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Oral and pharyngeal phases of swallowing in removable complete denture wearers

Fases oral e faríngea da deglutição em usuários de prótese dentária total removível

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ABSTRACT

Objective: To compare swallowing and bolus transit time through the oral cavity and pharynx between well-fitted complete denture wearers and toothed individuals. **Methods**: Altogether, 27 complete denture wearers (43 to 77 years old) and 26 controls (41 to 74 years old) were examined with videofluoroscopic swallowing study using liquid, pureed, and solid (crackers and toasts) bolus, twice and in a random sequence. Denture wearers were assessed with and without dentures. **Results**: Individuals wearing dentures had oral residues after swallowing liquid (in 56% of swallows) and pureed boluses (in 71% of swallows) and with toasts (in 41% of swallows), more often than controls (liquid 13%, pureed 43% and toast 15% of

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swallows, p ≤ 0.04). In denture wearers, the oral, upper esophageal sphincter, and pharyngeal transit times were longer after swallowing liquid bolus; the pharyngeal and oropharyngeal transit times were longer after swallowing pureed bolus; and the oropharyngeal transit time was longer after eating crackers. Assessment results without dentures were closer to that of controls when swallowing pureed bolus. Laryngeal aspiration was not observed in any of the individuals. **Conclusion**: Removable complete denture wearers tend to have longer pharyngeal transit time than toothed individuals. Although oral residues and longer pharyngeal transit in individuals wearing dentures increase the risk of airway aspiration, this investigation did not verify such a condition.

Indexing terms: Deglutition. Dental prosthesis. Deglutition disorders.

RESUMO

Objetivos: Comparar a dinâmica da deglutição e trânsito do bolo alimentar na cavidade oral e na faringe entre usuários de próteses totais bem adaptadas e indivíduos dentados. **Métodos**: Vinte e sete usuários de prótese total (43 a 77 anos), avaliados com e sem as próteses, e 26 controles (41 a 74 anos) foram examinados com estudo videofluoroscópico da deglutição com bolos líquido, pastosos e sólido (biscoito e torrada), em duplicata e em sequência aleatória. **Resultados**: Resíduos orais após a deglutição líquida (em 56% das deglutições), na consistência purê (em 71% das deglutições) e com torradas (em 41% das deglutições), foram mais frequentes do que nos controles (líquido 13%, purê 43 % e torradas 15% das deglutições, p ≤ 0,04). Em usuários de próteses os tempos de trânsito oral, trânsito faríngeo e trânsito pelo esfíncter superior do esôfago foram mais longos com o bolo líquido; os tempos de trânsito faríngeo e orofaríngeo foram mais longos com o bolo purê; e o tempo de trânsito orofaríngeo foi mais longo com o biscoito. Os resultados da avaliação sem próteses foram mais próximos dos controles ao engolir bolo pastoso. A aspiração laríngea não foi observada em nenhum dos indivíduos. **Conclusão**: Usuários de próteses totais removíveis tendem a ter maior tempo de trânsito faríngeo do que indivíduos dentados. Embora resíduo oral e longo trânsito faríngeo aumentem o risco de aspiração para vias aéreas, isso não foi observado nesta investigação.

Termos de indexação: Deglutição. Prótese dentária. Transtornos de deglutição.

INTRODUCTION

Swallowing is a complex process that requires coordination between mastication (to prepare the food bolus) and structures directly related to swallowing, such as bones (mandible, maxilla, hard palate, hyoid bone, cervical vertebrae, skull, and styloid and mastoid processes) and cartilages (thyroid, cricoid, arytenoid, and epiglottis). Salivary glands (parotid, sublingual, and submandibular glands) are responsible for producing 95% of the saliva that helps form the bolus and transport it to the esophagus through the oral cavity, oropharynx, and hypopharynx [1].

Swallowing activates various muscles, such as the masticatory, mylohyoid, tensor veli palatini, digastric anterior belly, tensor veli palatini, facial, styloid/hyoid, digastric posterior belly, levator veli palatini, palatopharyngeal, salpingopharyngeal, intrinsic laryngeal, cricopharyngeal, pharyngeal constrictor, intrinsic tongue, hyoglossus, geniohyoid, genioglossus, styloglossus, and thyroid muscles. It also activates six pairs of cranial nerves, namely: the trigeminal (V), facial (VII), glossopharyngeal (IX), vagus (X), accessory (XI), and hypoglossal nerves (XII) [1-3]. The coordination and integrity of all these structures determine the effectiveness and safety of swallowing.

The esophageal phase of swallowing counts also with the participation of striated muscles (in the proximal part of the esophagus) and smooth muscles (in the distal part of the esophagus), with peristaltic contractions that direct the swallowed bolus from the proximal part of the esophagus to the stomach [3].

Among such structures, the teeth have important functions, specifically in the oral phase, as they masticate and grind the food to adequately form the bolus that will be swallowed. They also define maxillary relationships, participate in speech articulation, and stimulate mandible movements through occlusal contact.

Over the years, the teeth can be affected by various oral diseases, such as caries and/or periodontal diseases, whose greatest consequence is tooth loss. Oral rehabilitation with dentures aims to replace the teeth and adjacent structures that have been lost, ensuring satisfactory functional and aesthetic conditions. Besides restoring the stomatognathic system, it aims at the patient's psychic and social well-being. Dentures play an important role in improving mastication and may even have a good performance in oropharyngeal swallowing [4,5].

This study assessed the effects of the absence of teeth and the use of conventional complete dentures on swallowing. It aimed to verify the effectiveness and duration of the oral and pharyngeal phases of swallowing in removable complete denture wearers (both with and without dentures in the assessment) and compare them with individuals who had 24 or more teeth. The hypothesis was that wearing dentures changes these phases of swallowing, in comparison with toothed individuals.

METHODS

Ethical approval

This study was approved by the Human Research Ethics Committee of the Dental School of *Ribeirão Preto* (FORP-USP) (CAAE: 60611716.8.3001.5419) and of the Clinics Hospital of the Medical School of *Ribeirão Preto* (FMRP-USP) (CAAE: 60611716.8.0000.5440). All volunteers signed an informed consent form, and their identities were kept confidential.

Sample

Completely edentulous individuals who wore dentures and received treatment at the Dental School of *Ribeirão Preto* were assessed and invited to participate in the study, thus comprising the experimental group. The control group comprised personally invited toothed individuals. The inclusion criteria for the experimental group were as follows: being completely edentulous, wearing well-fitted removable complete upper and lower dentures, and not having neurological diseases, dysphagia, or xerostomia; the exclusion criteria were poorly fitted dentures, oral diseases, neurological diseases, and swallowing complaints. As for the control group, the inclusion criteria were as follows: people who did not wear dentures, who had at least 24 well-preserved teeth – at least four molars (at least two molars in the lower arch and two in the upper arch) –, and did not have any neurological diseases, swallowing difficulties, or diet restrictions; the exclusion criteria were neurological diseases, xerostomia, and swallowing difficulties.

Videofluoroscopy

The videofluoroscopic swallowing study was performed in an Arcomax angiograph (Philips, model BV 300). The images were recorded at 30 frames per second and then transmitted to a computer through a video capture device (Dazzle Pinnacle Dvcptenam USB) to analyze the images frame by frame. During examinations, participants remained seated at approximately 90º, keeping habitual neck posture, and feet flat on the floor, according to the Frankfurt plane. The equipment was positioned to pick up lateral images of the mouth, pharynx, and proximal esophagus.

The sequence of liquid, pureed, and solid boluses (crackers and toasts) was previously defined in a draw. Denture wearers were first assessed with them.

Then, after a 5-minute interval, a new draw defined the new bolus sequence, and they removed the dentures to be reassessed. Control group participants likewise received the bolus in a random sequence but were assessed only once. Toast swallow was not assessed without dentures to avoid mastication discomfort and difficulty. Toothed and toothless individuals (both with and without dentures) were assessed twice with each type of bolus.

The liquid food was obtained by mixing 12 mL of liquid barium sulfate (Bariogel® 100%, *Cristália*, Brazil) in 28 mL of water, measured with a syringe, and served to participants 10 mL at a time in plastic cups. The pureed food was obtained by mixing 30 mL of liquid barium sulfate and 3.6 g of food thickener (ThickenUp Clear®, Nestle Health Science, Osthofen, Germany) in 70 mL of water, and served to participants 10 mL at a time in spoons. The solid foods comprised 2.5 g crackers with 3 mL of pureed barium sulfate (in the same concentration as described above) and 2 g toasts with 3 mL of pureed barium sulfate (same concentration). Crackers and toasts had to be masticated before swallowing. The liquid food was classified as thin liquid (level 0), the pureed food was classified as extremely thick or puree (level 4), crackers were classified as level 7 (easy to chew), and toasts were classified as level 7 (regular) in the classification proposed by the International Dysphagia Diet Standardisation Initiative (IDDSI) [6,7].

The assessment addressed the presence of residues in the oral cavity (after swallowing), multiple swallows (more than one swallow per bolus), premature loss of part of the bolus from the oral cavity to the pharynx (before beginning the swallowing process), residues of the swallowed bolus in the vallecula and/or pyriform sinuses, and penetration and aspiration of part of the bolus into the airways.

The bolus transit time through the mouth and pharynx was measured as follows:

- Oral preparation time (OPT): the time from lip closure with the bolus inside the oral cavity until the tip of the tongue touches the incisors.

- Oral transit time (OTT): the time from the tip of the tongue touching the incisors (beginning of the oral propulsive phase, causing the bolus to move posteriorly) until its tail passes the mandibular ramus.

- Swallowing reaction time (SRT): the interval between the passage of the head of the bolus by the mandibular ramus and the rapid hyoid movement.

- Velopharyngeal closure time (VPCT): the interval between the laryngeal vestibule closure and its opening.

- Upper esophageal sphincter transit (UEST): time between the beginning of the passage of the head of the bolus through the upper esophageal sphincter (UES) until the bolus completely passes it.

- Pharyngeal transit time (PTT): time from the arrival of the head of the bolus by the mandibular ramus until the bolus completely passes the UES.

- Oropharyngeal transit time (OPTT): time from the tip of the tongue touching the incisors (moving the bolus posteriorly at the beginning of the oral propulsive phase) until the tail of the bolus completely passes the UES.

The response variables encompassed swallowing changes and bolus transit times through the oral cavity and the pharynx. The variation factors were toothless individuals wearing and not wearing dentures, toothed individuals (controls), and types of boluses (liquid, pureed, and solid [crackers and toasts]), randomly assessed twice, without a command to swallow (non-cued swallow).

Statistical analysis

Data are presented as absolute and percentage frequencies (qualitative variables), means, and standard deviations. Data were submitted to mixed (random and fixed) effect linear regression models to compare the groups. The mixed-effect linear models analyzed data with grouped responses (more than one measure per person) when the assumption of independence between observations within each group is not adequate [8]. These models assume that their residues have a normal distribution, with a mean of 0, and constant σ^2 variance; they were analyzed based on charts, addressing histograms, dispersion curves, and quantile-quantile plots. When such an assumption was not verified, the analysis approached transformations in the response variable. Comparisons were made with orthogonal contrast post-test, and groups were compared regarding binary variables with the Poisson regression model with random effects [9]. All analyses were performed in SAS 9.4, and the significance in all comparisons was set at $p < 0.05$.

RESULTS

Based on the inclusion and exclusion criteria, the study recruited 27 denture wearers and 26 controls. None of the study participants withdrew from the research, and all of them had complete and quality examinations for analyses. The 27 edentulous individuals (14 women and 13 men) were 43 to 77 years old (median of 66 years) and had been wearing removable complete upper and lower dentures for at least 1 month and up to 10 years (median of 1 year and 2 months); the dentures were well-fitted at the time of the assessment.

All controls had at least 24 well-preserved teeth at the time of the assessment – 11 individuals (42.3%) had one or more dental implants, while the other ones had only their natural teeth. The control group had 26 volunteers (14 women and 12 men) aged 41 to 74 years (median of 60 years).

The experimental group, when wearing dentures, had frequent bolus residues in the oral cavity after swallowing liquid and pureed foods and toasts, in contrast with the control group (tables 1 and 2). Denture wearers had a premature loss when they were not wearing them to swallow liquid bolus (table 1). Airway penetration was observed only when swallowing liquid food – often in controls and denture wearers (with and without dentures) alike. Laryngeal aspiration was not observed in any of the individuals.

Table 1. Videofluoroscopic swallowing study of qualitative changes in controls (n = 26) and denture wearers (n = 27) with and without dentures when swallowing 10 mL of liquid and 10 mL of pureed bolus. Results in the percentage of swallows.

Qualitative evaluation	Controls	With Dentures	Without Dentures
Liquid bolus			
Oral residue	13.0	56.0*	63.0*
Multiple swallows	7.7	9.6	9.6
Premature loss	23.1	17.3	34.6**
Vallecular residue	25.0	19.2	26.9
Pyriform sinus residue	19.2	9.6	5.7
Pureed bolus			
Oral residue	43.1	71.1*	59.2
Multiple swallows	23.5	15.4	19.2
Premature loss	21.5	21.2	25.0
Vallecular residue	35.3	17.3	19.2
Pyriform sinus residue	13.7	11.5	13.4

Note: *p < 0.01 vs controls; **p = 0.04 vs with dentures.

Table 2. Videofluoroscopic swallowing study of qualitative changes in controls (n = 26) and denture wearers (n = 27) with and without dentures when swallowing crackers and toasts. Results in the percentage of swallows.

Qualitative evaluation	Controls	With Dentures	Without Dentures
Crackers			
Oral residue	27.4	39.6	40.0
Multiple swallows	19.6	16.6	12.0
Premature loss	45.1	47.9	42.0
Vallecular residue	33.0	18.7	14.0
Pyriform sinus residue	0.0	4.1	0.0
Toasts			
Oral residue	25.5	46.1*	-
Multiple swallows	27.6	30.7	-
Premature loss	38.3	44.2	-
Vallecular residue	31.9	13.4	-
Pyriform sinus residue	6.4	1.9	-

Note: *p = 0.04 vs controls.

OTT, VPCT, PTT, UEST, and OPTT of liquid bolus were longer in denture wearers (with and without dentures) than in controls (table 3).

Table 3. Videofluoroscopic swallowing study of the oral and pharyngeal phases of swallowing (in milliseconds) in controls (n = 26) and denture wearers (n = 27) with and without dentures when swallowing 10 mL of liquid bolus.

Swallowing timing	Controls		With Dentures		Without Dentures	
	Mean	SD	Mean	SD	Mean	SD
OPT	470	296	429	314	622	390
OTT	239	76	285	77*	268	81
SRT	94	57	110	71	121	77
VPCT	459	92	513	92*	500	96
UEST	307	71	369	61*	358	53*
PTT	427	81	501	103*	499	100*
OPTT	453	105	541	89*	515	91*

Note: * $p \leq 0.05$ vs controls. OPT = Oral preparation time; OTT = Oral transit time; SRT = Swallowing reaction time; VPCT = Velopharyngeal closure time; UEST = Upper esophageal sphincter transit; PTT = Pharyngeal transit time; OPTT = Oropharyngeal transit time; SD = Standard deviation.

As for pureed bolus, PTT and OPTT were longer among denture wearers than controls – although such times decreased in the test without dentures (table 4).

When swallowing crackers, denture wearers had longer OPT, OTT, SRT, and OPTT (table 5).

As for toasts, denture wearers had longer OPT and VPCT (table 6).

Table 4. Videofluoroscopic swallowing study of the oral and pharyngeal phases of swallowing (in milliseconds) in controls (n = 26) and denture wearers (n = 27) with and without dentures when swallowing 10 mL of pureed bolus.

Swallowing timing	Controls		With Dentures		Without Dentures	
	Mean	SD	Mean	SD	Mean	SD
OPT	1539	1262	1422	1129	1834	1394
OTT	259	115	308	196	280	103
SRT	95	84	124	99	95	70
VPCT	428	139	449	93	443	102
UEST	289	(55	307	52	298	41
PTT	409	109	459	128*	421	72**
OPTT	488	118	567	206*	520	98**

Note: * $p \leq 0.05$ vs controls; ** $p \leq 0.05$ vs with dentures. OPT = Oral preparation time; OTT = Oral transit time; SRT = Swallowing reaction time; VPCT = Velopharyngeal closure time; UEST = Upper esophageal sphincter transit; PTT = Pharyngeal transit time; OPTT =Oropharyngeal transit time; SD = Standard deviation.

Table 5. Videofluoroscopic swallowing study of the oral and pharyngeal phases of swallowing (in milliseconds) in controls (n = 26) and denture wearers (n = 27) with and without dentures when swallowing crackers.

Swallowing timing	Controls		With Dentures		Without Dentures	
	Mean	SD	Mean	SD	Mean	SD
OPT	9159	3181	12590	4494*	14918	4383**
OTT	225)	75	288	104*	281	110*
SRT	76	43	102	50*	96	45
VPCT	368	92	406	102	401	90
UEST	260	42	258	59	274	57
PTT	373	56	397	98	401	66
OPTT	456	72	517	115*	524	118*

Note: * $p \leq 0.05$ vs controls; ** $p \leq 0.05$ vs with dentures and control OPT = Oral preparation time; OTT = Oral transit time; SRT = Swallowing reaction time; VPCT = Velopharyngeal closure time; UEST = Upper esophageal sphincter transit; PTT = Pharyngeal transit time; OPTT = Oropharyngeal transit time; SD = Standard deviation.

Table 6. Videofluoroscopic swallowing study of the oral and pharyngeal phases of swallowing (in milliseconds) in controls (n = 26) and denture wearers (n = 27) with and without dentures when swallowing toasts.

Swallowing timing	Controls		With Dentures	
	Mean	SD	Mean	SD
OPT	11380	4536	18679	5653*
OTT	251	79	262	76
SRT	100	61	116	48
VPCT	357	87	398	95*
UEST	258	54	263	60
PTT	388	58	409	67
OPTT	480	93	503	80

Note: * $p \leq 0.05$ vs controls; OPT = Oral preparation time; OTT = Oral transit time; SRT =Swallowing reaction time; VPCT = Velopharyngeal closure time; UEST = Upper esophageal sphincter transit; PTT = Pharyngeal transit time; OPTT = Oropharyngeal transit time; SD = Standard deviation.

DISCUSSION

Results indicate that OPTT of the boluses swallowed in this study was longer in denture wearers than in controls. The comparison between examination results with and without dentures found decreased transit time only when individuals swallowed pureed food without dentures. OPT was longer in denture wearers when swallowing crackers and toasts – even longer in the case of crackers without dentures. On the other hand, such time was not different when swallowing liquid and pureed boluses.

Wearing dentures increases the activity of mandible closure muscles and improves the occlusal area and force and, therefore, the mastication process [10]. However, complete dentures cause oral cavity residues – which may also occur without dentures, though the results found no statistically significant differences. Aspiration did not occur in either group, which indicates that at least in this investigation, laryngeal aspiration and penetration were not associated with wearing dentures.

There was no difference in OTT between examinations with and without dentures. The difference found in previous studies [10,11] may be due to denture wearers' diseases (especially age-related ones) and bolus characteristics used in the assessments.

The laryngeal vestibule closure time is often longer in older people [12] and was longer in this study's denture wearers than in controls when swallowing liquid and solid boluses (toasts). This result may be due to the slightly older age of denture wearers than controls (although this difference was small) or their slower PTT, which would prolong the protection against airway aspiration.

PTT was longer in denture wearers when swallowing liquid and pureed boluses, even though it decreased when swallowing pureed food without dentures. This has been previously observed, considering that longer PTT increases the risk of airway aspiration [13,14]. In contrast, another paper observed longer PTT of pureed bolus swallowed without dentures [4].

Changes in OPTT are controversial. One investigation describes that removing the dentures increased OPTT [15], while another one presents contrary results [16]. The absence of dentures changes the oropharyngeal anatomy, which may enhance the effects of aging and decrease the swallowing reserve [5].

Denture wearers had higher means between time intervals than controls, and the difference between the means was greater when swallowing liquid bolus.

Wearing dentures may improve swallowing, though not achieving the same standard as toothed individuals. Possibly, the effects of aging on swallowing (especially when related to sarcopenia) can be more intense among toothless than toothed individuals – which requires further research.

This study has some limitations. Denture wearers were older than toothed subjects (controls), although such a difference was small and unlikely to have influenced the results. Half of the subjects had been wearing dentures for less than 1 year and 2 months, perhaps not long enough to cause greater changes in swallowing.

CONCLUSION

Complete denture wearers tend to have oral residues and longer oral transit time and pharyngeal transit time than toothed individuals. The transit time without dentures was shorter than with dentures only after swallowing pureed boluses. Although oral residues and longer pharyngeal transit in individuals wearing dentures increase the risk of airway aspiration, this investigation did not verify such a condition.

Collaborators

MR Montaldi and CHL Silva participated in study conceptualization, patients' evaluations, data collection, discussion of results, manuscript preparation, and the decision to submit the manuscript for publication. AB Ribeiro, CB Araujo, and CV Fortes participated in patients' evaluations, data collection, discussion of results,

manuscript preparation, and the decision to submit the manuscript for publication. RO Dantas participated in study conceptualization, patients' evaluations, data collection, discussion of results, manuscript preparation, and the decision to submit the manuscript for publication.

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