analyzed to assess whether the prosthesis and a correct OVD restored the golden proportion lost with edentulism. The golden phi number

(1.61 with 100%) was considered, and anthropometric reference points were marked and measured with a golden section gauge, a 15 cm Tacklife electronic vernier caliper, a 20 cm millimetric ruler, and the overlapping of a Marquardt beauty mask, to identify the differences in golden proportions. Quotients were established between higher and lower distances, which were exported to a spreadsheet to assess whether golden proportions were met before and after prosthesis placement, whether edentulous patients lacked golden proportions, and whether the latter was achieved with the prosthesis (Table S1).

The OVD of patients was subjectively increased, valuing facial aesthetics (harmony of the facial thirds, assessment of facial folds) using the phonetic tests described by Fradeani, swallowing, and analyzing the free interocclusal space with the casts of the patient's arches mounted on an articulator.

The four photographs of each patient were assessed by six observers, three dentists, and three laypersons. They were asked whether they perceived improved facial beauty following prosthetic rehabilitation. If they did, they were asked to score it from 1 to 10 on a Likert-type scale, where one indicated no improvement and 10 indicated total improvement.

Patient satisfaction survey

All patients completed a survey where they gave their opinion on the result of the oral rehabilitation, the restoration of an adequate OVD, and the facial aesthetics achieved upon completion of the treatment. Patients were asked the following: 1) If they believed that the prosthetic treatment had improved their facial aesthetics; if affirmative, they were asked to score said improvement from 1 to 5, with 1 being "no changes perceived" and five being "absolutely changed"; 2) What part of your face do you think has improved the most? 3) Would you use some aesthetic treatment to improve the appearance of your lower facial third after prosthetic rehabilitation?

Statistical analysis

A study including a descriptive analysis was conducted. Quantitative variables were described as means, standard deviations, and differences as percentages.

Results

The study included twelve patients, four in each of the three age groups mentioned prior, of which 50% (n = 2) were women. The mean sample age was 57.25 years (SD 9.85), with no differences based on gender.

Results of facial proportions

Horizontal golden proportions (Table 1) varied very little before and after prosthetic rehabilitation and, thus, with the restoration of the OVD. The distance a (chelion-chelion and alar-alar) showed a mean deviation of the golden proportion of 20.59% when toothless and 18.4% with the prosthesis. Distance b (exocation-exocation and chelion- chelion) showed a deviation of 15.6% and 13.76% with and without treatment. Finally, distance c (tragus-tragus and chelion-chelion) deviated from the golden proportion by 73.11% and 83% with and without restoration of the OVD.

In terms of golden vertical proportions (Table 2) before and after rehabilitation and restoration of the OVD, it was observed that for distance "a" (nasion-subnasal and subnasal-stomion), 83% of the patients experienced an improvement in the golden proportion between these measurements, with a reduction in the mean deviation of the golden number of 8.6%; for distance "b" (gnation-subnasal and subnasal-nasion), 66.6% of the patients saw an improvement, with a reduction over the mean deviation of the golden number of 1.23%; for distance "c" (gnation-stomion and stomion-subnasal), 66.6% of the patients saw an improvement, with a reduction over the mean deviation of the golden number of 4.53%, when restoring the vertical dimension. Finally, distance d (nasion- stomion and gnation-stomion) improved in 41.6% of the patients, with 16% remaining the same and 42.4% experiencing worsening when the OVD was restored, with only slight differences before and after treatment (3.6% vs. 3.77%).

In all participants, the height of the upper lip increased when placing the prosthesis due to the expansion of the tissues. The height of the lower lip only increased in patients with no remaining teeth, reinforcing the idea that intraoral support is essential for extraoral lip volume. Concerning the lower third, when the OVD was restored, almost all participants experienced an aesthetic improvement and, thus, a decreased need for fillers. This restoration remained unchanged in three participants because they already had their lower incisors, and decreased in a toothless participant, probably because at the time of the teleradiography, having no teeth, that is, no occlusal references, the patient could not adequately position the jaw to seal his lips. Ricketts's aesthetic plane remained the same or improved in most patients, thus restoring a lip profile with better aesthetic projection. Line E or Rickett's aesthetic plane is considered a highly valuable parameter, which can be easily applied in clinical practice to achieve a harmonious profile.

By overlapping Marquardt's beauty mask on frontal photographs, no participant fit the mask's design perfectly, whether before or after rehabilitation. Protrusion of the upper lip increased in all patients with the prothesis placement and increase of the OVD. On the contrary, protrusion of the lower lip decreased in almost all patients when the OVD was restored because of the dental support for the lip. The balance between the upper and lower lip was restored to a certain degree, which means that the conditions were adequate for the aesthetics physician to assess the type and number of fillers and to optimize lip volumes and profiles.

Patient satisfaction survey

All the patients answered that they perceived a significant general improvement in their faces and were highly satisfied with the results, with a level of 5 over 5 regarding the appearance of the lower third following prosthetic rehabilitation. When asked if they would undergo a lower third filler procedure, such as hyaluronic acid to improve its appearance following rehabilitation, 100% of the men replied that they would not, while 66.7% of the women (n=4) said that they would; this procedure was refused by women aged 61 to 70 years old.

When showing before and after rehabilitation photographs to 3 lay observers, they stated that they

Table 2. Vertical measurements.

Distance a									
		Nasion-Subnasal		Subnasal-Stomion		Quotient		% PHI deviation	
		WOT	WT	WOT	WT	WOT	WT	WOT	WT
Group 1	Patient 1	34.67	34.98	23.82	21.54	1.46	1.62	-9.60	0.87
	Patient 5	43.90	43.26	15.5	17.86	2.73	2.42	75.92	50.45
	Patient 6	39.86	35.53	20.43	19.42	1.95	1.83	21.18	13.64
	Patient 8	43.88	42.98	16.26	16.84	2.70	2.55	67.62	58.53
Group 2	Patient 7	46.85	47.02	22.12	24.89	2.12	1.98	31.55	17.34
	Patient 10	47.49	51.05	20.58	27.83	2.33	1.83	44.69	13.93
	Patient 9	33.37	34.98	19.07	17.68	1.75	1.98	8.69	22.89
	Patient 3	35.88	37.26	15.81	17.53	2.27	2.13	40.96	32.02
Group 3	Patient 2	41.69	39.25	21.32	20.49	1.96	1.92	21.46	18.98
	Patient 4	39.46	34.35	20.27	18.91	1.95	1.82	20.91	12.83
	Patient 11	44.87	45.38	19.30	19.01	2.32	2.39	44.4	48.27
	Patient 12	43.34	42.21	21.27	21.81	2.04	1.94	26.56	20.21
Distance b									
		Nasion-Subnasal		Subnasal-Stomion		Quotient		% PHI deviation	
		WOT	WT	WOT	WT	WOT	WT	WOT	WT
Group 1	Patient 1	70.34	66.78	34.67	34.98	2.03	1.91	26.02	15.58
	Patient 5	48.74	49.90	43.90	43.26	1.11	1.15	-31.04	-28.35
	Patient 6	55.04	55.98	39.86	35.53	1.38	1.58	-14.23	-2.14
	Patient 8	59.78	59.38	43.88	42.98	1.36	1.38	-15.38	-14.19
Group 2	Patient 7	67.98	63.99	48.85	47.02	1.45	1.36	-9.87	-15.47
	Patient 10	67.40	80.44	47.94	51.05	1.41	1.58	-12.68	-2.13
	Patient 9	54.82	50.65	33.37	34.98	1.64	1.45	2.04	-10.06
	Patient 3	49.92	50.96	35.88	37.26	1.39	1.37	-13.58	-15.05
Group 3	Patient 2	59.53	57.64	41.69	39.25	1.43	1.47	-11.31	-8.79
	Patient 4	59.40	53.67	39.46	34.35	1.51	1.56	-6.50	-2.95
	Patient 11	63.25	70.39	44.87	43.38	1.41	1.55	-12.45	-3.66
	Patient 12	65.64	63.21	43.34	42.21	1.51	1.50	-5.93	-6.99
Distance c									
		Gnation-stomion		Subnasal-Stomion		Quotient		% PHI deviation	
		WOT	WT	WOT	WT	WOT	WT	WOT	WT
Group 1	Patient 1	46.45	45.35	23.82	21.54	1.95	2.11	21.12	30.77
	Patient 5	32.73	32.51	15.50	17.86	2.11	1.82	31.16	13.06
	Patient 6	34.68	36.83	20.43	19.42	1.70	1.90	5.44	17.79
	Patient 8	42.64	41.99	16.26	16.84	2.62	2.49	62.88	54.87
Group 2	Patient 7	44.14	38.87	22.12	24.89	2.00	1.56	23.94	-3.00
	Patient 10	46.17	52.27	20.58	27.83	2.24	1.88	39.34	16.66
	Patient 9	35.50	32.10	19.07	17.68	1.86	1.82	15.63	9.77
	Patient 3	33.48	33.65	15.81	17.53	2.12	1.92	31.53	19.23

Distance c									
		Gnation-stomion		Subnasal-Stomion		Quotient		% PHI deviation	
		WOT	WT	WOT	WT	WOT	WT	WOT	WT
Group 3	Patient 2	38.26	37.07	21.32	20.49	1.79	1.81	11.46	12.37
	Patient 4	38.92	34.53	20.27	18.91	1.92	1.83	19.26	13.42
	Patient 11	43.33	51.83	19.30	19.01	2.25	2.73	39.45	69.35
	Patient 12	43.66	41.11	21.27	21.81	2.05	1.88	27.49	17.08
Distance d									
		Nasion-stomion		Gnation-Stomion		Quotient		% PHI deviation	
		WOT	WT	WOT	WT	WOT	WT	WOT	WT
Group 1	Patient 1	58.99	56.18	46.45	45.35	1.27	1.24	-21.12	-23.06
	Patient 5	59.62	60.48	32.73	32.51	1.82	1.86	13.14	15.55
	Patient 6	60.62	54.63	34.68	37.29	1.75	1.47	8.57	-9.01
	Patient 8	60.60	60.53	42.64	41.99	1.42	1.44	-11.73	-10.46
Group 2	Patient 7	70.78	71.75	44.14	38.87	1.60	1.85	-0.40	14.65
	Patient 10	69.26	78.48	46.17	52.27	1.50	1.50	-6.83	-6.74
	Patient 9	53.44	52.79	35.5	32.10	1.51	1.64	-6.50	2.15
	Patient 3	51.89	54.77	33.48	33.65	1.55	1.63	-3.73	1.10
Group 3	Patient 2	63.62	60.13	38.26	37.07	1.66	1.62	3.28	0.75
	Patient 4	60.35	53.57	38.92	34.53	.55	1.55	-3.69	-3.64
	Patient 11	64.45	64.04	43.33	51.83	1.49	1.24	-7.61	-23.26
	Patient 12	65.59	63.79	43.66	41.11	1.50	1.55	-6.69	-3.62

perceived an aesthetic improvement in most participants (8-9 out of 12), which accounts for more than 65%.

Assessment by independent observers

When shown the photographs, the expert observers (two dentists and a prosthetic specialist) saw a before and after difference in a higher number of patients, over 83%, representing a high perception of aesthetic improvement. These professionals did not see aesthetic changes in 1-2 patients out of 12. This fact can be interpreted to mean that these faces did not have as much loss of inner volume or vertical dimension as in other cases.

Discussion

The study results were auspicious since they showed a direct relationship between OVD and orofacial aesthetics, highlighting the importance of an early intervention in intraoral treatments to optimize subsequent facial treatments. Through this study, we can identify areas of the lower third that can be improved to achieve an optimal intraoral situation prior to facial treatment and the approximate percentage of different structures that can be improved, such as the nasolabial angle, facial height, or lip projection. Our results obtained better volumes and projections of facial structures by using different techniques, tests, and records such as radiography, photography, cephalometric studies, the Golden Compass, and the Marquardt mask to treat asymmetries, a gummy smile, improve muscle activity resulting from total or partial edentulism while improving the vertical dimension of the lower third with a correct occlusal plane. Our protocol improved patients' extraoral and facial structures by up to 70%, with a more natural and rejuvenated appearance results and higher patient satisfaction[16]. It helped us manage the clinical cases, minimize the number of

fillers, and avoid more invasive surgical facial treatments. Therefore, the cooperation between dentists and physicians specialized in facial aesthetics has proven to be essential.

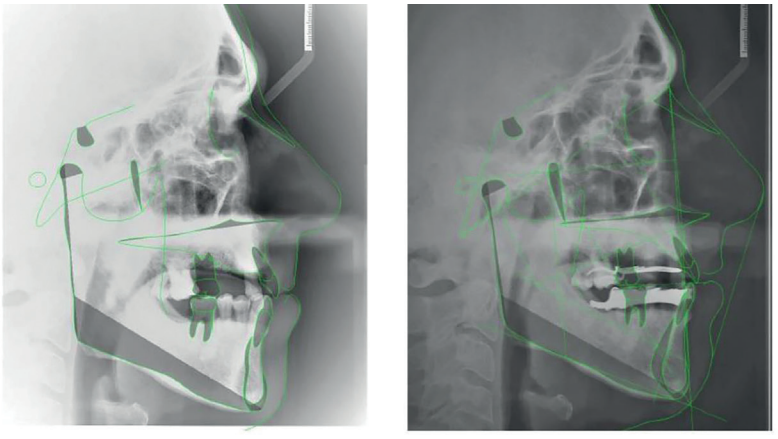
We assessed the behavior of OVD in maxillary occlusion in patients of different ages, genders, and skeletal makeup. However, we have observed that following prosthetic rehabilitation, OVD increased in approximately 60% of the patients. On the contrary, lip protrusion increased or normalized by 60%, especially for the upper lip, often compensating for the protrusion of the lower lip or restoring the relationship between the profile of both lips. By overlapping the golden section gauge on pre-rehabilitation frontal photographs, with and without prosthesis, it was observed that anthropometric distances did not meet golden proportions in any of the patients. However, following prosthetic rehabilitation, some patients were closer to the golden proportions in some distances, especially those determined by the vertical proportions, such as the nasion-subnasal/subnasal stomion, which improved in 10 out of the 12 participants.

When calculating horizontal golden proportions, it was observed that each variation was minimal before and after the treatment, which means that the mean deviation of the golden proportion varied only slightly. After assessing the measurements, we observed that the horizontal measurement of the mouth (from corner to corner) was the only one that varied since the other references were fixed. These findings correlate with studies such as the one by Farkas et al. of 1985[17], which found slight variations between horizontal facial proportions for these variables.

The results from the vertical golden proportions showed that, when placing the prosthesis, the distance of the upper lip and that of the lower third of the face increased, respectively.

Fixed distances, such as nasion-subnasal points, combined with variable distances, such as subnasal-stomion and gnation-subnasal, should have come closer to the golden proportion, but this was not the case. For instance, distance "b" (gnation-subnasal and nasion-subnasal) should have improved in all participants, given that, when placed the prosthesis, the OVD was restored, lips were everted, and some of the lines of the upper lip disappeared, but this did not happen in patients with lower remaining teeth, in which no improvement was observed (Figure 1).

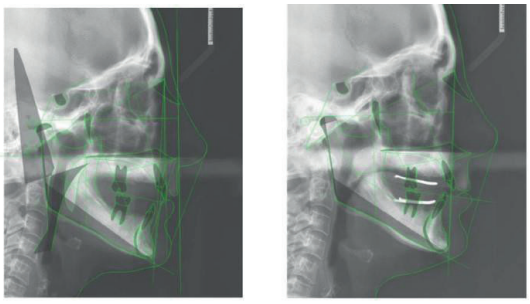
We observed remarkable differences in seven patients in whom the nasolabial angle increased when



Labiomental Furrow						
	Value		Range		DIF	
	WOT	WT	WOT	WT	WOT	WT
Patient 1	26.6	22.1	22.0 ±2.3	22.0 ±2.3	4.6	0.1

Abbreviations: WOT, without teeth; WT, with teeth; DIF, difference.

Figure 1. Patient 1, 45-year old man, no major changes due to the presence of remaining lower teeth.



Labiomental Furrow						
	Value		Range		DIF	
	WOT	WT	WOT	WT	WOT	WT
Patient 1	20.4	22.3	15.05 ±2,3	22,0 ±2.3	0.9	2.8

Abbreviations: WOT, without teeth; WT, with teeth; DIF, difference.

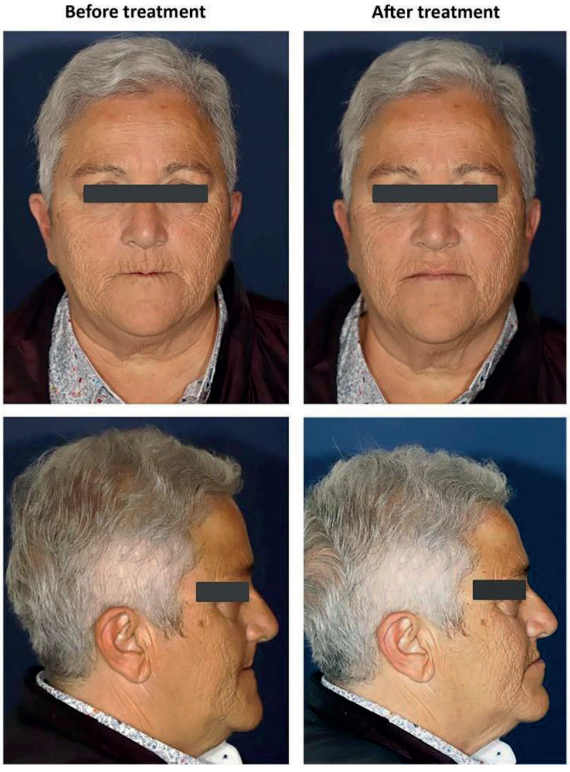
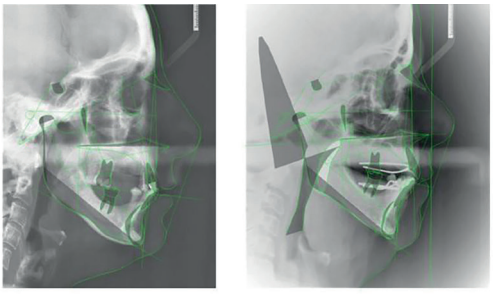


Figure 2. Patient 3, a 60-year-old woman whose nasolabial angle increased with placement of the prosthesis, upper lip protruded due to the presence of teeth and the tip of the nose rose.



Labiomental Furrow						
	Value		Range		DIF	
	WOT	WT	WOT	WT	WOT	WT
Patient 1	21.6	23.6	19.50 ±2.3	19.50 ±2.3	2.1	4.1

Abbreviations: WOT, without teeth; WT, with teeth; DIF, difference.

Figure 3. Patient 9, 58-year-old woman with remaining lower teeth who experienced a decrease in the labiomental fold depth with placement of the prosthesis.

placing the prosthesis since the presence of teeth led to the protrusion of the upper lip, raising the tip of the nose (Figure 2). The labiomental fold increased with the prostheses, and the fold tended to be flatter without them. Among the three patients who still had their lower incisors, we observed a decrease in the depth of the labiomental fold. When placing the posterior teeth lower prosthesis, there was a slight variation in the fold measurements (Figure 3). The nasomental angle decreased in almost all patients when placing the prostheses since it improved the relationship between the lips and decreased the protrusion of the lower lip, resulting in more convex profiles. This angle is the most important one in Powell´s famous aesthetic triangle,

and its standard value is usually between 120-130º. It is related to two facial structures that may be modified surgically or using fillers, such as the nose and chin. It is therefore essential to define this angle thoroughly to be able to study and optimize potential fillers to be used in these structures.

The older the patient, the higher the loss of collagen and detachment of the fatty compartments of the middle and lower facial thirds[18]. A prosthesis placement improves the intraoral support and outer volume, especially in the lips, which recover part of their profile and volume. In addition, as we have seen in our patients' survey, they expressed that they perceived an aesthetic improvement. However, the patient will need other aesthetic treatments to optimize results despite restoring OVD and support of the lower third with the prosthesis. These will be minor and minimally invasive, resulting in more predictable and safer results, which will optimize intraoral and extraoral conditions[19,20]. However, some authors disagree, like J. Abduo and Lyons, who state that OVD is constant throughout a person's life and that its increase results in hyperactivity of the masticatory muscles, increased occlusal force, bruxism and temporomandibular disorders[21]. However, their studies only assessed patients following dental loss or extreme bruxism, which led to a very high proportion and loss of OVD. Aesthetic consequences of losing the occlusal vertical dimension can be seen in the decrease in facial height derived from the collapse of the vertical dimension, resulting in various facial changes, such as a prognathic face, which impairs facial aesthetics[22], with these factors being more apparent in older patients. In contrast to this study and consistent with our work, J. Sun et al. stated that by increasing the OVD, lower facial height could be increased, and so could its relationship with total facial and lip height and the nasolabial angle[20]. Both studies agree that a significant increase in the OVD leads to a more elongated face and, consequently, to a lower aesthetic perception.

The aesthetics of the dental arches, based on the "divine proportion" principle, establishes that the two arches must be symmetrical and parallel to each other and that the upper arch should circumscribe the lower one[23]. If Ricketts' hypotheses were true, it could be expected that patients with better facial aesthetic results would have dental-facial proportions closer to the divine proportion[24]. Consequently, proportions closer to phi would be theoretically more attractive, which means that an individual with a lower number of proportions closer to phi would not be attractive. Although there was a certain degree of correlation between the phi absolute difference mean and aesthetic scores prior to the treatment, this correlation was not met for all proportions and scores post-treatment, consistently with the controversy on divine and aesthetic proportions, as expressed in studies that have supported it, such as those by E. Pierce[25], G. T. Fechner[26], or J. Piehl[27], and those which have challenged it, such as T.H. Haines[28] or Godkewistsch[29].

Study limitations

One of the study's limitations was the reduced sample size and the fact that no patients younger than 41 were included since not enough cases of patients with upper, lower, or complete edentulism could be found to create a study group. On the other hand, the anthropometric point measurements were duplicated by a single observer to avoid inter- observer variations. However, despite this, results varied, so the mean was used. No analyses were undertaken with the patient in movement, such as talking or smiling, as in other studies, where the differences observed are more significant than resting. Patients were also never asked to tie their hair, take off their glasses or shave before taking the pictures, which means that the localization of anthropometric points may have been less accurate. When printing frontal photographs, the size (20x30 cm) was different from the one used when expanding the image in the computer with the editing software. However, no errors were found given that quotients (linear measurements as proportional ratios) were analyzed, as opposed to exact linear measurements, as done by Mantelakis and M. Iosifidis in their 2018 study on Afro-Caribbean facial proportions[30]. Given some deficiencies observed in the records, which led to some level of bias, the need to develop a more detailed protocol arose, in order to control the obsercved errors, such as inter-observer variability, differences in anthropometric measurements,

data collection flaws, image processing, the position of the head when obtaining teleradiographs, or potential variations when drawing the profiles.

Conclusions

Achieving optimal intraoral volume helps improve asymmetries resulting from edentulism, while improving the vertical dimension of the lower third, improving extraoral and facial patient management, minimizing the fillers needed, and avoiding more invasive surgical facial treatments. The study results highlighted the importance of establishing a collaboration between dentists and aesthetic medicine specialists.

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References

1. Ricketts RM. The biologic significance of the divine proportion and Fibonacci series. Am J Orthod. 1982; 81(5): 351–70.
2. Burden DJ. An investigation of the association between overjet size, lip coverage, and traumatic injury to maxillary incisors. Eur J Orthod. 1995; 17(6):513–7.
3. Lee RL. Standardized head position and reference planes for dento-facial aesthetics. Dent Today. 2000; 19(2):82–7.
4. Klages U, Bruckner A, Zentner A. Dental aesthetics, self-awareness, and oral health-related quality of life in young adults. Eur J Orthod. 2004; 26(5):507– 14.
5. Ahmad I. Anterior dental aesthetics: gingival perspective. Br Dent J. 2005; 199(4):195–202.
6. Naini RB, Nokar S, Borghei H, Alikhasi M. Tilted or parallel implant placement in the completely edentulous mandible? A three-dimensional finite element analysis. Int J Oral Maxillofac Implants. 2011; 26(4):776–81.
7. Levin L, Ofec R, Grossmann Y, Anner R. Periodontal disease as a risk for dental implant failure over time: a long-term historical cohort study. J Clin Periodontol. 2011; 38(8):732–7.
8. Marin DOM, Leite ARP, de Oliveira Junior NM, Compagnoni MA, Pero AC, Arioli Filho JN. Reestablishment of occlusal vertical dimension in complete denture wearing in two stages. Case Rep Dent. 2015; 2015:762914.
9. Yanikoğlu ND, Güldağ MU, Duymuş ZY. Determination of the occlusal vertical dimension: use of maxillary and mandibular posterior teeth measurement in edentate subjects. Eur J Prosthodont Restor Dent. 2005; 13(2):75–7.
10. Martin Santiago MP. Sistema oclusal postural humano. in: kinesiología médica odontológica y posturología. 2012. p. 561.
11. Dantas EM. The importance of restoring occlusal vertical dimension in the prosthetic rehabilitation. Odonto. 2012; 20(40):41–8.
12. Arnett GW, Bergman RT. Facial keys to orthodontic diagnosis and treatment planning. Part I. Am J Orthod Dentofac Orthop. 1993; 103(4):299–312.
13. Burstone CJ, James RB, Legan H, Murphy GA, Norton LA. Cephalometrics for orthognathic surgery. J Oral Surg. 1978; 36(4):269–77.
14. Legan HL, Burstone CJ. Soft tissue cephalometric analysis for orthognathic surgery. J Oral Surg. 1980; 38(10):744–51.
15. Powell K, Amin D, Sesanto R, Bryant A, Kukreja P, Waite P. Do oropharyngeal throat packs prevent fluid ingestion during orthognathic surgery? Int J Oral Maxillofac Surg. 2022; 51(3):366–70.
16. Martín Santiago MP. La boca bajo sospecha. 2019. 200 p.
17. Farkas LG, Hreczko TA, Kolar JC, Munro IR. Vertical and horizontal proportions of the face in young adult North American caucasians: revision of neoclassical canons. Plast Reconstr Surg. 1985; 75(3):328–38.
18. Swift A, Liew S, Weinkle S, Garcia JK, Silberberg MB. The facial aging process from the "Inside Out". Aesthet Surg J. 2021; 41(10):1107–19.
19. Mohindra NK, Bulman JS. The effect of increasing vertical dimension of occlusion on facial aesthetics. Br Dent J. 2002; 192(3):164–8.
20. Sun J, Lin Y-C, Lee JD, Lee SJ. Effect of increasing occlusal vertical dimension on lower facial form and perceived facial esthetics: a digital evaluation. J Prosthet Dent. 2021; 126(4):546–52.
21. Abduo J, Lyons K. Clinical considerations for increasing occlusal vertical dimension: a review. Aust Dent J. 2012; 57(1):2–10.
22. Levartovsky S, Aharonov O, Emodi Perlman A, Winocur E, Sarig R. The effect of tooth wear, age and sex on facial height assessed by soft tissue analysis. J Oral Rehabil. 2020; 47(3):346–52.
23. Popescu MR, Trană F, Manolea H, Rauten A-M, Șurlin P, Dragomir LP. Theoretical study on the mechanics of the conjunct gnatoprothetic devices in the context of occlusive function rehabilitation. Curr Health Sci J. 2014; 40(2):119–25.

24. Shell TL, Woods MG. Facial aesthetics and the divine proportion: A comparison of surgical and non-surgical Class II treatment. Aust Orthod J. 2004; 20(2):51–63.
25. Pierce E. Aesthetics of simple forms. Psychol Rev. 1894; 1:483–95.
26. Fechner GT, Höge H. Various attempts to establish a basic form of beauty: experimental aesthetics, golden section, and square. Empir Stud Arts. 1997; 15:115–30.
27. Piehl J. The golden section: the "true" ratio? Percept Mot Skills. 1978; 46(3 Pt 1):831-4.
28. Haines TH, Davies AE. The psychology of aesthetic reaction to rectangular forms. Psychol Rev. 1904; 11(4–5):249–81.
29. Godkewitsch M. The "golden section": an artifact of stimulus range and measure of preference. Am J Psychol. 1974; 87(1–2):269–77.
30. Mantelakis A, Iosifidis M, Al-Bitar, et al. Proportions of the aesthetic African-Caribbean face: idealized ratios, comparison with the golden proportion and perceptions of attractiveness. Maxillofac Plast Reconstr Surg. 2018; 40(1):20.

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Appendix – Supplementary files

Table S1. Points of reference, measurements and variables analyzed during the study.

Anthropometric facial points of reference:
i. Trichion (tr), point on the midline sagittal plane where the hairline starts. ii. Soft tissue nasion (n'), intersection of the frontal bone and the two nasal bones of the human skull corresponding to the frontonasal suture, and visualized as the deepest area in the concavity of the forehead and the soft tissue around the nose. iii. Endocanthion (en), innermost point of the palpebral commissure. iv. Exocanthion (ex), outermost point of the palpebral commissure. v. Alar (al), formed by the lateral cartilages of the nasal tip which join the lobe of the tip with the skin of the face. vi. Chelion (ch), outer vertex of the labial commissure. vii. Stomion (st), lowermost point of the upper lip or uppermost point of the lower lip, in the lip contact area. viii. Soft gnation-(gn'), most anterior and lower point in the midline of the lower edge of the jaw. ix. Tragus or zygions (t), most lateral point of each zygomatic arch.
Measures to determine horizontal proportions:
a. Distance ch-ch / al-al b. Distance ch-ch / ex -ex c. Distance ch-ch / t-t
Measures to determine vertical proportions:
a. Distance n'-subnasal/subnasal-st b. Distance gn'-subnasal/subnasal-n' c. Distance gn'-stomion/st-subnasal d. Distance n'-st/st-gn'
Analyses performed:
a. Arnett facial analysis to determine the height of the upper lip, height of the lower lip and height of the lower third. b. Burstone-Legan analysis to study lip profile values (labiomental fold, upper and lower lip protrusion), and to examine the position of the lips with respect to the subnasal line to pogonion. c. Powell's analysis to study the nasolabial angle. d. Ricketts's analysis to calculate the protrusion of the lower lip showing the position of the lower lip with respect to the subnasal-pogonion line, and defined as Ricketts's aesthetic plane.
Variables assessed:
i. Nasolabial angle, formed by the intersection of a tangent line to the upper lip from the subnasal point (sn) and a tangent to the most anterior point of the columella describing the inclination of the columella in relation to the upper lip. In women, it measures from 95º to 100º, and in men, from 90º to 95º. This angle is determined by several factors, such as the antero-posterior position of the maxilla and the teeth, the position of the nose and the thickness of the upper lip. ii. Length of the upper lip, from the subnasal point to the vermilion, with values of 21 mm for women and 22 mm for men. iii. Length of the lower lip, from its lower border to the chin, at a 2:1 ratio with the upper lip, with values of 48 mm in women and 50 mm in men. iv. Position and shape of the lips, measured as a soft profile ratio. A line was drawn from the tip of the nose to the chin-pogonion (nasomental line or Ricketts's aesthetic plane), where the lower lip should be 4 mm behind and the lower lip, 2 mm. v. Nasomental angle, angle formed between the tangent line from the nasion to the tip of the nose with the intersection of the line from the tip of the nose to the pogonion. It is the most important angle of the so called Powell's aesthetic triangle (nasofrontal, nasofacial, nasomental and mentocervical), which should measure between 120º and 130º. vi. Labiomental fold, soft tissue fold between the lower lip and the chin, which should not be over 4 mm deep; if the facial height of the lower third decreases, it becomes much deeper and less aesthetically pleasing; it is influenced by bite depth, shape of the lip, upper and lower dental protrusion, and bone deformity in the chin area. vii. Lower third distance, measured from the subnasal point — point where the nasal columella base joins the upper lip — to the chin — lowest point of the soft tissue covering the mandibular symphysis, which is usually 63 to 66 mm in size.