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Progress Report on Pressures Exerted on Complete Dentures During Swallowing

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U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

Pressures Exerted on Complete Dentures During Swallowing

Abstract

The projected areas of the tissue bearing surfaces of dentures were determined by making tracings on tared pieces of cellulose acetate sheets. The upper dentures of 21 patients had projected areas ranging from 22.8 to 36.6 cm^2 (3.5 to 5.7 in^2), the lower dentures from 14.5 to 24.4 cm^2 (2.2 to 3.8 in^2). The areas of the upper dentures were from 1.2 to 1.9 times the area of the lower dentures. The forces exerted on complete dentures during swallowing were measured by a Brinell indentation method employed in a modified "Coble Intra-Oral Balancer". Forces ranged on the average from 1.5 to 15.8 kilograms (3.3 to 34.8 lb). The pressure on the upper dentures ranged on the average from 0.06 to 0.56 kg/cm^2 (0.85 to 8.0 lb/in^2); for the lower dentures 0.09 to 0.80 kg/cm^2 (1.3 to 11.4 lb/in^2).

Introduction

There has been a continuing clinical and physical research on twelve organic denture bases since 1957 in the laboratories of the Dental Research Section of the National Bureau of Standards. Twenty one of the complete denture cases begun in 1957 and 1958 were available in 1964 for a determination of the projected areas of the tissue supporting surfaces of the dentures and for measurement of the force exerted on the dentures during swallowing. From these findings the pressure exerted on the supporting tissues could be calculated. The ultimate aim of the investigation is the development of waxes with the proper flow characteristics for use in taking functional impressions or perhaps even for the temporary relining of dentures or as tissue treatment materials.

Review of the literature.-- Haber [1] in his book published in 1926 "Die Aufgaben der Kaudruck-Messung- und der Zahndruck Prufung" gives an excellent history of the investigations of the forces exerted on the human dentition and artificial substitutes for it. The earliest record he could find was that of Professor Borelli [1] of Italy in 1681. The instruments used for measuring intra-maxillary forces were devided by Haber into four classes:

Those based on displacement of a calibrated lever or a spring; a hydraulic system; a combination of the foregoing; or an indentation method. While work had been done earlier by Schönwaldt and Günther [1] it appears that the first published work on the indentation method, similar to that employed in the Brinnel test for hardness, was done by Köhler and Etling [2]. They employed a steel ball 5.73 mm in diameter which was stuck into the fossa of a posterior tooth with wax. A metal plate of rolled tin or cast tin or of solder (90% lead and 10% tin) was held in position in the opposing teeth with cement or modeling compound. The ball was forced into the metal when the jaw closed. The area of the resulting indentation was used to obtain the force exerted on the ball.

Both resistance [3] and inductance [4] strain gages have been used to measure force exerted on dentures. A mathematical analysis method has also been proposed [5]. Mahler [6] has used a tiny transducer employing wire strain gages between subject's teeth to measure the force capability of an individual. Finnegan [7] determined the intermaxillary force during swallowing in two partially edentulous patients by an intra-oral hydraulic system monitored with a resistance strain gage. He reported forces ranging from 150 to 600 grams (0.33 to 1.33 lb) for one subject and from 150 to 1450 grams (0.33 to 3.20 lb) for the other. There was a linear relationship between the force and the vertical dimension at the lower occlusal levels, but this did not hold at the greatest openings of the lower jaw.

Measurement of the projected areas of the tissue-supporting surfaces of dentures.-- The projected areas of the tissue-bearing surfaces were determined by making tracings on tared pieces of cellulose acetate sheet. Five strips each 10 cm wide, 70 cm long and 185 ± 5 microns thick were cut from those sections of a large sheet which had the most uniform thickness. The strips were conditioned at 23 ± 2°C and 50 ± 10 percent relative humidity. Sections of the strips were measured on a toolmakers microscope and with a hand micrometer caliper. The areas of these sections were plotted in

relation to their wieght. The area-weight ratio of the selected portions varied from 41.6 to 42.5 cm^2/g (2.9 to 3.0x 10^3 in^2/lb).

The actual tracings were made with the simple device shown in Figure 1. The cutouts of the projected areas ranged from 22.8 to 36.6 cm^2 (3.5 to 5.7 in^2) for the upper dentures and from 14.5 to 24.4 cm^2 (2.2 to 3.8 in^2) for the lower dentures (Figure 2). The extremes of the ranges were on the same sets of complete dentures. The projected area of the upper dentures was from 1.2 to 1.8 times that of the lower dentures in individual sets. Measurements of the areas of the dentures could be repeated to ± 2%. Data on individual dentures are in Table 1, columns 6-8.

Measurement of the vertically applied forces exerted on the tissues by patients with complete dentures during swallowing.-- About 30 years ago Coble [8] developed a small intra-oral device to aid in establishing jaw relationship and specifically for use in balancing the occlusion of dentures in place. This "Coble Intra-Oral Balancer" was modified by mounting a steel ball 1.59 mm (0.0625 in) in diameter on the end of the tracing pin of the upper member of the balancer as shown in A of Figure 3. The lower member of the balancer as modified is shown mounted in a lower denture in B of Figure 3. A new pin on which a metal disk is mounted is shown in place on the lower member of the balancer. The disk is rotated after each swallow so that the steel ball of the upper member can make a series of indentations in the metal disk when the jaws are brought together during swallowing. The modified Coble instrument provides a central bearing point which permits a relatively equal distribution of stress over the tissues which support the dentures.

The pin containing the ball indenter screws into the upper member so the indenter may be raised or lowered. In practice the ball was in contact with the metal disk when there was about one millimeter between the upper and lower teeth as shown in the rear view of the mountings (Figure 4). The chief disadvantage of the method is the crowding of the tongue in the back of the mouth as shown in Figure 5. However, most patients seemed to accommodate this abnormality readily; some patients experienced hardship in swallowing when the device was in place. There was also some difficulty in having the patient close the jaws precisely vertically without lateral motion. This caused a groove instead of a spherical indentation to be made in the metal disk. Some of these grooves are apparent on the indentations shown on the disk in Figure 3-B. The skidding of the ball due to lateral movements of the mandible was much more troublesome on the disks of the harder metals and alloys.

The metal disks into which the ball penetrated were made from rolled lead sheet, rolled solder consisting of 50 percent lead and 50 percent tin, cold-rolled copper, cold rolled brass, aluminum alloy 2024-T3, and cold finished carbon steel AlSl 1015-1020. These disks were idented by forcing the ball into them with a one second application of the load. The relationship between the diameters of the indentation and the loads on the metal disks is shown in Figure 6.

Data in Table 1, columns 10-14, not only show a wide variation in the forces on the dentures during swallowing among the various patients but also a wide variation often in individual patients. The average values of the forces for individual patients ranged from 1.5 to 15.8 kilograms (3.3 to 34.7 lb). The values could not be correlated with the sex, age, height, or weight of the patients (Table 1, columns 2-5). Sometimes the heaviest closure force that one patient would exert would be five times as great as the lightest in the series. The pressures on the tissues ranged from the average from 0.06 to 0.56 kg/cm^2 (0.85 to 8.0 lb/in^2) for the upper dentures. Of course, the stress per unit area would be higher on the lower dentures since they have a smaller projected area than the upper dentures. The range was from 0.09 to 0.08 kg/cm^2 (1.3 to 11.4 lb/in^2). The relation between the pressures exerted on the upper and lower dentures is the same as the relation between the projected areas (Table 1, column 8) as the average closing force is the same on both dentures.

Recent studies have shown that 20 young adults swallowed on the average about 600 times in 24 hours [9]. Thus, the tissues that support the dentures must endure many applications of stress.

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TABLE 1

The Projected Areas of the Tissue Bearing Surface of Complete Dentures and the Forces Exerted on the Dentures During Swallowing

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Denture	Sex	Age	Height	Weight	Projected Area		Ratio	Number of Swallows	Average Closing Force	Heaviest Closure Force	Lightest Closure Force	Average Force Per Unit Area	
					Upper Denture	Lower Denture						Upper Denture	Lower Denture
					Cm^2*	Cm^2*			Kg**	Kg**	Kg**	Kg/Cm^2***	Kg/Cm^2***
A-149-V-4/5	M	54	5'11½"	184	27.2	14.0	1.9	66	9.3	12.3	5.0	0.34	0.66
A-167-L-6	M	56	5'10"	176	30.1	17.2	1.8	21	4.0	6.4	2.8	0.13	0.23
A-167-T-5/6	M	64	5'7½"	170	28.7	19.8	1.5	27	15.8	26.6	7.9	0.55	0.80
A-149-V-2/3	M	68	5'9"	150	27.4	19.2	1.4	17	3.6	5.0	2.7	0.13	0.19
A-149-J-1/2	M	60	5'7"	164	36.6	24.4	1.5	37	7.0	9.1	3.5	0.19	0.29
A-167-T-9 and A-8	M	45	5'9"	156	27.0	16.3	1.7	16	5.1	7.5	3.8	0.19	0.31
A-149-E-4/5	M	64			23.0	17.4	1.3	15	4.8	6.9	3.4	0.21	0.28
A-167-H-9/10	F	66	5'1"	160	22.5	11.3	1.9	33	2.8	6.4	1.3	0.12	0.25
A-167-H-6/7	M	49	5'9½"	174	28.1	17.8	1.6	16	5.3	7.5	2.7	0.19	0.30
A-149-D-3/4	M	61	5'9"	176	28.6	17.2	1.7	17	4.4	7.6	2.3	0.15	0.26
A-149-L-2/3	F	69	5'1"	160	25.4	15.8	1.6	18	1.5	2.2	0.9	0.06	0.09
A-149-J-5/6	F	47	5'6"	135	27.5	15.6	1.8	16	2.8	3.9	2.0	0.10	0.18
A-149-T-3/4	F	56	5'4½"	136	24.1	14.6	1.6	15	4.2	2.9	6.9	0.17	0.29
A-149-E-2/3	M	48	5'5½"	175	22.8	14.5	1.6	23	2.3	3.0	1.2	0.10	0.16
A-167-VUL-1/2	M	81	5'11"	198	32.8	21.6	1.5	20	4.5	12.5	2.5	0.14	0.21
A-149-H-3/4	M	71	5'6"	150	32.6	20.9	1.6	24	4.1	9.7	2.5	0.13	0.20
A-149-J-3/4	M	73	5'7"	151	26.9	17.1	1.6	14	3.0	4.2	1.6	0.11	0.18
A-167-E-6/7	M	73	5'9"	130	31.7	20.8	1.5	20	2.7	4.8	2.2	0.09	0.13
A-167-V-6/7	M	51	5'8"	160	26.2	17.0	1.5	13	3.3	2.0	1.0	0.06	0.09
A-149-H-1/2	M	70	5'9"	155	20.6	17.5	1.2	20	4.9	7.7	2.6	0.24	0.28
A-167-D-6/7	F	66	5'4"	140	24.2	18.5	1.3	25	13.6	22.7	5.0	0.56	0.74

* To convert to square inches multiply by 0.155
** To convert to pounds multiply by 2.2
*** To convert to pounds per square inch multiply by 14.22

Figure 1. Apparatus used in obtaining tracings of the projected areas of the tissue-bearing surfaces of complete dentures.

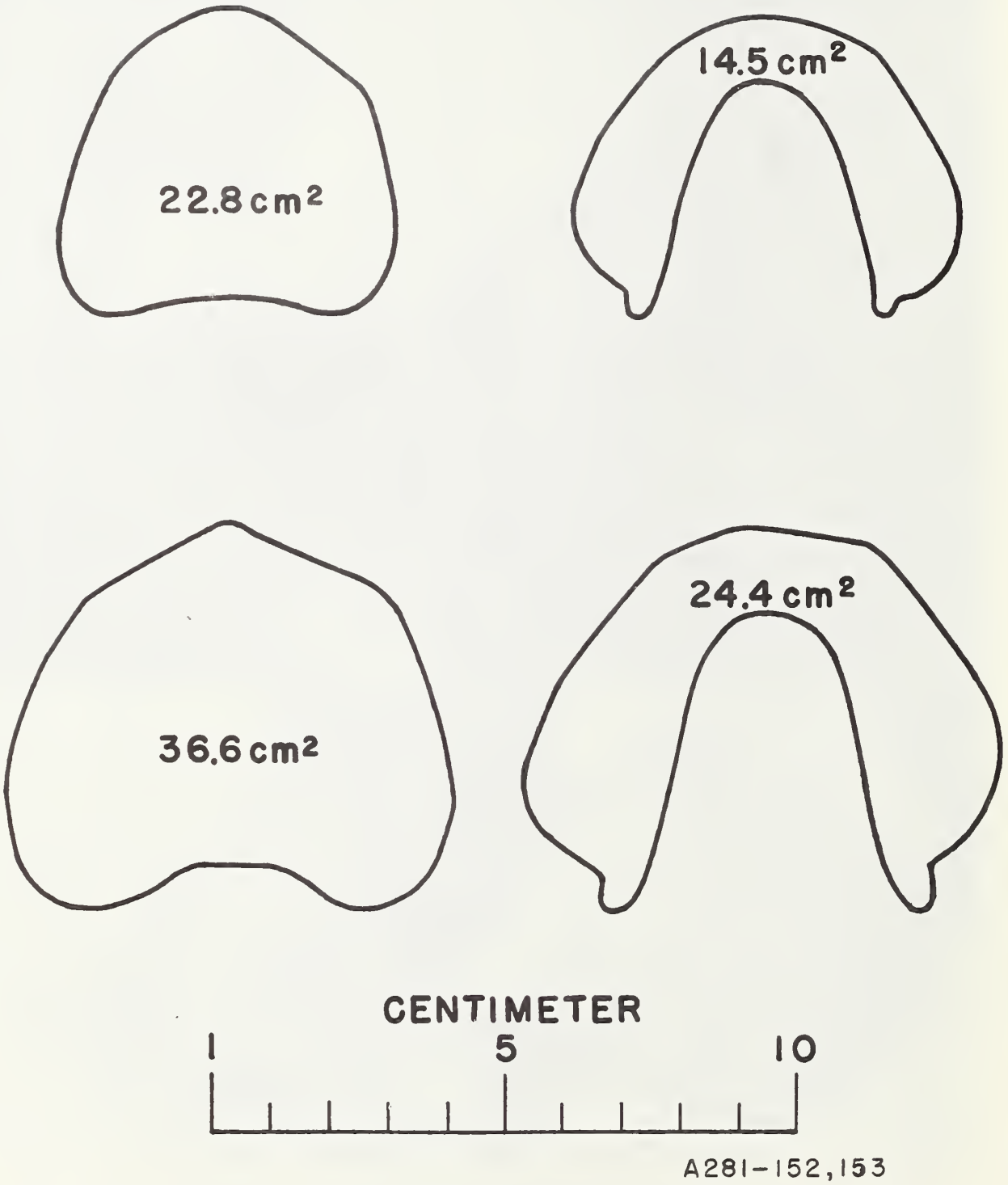

Figure 2. The smallest and largest projected areas of the tissue-bearing surface of individual sets of complete upper and lower dentures.

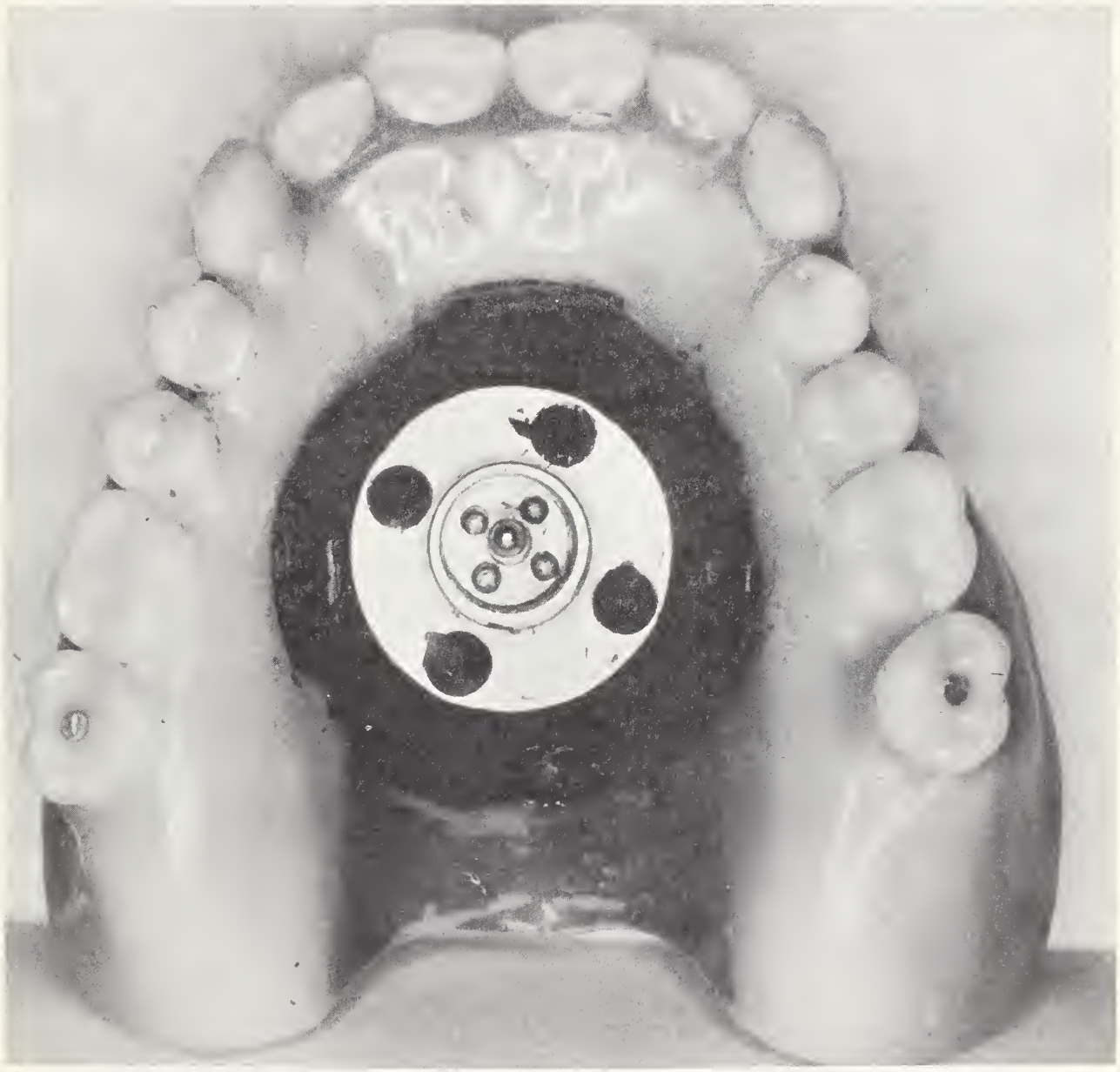

Figure 3-A. Modified "Coble Intra-Oral Balancer" mounted in upper denture.

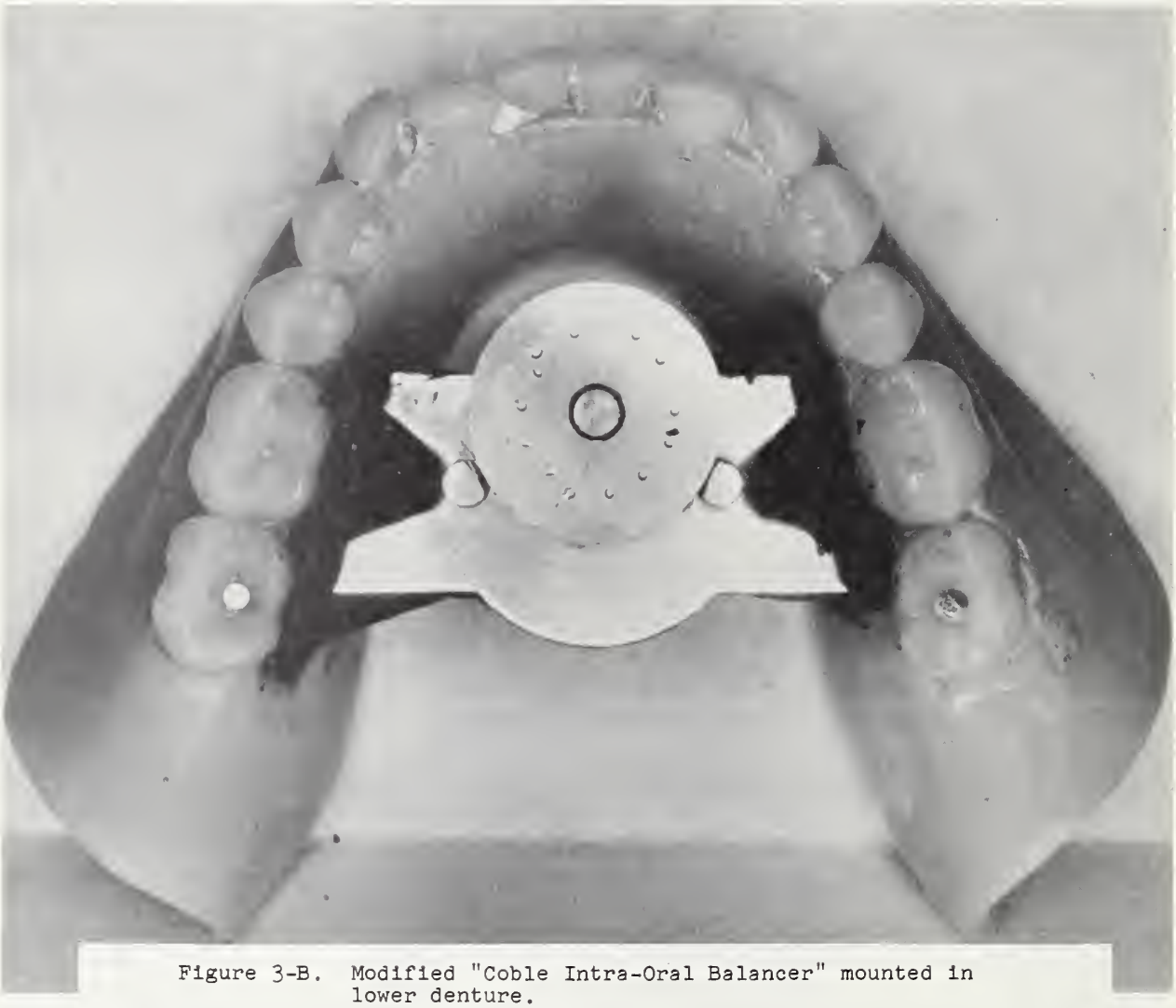

Figure 3-B. Modified "Coble Intra-Oral Balancer" mounted in lower denture.

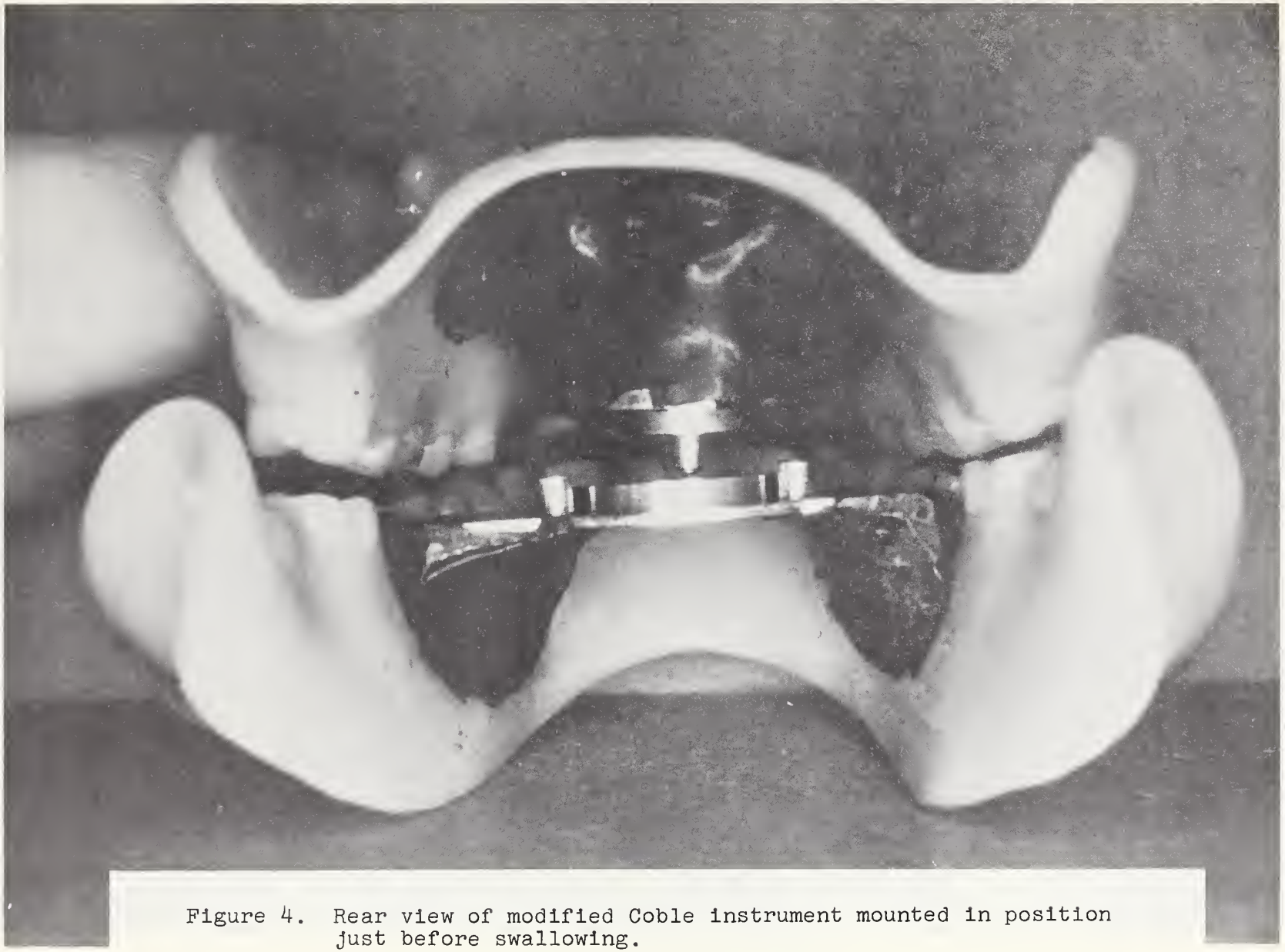

Figure 4. Rear view of modified Coble instrument mounted in position just before swallowing.

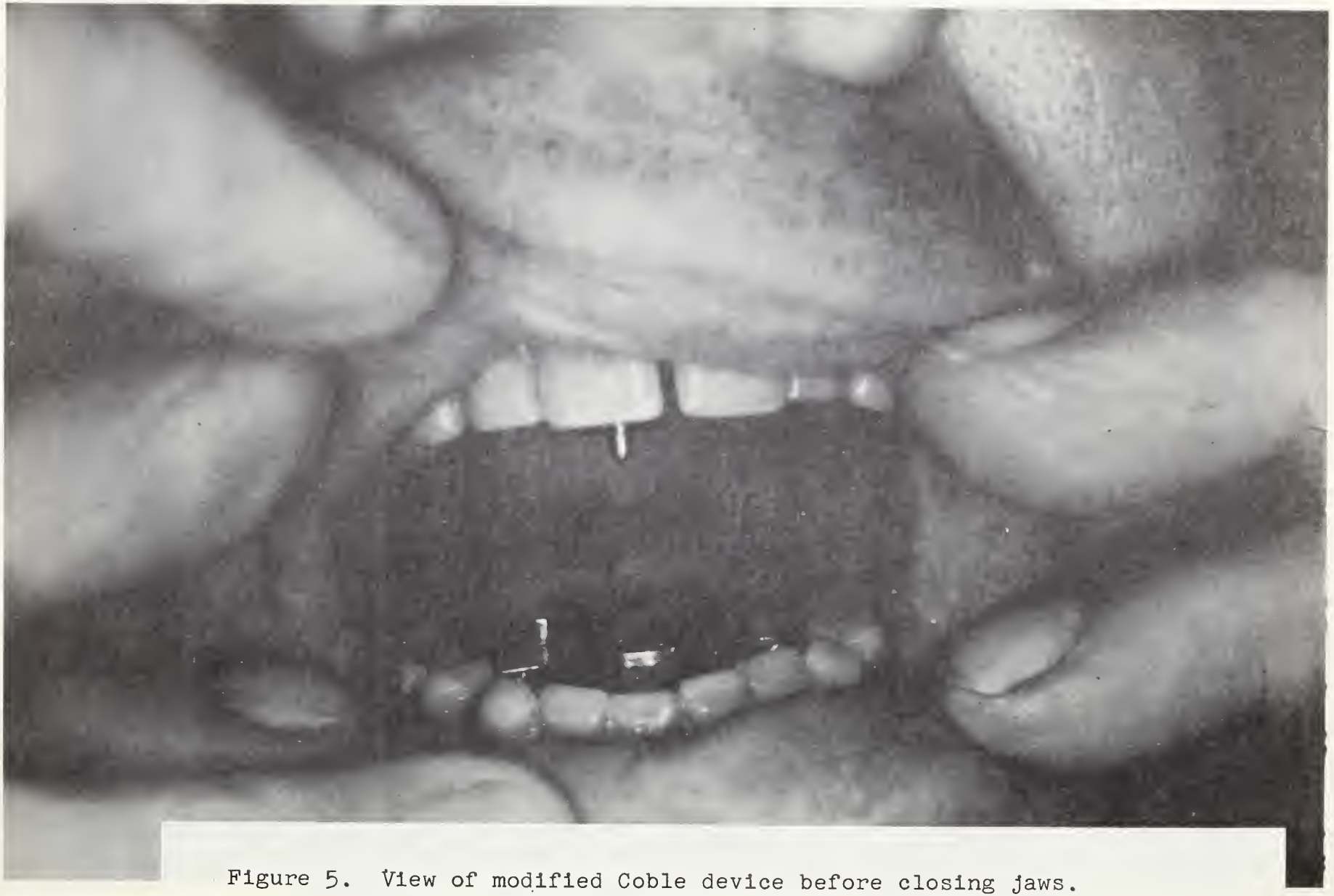

Figure 5. View of modified Coble device before closing jaws.

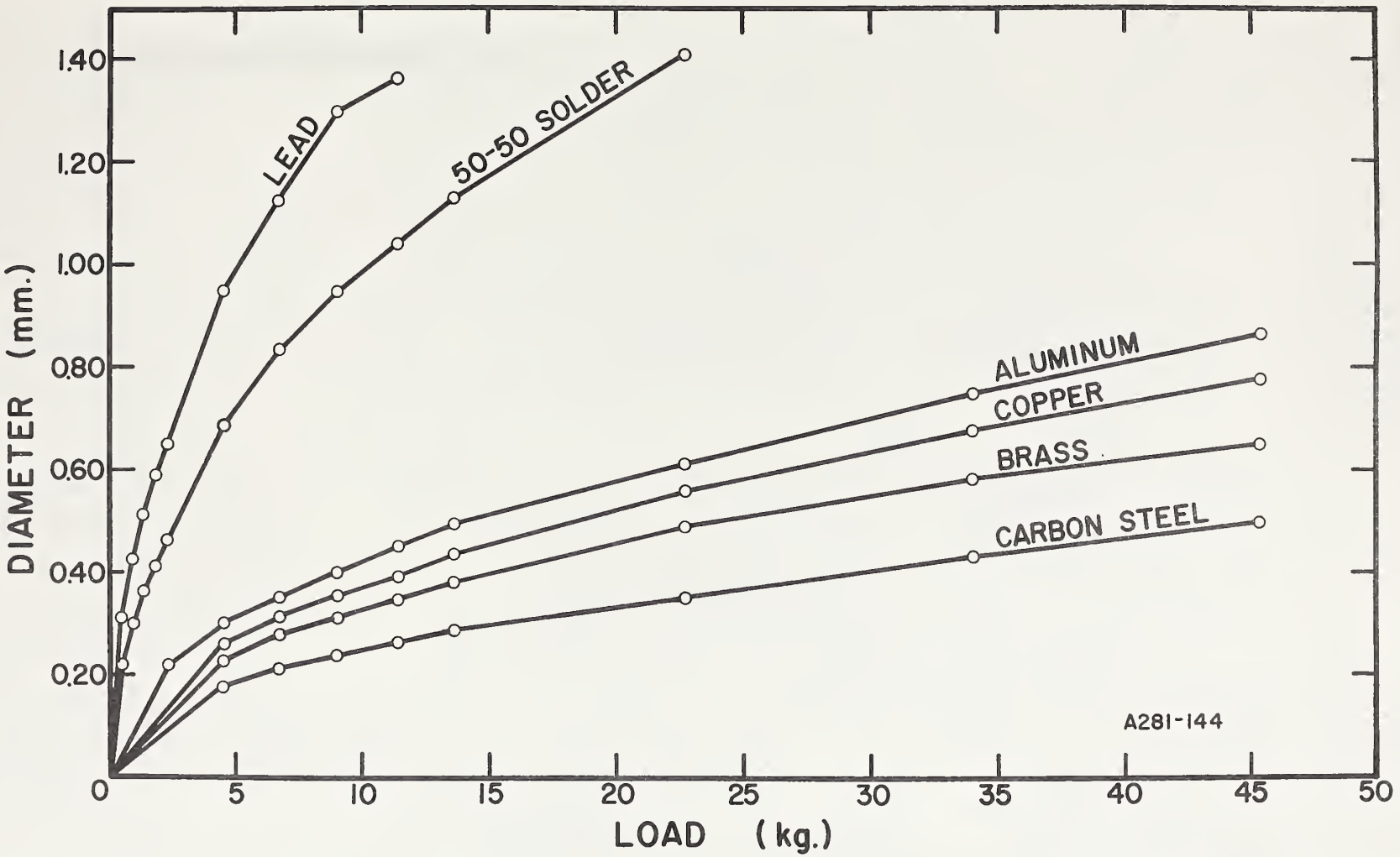

Figure 6. Relation between diameter of indentation and load.