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The influence of the occlusal vertical dimension on masticatory muscle activities and hyoid bone position in complete denture wearers

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ABSTRACT

Purpose: Long lasting usage of complete dentures causes lower occlusal vertical dimension, producing potential detrimental consequences. The aim of this study was to investigate how changes in vertical dimension during denture exchange affect muscular activity and hyoid bone position.

Material and Methods: Twenty-five edentulous, otherwise healthy patients (14 females, 11 males) aged 70.5 +/- 9 years, wearing their dentures over 5 years but no longer than 15 years (mean 9.8 +/- 5.2), were studied. New dentures were fabricated and the occlusal vertical dimension was recorded on cephalometric radiographs. Cephalograms were analyzed according to Ricketts. The relation of the hyoid bone position to the mandible was estimated. An evaluation of muscular activity was performed using the Biopak Electromyography Recording System synchronized with the T-Scan II Occlusal Analysis System.

Results: The occlusal vertical dimension was higher with the new dentures compared with the old dentures. The transition to new dentures was accompanied by a change of the vertical position of the hyoid bone. Digastric muscle activity was lower with the new dentures in comparison with the old dentures

Conclusions: Increase of the occlusal vertical dimension in complete denture wearers affects the hyoid bone position and masticatory muscle activity.

Key words: occlusal vertical dimension, complete dentures, muscular activity, hyoid bone

INTRODUCTION

The loss of teeth determines important changes in the masticatory system, which affects bone, oral mucosa and muscles. Both resorption of the alveolar bone and the reduced formation of new bone is reported, while a decreased number of receptors is found in the overlying mucosa during this process [1-3]. These changes in bone structure are characterized by upward rotation of the mandible with a subsequent decrease in the occlusal vertical dimension and an increase in mandibular prognathism. Sensory receptors such as muscle spindles, periodontal and intradental pressoreceptors strongly influence the activity of motor neurons and muscle control [3,4]. Prolonged use of complete dentures affects the hyoid bone position and is likely to influence craniofacial relations [5]. Several functional muscle groups that are attached to the hyoid are involved in both jaw movement and the swallowing process [6-9].

One of the major problems in constructing complete dentures is the lack of reproducible reference structures for determining the occlusal vertical dimension [10,11]. Therefore, success in oral rehabilitation with complete dentures depends considerably on the clinical skills of the operator, and a precise assessment of the outcome is often difficult [12]. This study was aimed at determining the effect of changes in the occlusal vertical dimension during complete denture replacement on muscular activity and hyoid bone position. The objectives were to answer the questions of whether muscular activity following denture replacement was dependent on occlusal vertical dimension and whether the replacement produced alterations in hyoid bone position.

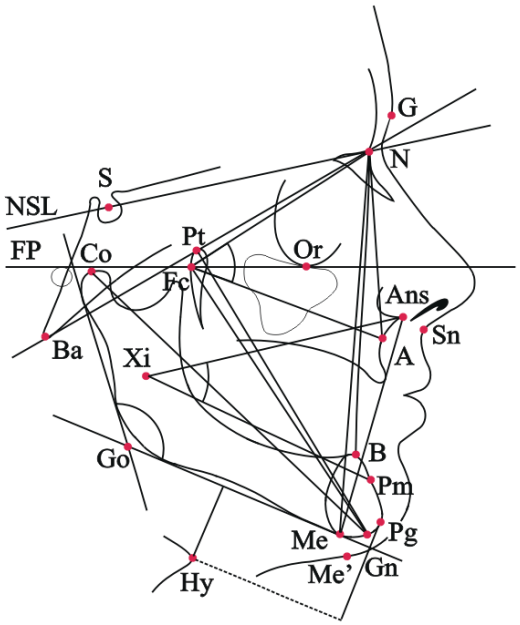
MATERIALS AND METHODS

The studied group consisted of 25 healthy white patients (14 females, 11 males) aged 44 – 86 years (mean 70.5 +/- 9), who were referred to the Department of Prosthodontics at the Medical University of Bialystok to make new dentures. They had worn their existing appliances for over 5 yrs, but no longer than 15 yrs (mean 9.8 +/- 5.2). The mean time of edentulism was 17 years +/- 10. Most of the participants had used 2 sets of dentures prior to their recruitment to the study. All participants had skeletal Class I with a tendency to class III (ANB angle 1.7^0 +/- 0.8^0), which is typical of long-term use of complete dentures with decreased occlusal vertical dimension. Exclusion criteria were the presence of major medical problems or severe chronic diseases, oral disorders of soft or hard tissue, mandibular dysfunction and any pathology affecting mandibular movements.

New dentures were manufactured according to the structural standards used by the Department of Prosthetic Dentistry. During the determination of the vertical dimension of occlusion, physiologic rest position as a reference to the occlusal vertical dimension was used [13-17]**.** Additionally, during the procedure, cephalometric analysis was used to evaluate and verify the occlusal vertical dimension. Electromyographic and occlusal analysis was carried out to monitor the treatment. In order to analyze and determine changes in the occlusal vertical dimension, lateral radiographs were taken with the old dentures. Radiographs were analyzed according to Ricketts measurements for hard tissue evaluation [18] (*Fig.1*).

To determine the change in the occlusal vertical dimension, cephalometric X-ray with the old dentures in the intercuspal position was performed. It was planned to increase the occlusal vertical dimension regarding mandibular rotation during denture replacement. Additionally, the radiographs were carried out on the first day of delivery of the new dentures, in order to confirm the compatibility of the occlusal vertical dimension with the measurements made previously. After three months (final adaptation) of wearing the new dentures, consecutive radiographs were performed to observe any possible changes. Lateral standardized cephalograms were taken of each subject by a technician using the same X-ray device and standardized procedure: the distance between the focus and the mid-sagittal plane was 152 cm, and between the film and the mid-sagittal plane was 10 cm. The values measured were not corrected for linear enlargement. The patient was not allowed to swallow through the X-ray performance. A single examiner performed all cephalometric measurements. Subsequently, the new dentures were made and changes in skeletal measurements, hyoid bone position, muscular activity and occlusal parameters were observed. The vertical position of the hyoid bone in relation to the mandibular base was defined as the perpendicular distance from point hy (most anterior-superior point on the hyoid bone) to the mandibular line (ML), and the horizontal position as the distance from point hy to the mandibular line perpendicular

Figure 1. **Morphological measurements according to Ricketts for hard tissue evaluation.**



A (subspinale): the deepest point in the midsagittal plane between the anterior nasal spine and prosthion, **ANS** (anterior nasal spine): the anterior point of the nasal floor, **B** (supramental) : the deepest point in the midsagittal plane between infradental and Pg, **Co** (condylion) : the most superior posterior point on condyle, **FC** (facial centre) : intersection of the Frankfort plane and the perpendicular through the posterior side of the pterygomaxillary fissure, **Gn** (gnation): most anterior and lowest point of the symphysis, **Me** (menton) : the lowest point of the contour of the mandibular symphysis, **N** (nasion) : most anterior point of nasofrontal suture in the midsagittal plane, **Or** (orbitale) : the lowest point on the margin of the orbit, **Pm** (suprapogonion): point where curvature of the anterior contour of the symphysis changes from concave to convex, **Po** (porion) the midpoint on the upper edge of the external auditory meatus, **S** (sella) middle point of sella turcica, **Xi** (xilion) the point placed in the center of the mandibular ascending ramus, determined by the Frankfort plane and pterygomaxillary fissure, **N-FC-A** : used in the determination of the maxillary height, **ANS-Xi-Pm** : used in the determination of the lower facial height, gonial angle, Facial axis angle (Ba-N/ Pm –Gn).

(MLP). The evaluation of muscular activity was performed using the Biopak Electromyography Recording System (BioResearch, Inc, Milwaukee, WI) synchronized with the T-Scan II Occlusal Analysis System (Tekscan, Inc, Boston, MA). Recordings were made in the intercuspal position during clench with the old dentures, on the first day of delivery of the new dentures, two weeks later (primary adaptation) and three months after replacement (final adaptation). The Biopak EMG System records electrical activity from 8 muscles: the anterior temporalis, masseter, digastric and the sternocleidomastoid simultaneously. Surface EMG measurements were obtained by means of adhesive bipolar Ag/AgCl electrodes with an inter-electrode separation of 19 mm (center to center). The electrodes were attached to the skin, over the palpated main bulk of the contracted muscle and oriented parallel to the general direction of the muscle fibers.

Table 1. **Results of parameters of lateral craniofacial forms. Means and ± SD are reported.**

		Referencevalues	Old dentures	1st day of delivery	3 months later
Distance	N-ANS		56 ± 4	57 ± 4	56 ± 5
analysis	N-Me	106 – 136	123 ± 10	129 ± 8*	128 ± 10*
(mm)	ANS-Me		67 ± 9	73 ± 6*	72 ± 8*
	Co-Gn	120 – 130	127 ± 7	127 ± 7	128 ± 7
	Co-Go		68 ± 10	65 ± 6	65 ± 5
Angle	N-FC-A	53º ± 0.4º	58.8 ± 4.1	58.3 ± 3.8	58.5 ± 4.0
analysis	ANS-Xi-Pm	47º ± 4º	41 ± 6	47 ± 3*	46.9 ± 3.6*
(degree)	Gonial angle	122º ± 6,9º	130 ± 6	129 ± 6.6	129 ± 7.3
	Facial axis angle	90º ± 3º	94 ± 7	91 ± 4	92 ± 5

N (nasion): most anterior point of nasofrontal suture in midsagittal plane,
Me (menton): lowest point of the contour of mandibular symphysis,
ANS (anterior nasal spine): anterior point of nasal floor,
Co (condylion): most superior posterior point on condyle,
Gn (gnation): most anterior and lowest point of symphysis,
N-FC-A used in determination of the maxillary height,
ANS-Xi-Pm used in determination of lower facial height,
Facial axis : Ba-N/ Pm –Gn.
* statistical significance of differences in mean values (P<.01) in relation to old dentures

Table 2. **Vertical and horizontal hyoid bone position in relation to the mandible (mm). Means and ± SD are reported.**

	Old dentures	1st day of delivery	3 months later
Hy ML	23±6	19±5*	19±5*
Hy MLP	46±8	43±5*	45±7

Hy ML- vertical position = perpendicular distance from point hy to the mandibular line (ML),
Hy MLP-horizontal position =distance from point hy to mandibular line perpendicular (MLP).
* statistical significance of differences in mean values (P<.05) in relation to old dentures

The T-Scan II Occlusal Analysis System allows for the quantification of occlusal contact data. The system consists of a sensor and a support, the handle assembly, the processing unit, software and a printer (Tekscan, Inc). When a patient closes his jaws firmly on the sensor, the resultant reduction in electric resistance is translated into an image on the screen. The integration and synchronization of the two separate systems affords the operator a real-time recording of occlusal contacts and the electrical potential of selected masticatory muscles in dynamic movie form [19,20].

The data were reported as means and standard deviations (SD). The Kolmogorov–Smirnov 1-sample test for testing the distribution of the variable for normality was used. The Student's test for samples with a normal distribution was applied. The statistical package Statistica 5.0 was used for statistical calculations. Differences with $P<0.05$ were considered statistically significant.

The protocol was approved by the Institutional Bioethic Committee. Informed written consent was obtained from the patients.

RESULTS

Tab. 1 shows the differences in skeletal parameters after an increase in the occlusal vertical dimension. The distance N-Me, ANS-Me and ANS-Xi-Pm angle in the new dentures, which are habitual for the occlusal vertical dimension, were statistically different compared with the old dentures ($P<0.01$). The mean value of ANS-Xi-Pm in the new dentures was comparable with the reference value of this angle. Similar observations have been made for the facial axis. The gonial angle was higher than the reference, being typical for edentulous patients.

As a consequence of the occlusal vertical dimension changes, displacement of the hyoid bone position was found (*Tab. 2*). The vertical position of the hyoid bone (hy ML) had sufficiently decreased in comparison with the old dentures ($P<0.05$). A similar association was found with regard to the horizontal position (hy MLP), but this result was not statistically significant. The vertical position of the hyoid in relation to the mandibular plane (hy ML) was negatively correlated with the angle of the facial axis ($r= - 0.488$, $P<0.05$). A significant positive correlation of the hyoid horizontal position (hy MLP) was found with respect to the facial axis angle ($r= 0.517$, $P<0.05$), and a positive correlation was observed in relation to N-Me and ANS-Me distances and the ANS-Xi-Pm angle ($r= 0.456$, $r= 0.414$, $P<0.05$).

Muscular activity of the temporales, masseters and digastrics in occlusion on the first day of new denture insertion was significantly different compared with that in old dentures (*Tab. 3*). However, this reduced activity was maintained only for the digastrics through the three-month period of observation ($P<0.05$). A positive correlation was found between the muscular activity of the digastrics and the vertical position of the hyoid bone (hy ML), ($r= 0.542$, $P<0.05$).

Table 3. **Muscle activity levels (μV) registered using the Biopak EMG system. Means and ± SD are reported.**

	Old dentures		1st day of delivery		2 weeks later		3 months later	
	clench	open	clench	open	clench	Open	clench	open
MTL	37±20	12±9	28±15*	11±8	31±15*	13±6	33±10	9±4
MML	34±19	13±11	25±10*	9±5	31±15	10±6	35±10	8±4
MDL	16±6	21±9	8±3*	17±7	8±4*	20±9	8±2*	18±11
STML	9±6	9±6	7±4	11±6	8±5	8±5	9±4	9±6
MTR	43±22	14±12	31±18*	11±7	31±16*	12±6	33±10*	8±3
MMR	38±20	12±10	27±10*	9±3	34±16	11±6	36±10	8±4
MDR	16±7	22±11	7±3*	17±8	8±4*	20±11	8±1*	17±13
STMR	8±4	9±4	8±5	10±7	8±6	9±6	7±4	8±5

MT- temporalis anterior muscle, MM- masseter muscle, MD- digastric muscle, STM- sternocleidomastoid muscle, L-left, R-right
* statistical significance of differences in mean values (P <0.05) in relation to old dentures

Table 4. **Occlusal analysis performed using the T-Scan II System (s). Means and ± SD are reported.**

	Old dentures	1st day of delivery	2 weeks later	3 months later
TO	0.43±0.18	0.42±0.13	0.41±0.17	0.36±0.1*
TD right	0.56±0.38	0.48±0.19	0.44±0.16	0.37±0.1*
TD- left	0.51±0.31	0.45±0.15	0.43±0.18	0.40±0.1*

TO- time of occlusion=time from first contact of occluding teeth to maximal intercuspidation
TD- time of disclusion= time from maximal intercuspidation to complete disclusion during lateral movement
* statistical significance of differences in mean values (P<.05) in relation to old dentures

To evaluate the occlusal conditions, parameters such as the time of occlusion (time from the first contact of occluding teeth to maximal intercuspidation) and the time of disclusion (time from maximal intercuspidation to complete disclusion during lateral movement) were used (*Tab. 4*). The time of occlusion and the time of disclusion left and right decreased within the three months and the difference was significant compared with the old dentures (P <0.05).

DISCUSSION

No single, reliable method is recognized as giving a precise determination of the occlusal vertical dimension in edentulous patients because of limited reproducible reference structures of orientation. In this study, it was decided to use cephalometric analysis for these purposes. This method would appear to be reliable and reproducible due to the advantageous conditions for the use of cephalometic X-ray.

A number of reference measurements such as the ANS-Xi-Pm angle were used to describe the lower facial height. This measurement related directly to the occlusal vertical dimension. It has been reported that the occlusal vertical dimension in edentulous patients suffering from advanced mandibular alveoral ridge resorption was reduced probably due to attempts to achieve denture stability [14]. Furthermore, different recordings of the rest position may be found between treatment visits and even during the same visit in the same patient [13,15-17]. Thus, restoration of the former oral conditions was made on the pattern of dentate subjects concerning with the ANS-Xi-Pm angle.

The observation regarding the position of the hyoid bone during denture replacement suggests that the reduced occlusal vertical dimension is associated with a decrease of the hyoid position. It is unclear whether this reduction increases mandibular ridge resorption and, consequently, produces positional instability of the lower denture [5]. It is difficult to predict whether the position of the hyoid bone will remain stable over a longer period of time. This may affect its vertical, but not necessarily perpendicular, position in relation to the mandible. The main reason for the large variability in the position of the hyoid bone is the multidimensional activity of the hyoid bone muscle groups.

Muscular activities were altered after complete denture replacement in the studied patients. Not surprisingly, a decrease in activity was observed on the first day of delivery. During the adaptation process, the muscular activity of the temporales and masseters gradually increased. It has been suggested that during this period of three months, the activity of the masseters and temporales returned to a level similar to that found with the old dentures [3]. This was not observed in relation to the digastric muscles which remained at a low level of activity during clench throughout the duration of the study. There are contradictory reports as to whether muscular activities and facial morphology affect each other [6,7,12]. However, a patient has the possibility of adapting to an increase in the vertical dimension due to muscular function [9].

There is no published data concerning occlusal analysis with regard to the time of occlusion and disclusion among patients wearing complete dentures. The significance of the occlusion time is based on a measure of the degree of the bilateral simultaneous contacts. It is known that in subjects with their own natural dentition, teeth can occlude simultaneously in 0.1 seconds or less and that all teeth can measurably disclude immediately in less than 0.3-0.5 seconds [19]. The closer to 0.1 second that passes from the first to the last contact, the better the right side to left side, and the better the antero-posterior simultaneity is. So, the overall occlusal force balance is consequently distributed throughout the arch in a better way. This result indicates that the adaptation to the occlusal design occurs and muscular responses to the masseters and the temporales are considerably improved [20].

CONCLUSIONS

Increase in the occlusal vertical dimension in patients suffering from prolonged edentulism appears to lower the pre-treatment hyoid bone position. In addition, muscular activity levels, resultant from the increase in vertical dimension, appear to initially drop when new dentures are installed, only to return to near pre-treatment levels after a few months of new denture use. Despite the fact that radiographic determination of occlusal vertical dimension has been accomplished with variable treatment acceptance, in this study it was observed that cephalometric analysis can aid in recording the occlusal vertical dimension in edentulous patients.

REFERENCES

1. Preti G. Load transfer, tissue reaction and oral function in mandibular implant-retained overdentures. In: Zarb G, Lekholm U, Albrektsson T, Tenenbaum H. Aging, osteoporosis and dental implants. Hong Kong: Quintessence 2002; p.161-7.

2. Bassi F, Deregibus A, Previgliano V, Bracco P, Preti G. Evaluation of the utility of cephalometric parameters in constructing complete denture. Part I: placement of posterior teeth. J Oral Rehabil. 2001 Mar;28(3):234-8.

3. Piancino MG, Farina D, Talpone F, Castroflorio T, Gassino G, Margarino V, Bracco P. Surface EMG of jaw-elevator muscles and chewing pattern in complete denture wearers. J Oral Rehabil. 2005 Dec;32(12):863-70.

4. Lund JP. Mastication and its control by the brain stem. Crit Rev Oral Biol Med. 1991;2(1):33-64.

5. Tallgren A, Lang BR, Walker GF, Ash MM Jr. Changes in jaw relations, hyoid position, and head posture in complete denture wearers. J Prosthet Dent. 1983 Aug;50(2):148-56.

6. Serrao G, Sforza C, Dellavia C, Antinori M, Ferrario VF. Relation between vertical facial morphology and jaw muscle activity in healthy young men. Prog Orthod. 2003;4:45-51.

7. Farella M, Michelotti A, Carbone G, Gallo LM, Palla S, Martina R. Habitual daily masseter activity of subjects with different vertical craniofacial morphology. Eur J Oral Sci. 2005 Oct;113(5):380-5.

8. Walther W. Determinants of a healthy aging dentition: maximum number of bilateral centric stops and optimum vertical dimension of occlusion. Int J Prosthodont. 2005 Jul-Aug;18(4):287-9.

9. Nakai N, Abekura H, Hamada T, Morimoto T. Comparison of the most comfortable mandibular position with the intercuspal position using cephalometric analysis. J Oral Rehabil. 1998 May;25(5):370-5.

10. Brzoza D, Barrera N, Contasti G, Hernández A. Predicting vertical dimension with cephalograms, for edentulous patients. Gerodontology. 2005 Jun;22(2):98-103.

11. Koller MM, Merlini L, Spandre G, Palla S. A comparative study of two methods for the orientation of the occlusal plane and the determination of the vertical dimension of occlusion in edentulous patients. J Oral Rehabil. 1992 Jul;19(4):413-25.

12. Moriya Y, Tuchida K, Moriya Y, Sawada T, Koga J, Sato J, Nishikawa M, Takizawa T, Uematsu H, Ozaki T, Gionhaku N. The influence of craniofacial form on bite force and EMG activity of masticatory muscles. VIII-1. Bite force of complete denture wearers. J Oral Sci. 1999 Mar;41(1):19-27.

13. Unger JW. Comparison of vertical morphologic measurements on dentulous and edentulous patients. J Prosthet Dent. 1990 Aug;64(2):232-4.

14. Boucher CO. Boucher's prosthodontic treatment for edentulous patients. 11th ed. St. Louis: Mosby Inc; 1997. Chapter 5, Occlusion for the edentulous patients; p. 263-78.

15. Atwood DA. A cephalometric study of the clinical rest position of the mandible. Part III. Clinical factors related to variability of the clinical rest position following the removal of occlusal contacts. J Prosthet Dent. 1958;8:698-708.

16. Atwood DA. A cephalometric study of the clinical rest position of the mandible. Part I. The variability of the clinical rest position following the removal of occlusal contacts. J Prosthet Dent. 1956;6:504-19.

17. Tallgren A. Changes in adult face height due to aging, wear and loss of teeth and prosthetic treatment; a roentgencephalometric study mainly on Finnish women. Acta Odontol Scand. 1957;15(24):1-12.

18. Ricketts RM. The role of cephalometrics in prosthetic diagnosis. J Prosthet Dent. 1956;6:488-503.

19. Kerstein RB. Combining technologies: a computerized occlusal analysis system synchronized with a computerized electromyography system. Cranio. 2004 Apr;22(2):96-109.

20. Kerstein RB, Grundset K. Obtaining bilateral simultaneous occlusal contacts with computer analyzed and guided occlusal adjustments. Quint Int. 2001;32:7-18.