Review Article

Devices used for measuring tongue force: A Review

ABSTRACT

Over many decades, medical representatives, researchers, etc., are making an attempt to quantify the force/pressure put by the tongue within the oral cavity. Evaluation of the abovementioned may be done by qualitative or quantitative methods. The aim of this study was to assemble a review of literature regarding the devices to measure tongue strength used by different researchers over a period of time from everywhere the globe. A critical analysis regarding the devices custom-made or used to quantify tongue force was meted out in different words such as "tongue pressure," "role of tongue," and "malocclusion" in varied search engines using the Internet. The articles considered were over a period of 60 years approximately, i.e., 1956 dated up to March 2018. In addition, searches were also made within the references of the chosen articles. Every custom-made device has drawbacks in its own. In an overall view, most of the devices measure pressure in just one direction. However, tongue activity throughout the features entails a combination of dynamic and static forces because the tongue is oriented in a diffusion of various positions. The employment of quantitative ways to measure tongue force helps the skilled in the evaluation of orofacial physiology, making the diagnosis of tongue force more reliable, particularly in those subjects with a small strength deficit which are difficult to be noted by clinical evaluation.

Keywords: Devices, malocclusion, tongue force

INTRODUCTION

Over a couple of decades, medical representatives, researchers, etc., are making an attempt to quantify the force/pressure put by the tongue within the mouth. Tongue, as we all know, plays a really vital role in performing functions such as chewing, swallowing, suction, respiration, and speech articulation and conjointly keeps correct tooth position. Besides, it balances the force exerted by the lips and cheeks on the teeth.

Evaluation of the abovementioned may be done by qualitative or quantitative ways. Qualitative analysis is a kind used in speech-language clinical practice on a daily basis that depends a lot on the expertise of the skilled and is not free from controversies. Procedure includes protrusion of the tongue against the finger of the skilled or the depressor that exerts resistance. The opposite and therefore the more accepted technique of quantitative analysis are performed using instruments that help in the quantitative assessment of the force exerted by the individual's tongue. This technique ensures more accuracy.

The purpose of this study was to assemble a review of literature regarding the devices to measure tongue strength utilized by different researchers over a period of time from all over the globe.

MATERIALS AND METHODS

Inclusion criteria: a critical analysis regarding the devices customized or accustomed to quantify tongue force was carried out in different words such as "tongue pressure," "role of tongue," and "malocclusion" in various search engines using web. The articles considered were over a

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period of 60 years close to, i.e., 1956 dated up to March 2018. In addition, searches were additionally made within the references of the chosen articles. Exclusion criteria: all the results were totally scrutinized in three stages: foremost, those that were not almost like the target were excluded, second, the recurrent ones were removed, and in conclusion, the authors who used a similar variety of strategies were omitted from the ultimate list of references. The author name, year, and device used are listed in Table 1.

RESULTS

A total of 150 reference articles resembling the objectives were settled. After scrutinization, inclusion, and exclusion, 44 articles were left to contend with. The devices were divided into eight categories according to their technology: mouthpiece with gauge (n = 9), load cells (n = 1), or force-sensing resistors (n = 5); sensing elements connected on teeth or on palatal plates (n = 11); dynamometers (n = 4); Iowa Oral Performance Instrument and bulbs stuffed with some fluid and connected to a pressure sensor (n = 15); and different technologies (n = 10).

DISCUSSION

Mouthpiece with gauge

A plate base fabricated from methyl methacrylate was created by Kydd *et al*. (1963);[1] the vertical dimensions were maintained between the bases by four vertical rods embedded within the lower plate base. Electric resistance strain gauges were connected to those blocks. Pressure exerted by tongue on the block produced a deformation on the gauge, modifying its resistance. Proffit *et al*.[2] conjointly used the abovementioned, and three rather than two intraoral transducers were placed on the upper central tooth and first upper molar by a resin.

Sanders[3] described a device that consisted of a force-displacement electrical device connected to one-channel direct-writing portable audio system, a specially designed

Table 1: List of authors along with the year and the devices used by them

Researcher	Years	Device
Kydd *et al*.[1]	1963	Mouthpiece with 3 strain gauges
Proffit *et al*.[2]	1964	Mouthpiece with 2 strain gauges
Sanders *et al*.[3]	1968	Mouthpiece with 4 strain gauges
Posen[4]	1972	Dynamometer
Wallen[5]	1974	Pressure sensor mounted in acrylic base
Durkee and Manning[6]	1987	Mouthpiece with a strain gauge
Frohlich *et al*.[7]	1991	Cannula for water escape along with a pressure measuring system
Robin and Lushei[8]	1992	Bulb filled with water and a pressure sensor
Staehlin[9]	1999	Pressure sensors attached on palatal plate
Mortimore *et al*.[10]	1999	Mouthpiece with load cell
Hayashi *et al*.[11]	2002	Bulbs filled with air and connected to a pressure sensor
Wakumoto *et al*.[12]	2003	10 pressure sensors attached on palatal plate
Hori *et al*.[13]	2006 and 2009	6 and 7 pressure sensors on palatal plate
Ball *et al*.[14]	2006	3 bulbs filled with air connected to a pressure sensor
Sangave *et al*.[15]	2008	Mouthpiece with 6 force-sensing sensor
Hewitt *et al*.[16]	2008	Pressure sensor attached to palatal plate
Lambrechts *et al*.[17]	2010	The Myometer 160
Trawitzki *et al*.[18]	2011	Calibrated electronic dynamometer
Sardini *et al*.[19]	2013 and 2014	Tactile sensors fabricated over a plastic sheet
Ueki *et al*.[20]	2014	LDC-110R
Van Lierde *et al*.[21]	2014	IOPI
Shiono *et al*.[22]	2015	Multidirectional lip closing force measuring system
Furlan *et al*.[23]	2013	The Forling instrument composed of piston assembly with a double oral protector
Lee *et al*.[24]	2016	IOPI
Xu *et al*.[25]	2016	FlexiForce resistive sensor
Hiraki *et al*.[26]	2017	Barometer
Partal and Aksu[27]	2017	IOPI
Hiraoka *et al*.[28]	2017	Balloon probe attached to a measuring device
Fujita *et al*.[29]	2018	Tongue pressure manometer
Sakai *et al*.[30]	2019	Balloon-type disposable oral probe and LDC-110R Instrument from JMS, Hiroshima, with a balloon-type oral probe

IOPI: Iowa Oral Performance Instrument, LDC: Lip de Cum

tongue pressure disk, and a head stabilizer. The electrical device consisted of 4 strain gauges that measured strain.

Durkee and Manning (1987)[6] custom built a tool to measure tongue force in three directions on the axes X, Y, and Z. Scardella *et al*.[31] quantified tongue force employing a force electrical device that interpreted direct compression forces generated by the tongue to an active arm outside of the mouth connected to a gauge with linear response for forces between 50 and 100 gf, which was incorporated into a two-arm active electric circuit.

Mouthpiece containing load cells

Mortimore *et al*.[10] customized a transducer consisting of a machined nylon hand grip and a mouthpiece along with a 0 ± 6 kgf button load cell behind it. The electrical device was connected to a linear visual scale displaying force in Newton or as a percentage of the subject's maximum force.

Mouthpiece containing force-sensing resistors

An instrument consisting of two mouthpieces, one superior and one inferior, with three force-sensing resistors in every, were planned by Sangave *et al*.[15] The sensors were piezoresistive FlexiForce with measuring range from 0 to 110 N. Every sensing element was mounted to a stainless-steel plate connected to the mouthpiece.

Xu *et al*.[25] changed the transpalatal arch used for vertical management of the molars, based on individual muscle strength and morphology features of the tongue during swallowing. Tongue pressure exerted on the surface and the acrylic pads at three distances to the palatal mucosa during swallowing was measured by pressure sensors.

Pressure sensors connected on teeth or on palatal plates

Staehlin *et al*.[9] created a palatal plate equipped with more than one pressure sensors to measure tongue force during function. Hori *et al*. (2009)[13] measured tongue pressure during manduction and swallowing using seven pressure sensors (capacity of 200 kPa) installed in a palatal plate and recorded on a computer. Hewitt *et al*.[16] introduced the Madison Oral Strengthening Therapeutic consisting of an adult sized polymer mouthguard with a palatal plate was connected with a semiconductive elastomeric force sensing element. The palatal plate developed by Kieser *et al*.[32] supplied simultaneous measuring of pressure at totally different locations within the mouth and was made from a chrome-cobalt alloy. Two pairs of gauges measured pressure contributions of the lateral tongue margin and cheeks on the canine and first molar teeth.

Sardini *et al*.[19] projected a tool with the aim to supply the continual force measuring on the surface wirelessly on show. The device consisted of tactile sensors fictional over a plastic sheet. Furlan *et al*. (2013)[23] quantified the tongue protrusion force employing a Forling instrument developed within the Biomechanical Engineering Group from Brazil.

Dynamometers

Posen[4] measured maximum tongue force in subjects with the instrument that was fabricated from a gauge and a spring. Trawitzki *et al*. (2011)[18] investigated the tongue strength in young adults and determined the variations during this strength between tongue regions.

Bulbs filled with some fluid and connected to a pressure-sensing element and intraoral performance instrument

Robin and Lushei[8] customized a portable pressure detecting device using a water-filled bulb of an acceptable size to fit inside the mouth. The Iowa Oral Performance Instrument (IOPI) was a second version of the instrument utilized by Robin *et al*. The difference was that the IOPI's bulb is full of air. IOPI was commercially available, and it was utilized by many authors in tongue pressure investigations (Laura L *et al*., 2014; Jong ha Lee *et al*., 2015; Imrak Partal; Dong Min *et al*.;[33] and Leen Van Steen *et al*., 2017).[27]

Hayashi *et al*.[11] used an air crammed bulb made up of rubber connected by a tube to a pressure electrical device, an amplifier, and a record system. Ball *et al*.[14] used another tongue pressure measuring device using bulbs, the Kay Swallowing Workstation. Utanohara *et al*.[34] created a tongue pressure measuring device consisting of a disposable oral probe, an infusion tube as a connector, and a recording device. Asami *et al*.[35] measured tongue pressure using JMS measuring device (balloon based).

Other technologies

Wallen[5] planned an electrical device system capable of measuring pressure in numerous planes. The transducers were mounted in acrylic base connected to the surface of incisor teeth. Secure Wires connected the transducers to the input of a dynograph. Fröhlich *et al*. (1991)[7] used an open cannula (internal diameter: 0.7 mm) embedded in a small customized acrylic shield that was secure to the teeth. The tubing was connected to a pressure instrument by a tube passing between lips.

Other analysis group measured tongue protrusion force employing a force electrical device (Grass FT10 force-displacement transducer) trapped in a surface. This piece had a cushion for teeth positioning that the subjects had to bite and press the tongue against a spherical button of

20 mm diameter connected to the force electrical device by a cylindrical steel beam of 5 mm diameter and 50 mm length.[36]

The Myometer 160 contained a probe that consisted of 2 plates that were screwed one along each side. On the other side (probe tip), the two plates can be pushed toward one another.[17]

CONCLUSION

Each custom-built device has drawbacks in its own. The primary disadvantage of utilizing dynamometers is that they are not sensitive to very little changes operative, and at times, the measures do not seem to be reliable, as a measure of force can be made by the patient's or the specialist's hand pushing the electrical device toward the patient's mouth. The problem of the bulb is that the issue of positioning and reproducibility within the oral cavity. Air-filled bulb positions are laborious to change because it slides too effortlessly on the tongue surface, and the connected tube is not scaled to demonstrate things of the bulb when lips closure. Palatal plates ought to be changed as each individual has his/her surface size and that they assess tongue force solely in a cranial direction, which is incompatible to the emotional assessment made by speech pathologists, not allowing examinations among quantitative and qualitative assessments. Anyway, they are produced to quantify tongue force amid the capabilities, as they enable the patient to shut his mouth and perform the capacities (speech, mastication, and swallowing) generally.

Another elective technique is to attach the sensors straightforwardly on the surface of the teeth. This strategy has two inconveniences. First, the difficulty to oblige the sensors at the setup focuses to form relative appraisal conceivable. The second weakness is that the sensors are laborious to clean and sterilize, so they cannot be utilized in numerous patients. This technique is better to measure tongue force during functions than the relatively bulkier palatal plates. The instruments that used strain gauges typically have a cumbersome mechanical structure needed for his or her performance, and therefore, the hard inflexible structure of the gauges will cause intraoral lacerations or discomfort to the patient. The device created by the Biomechanical Engineering Group from Universidade Federal de Minas Gerais (Federal University of Minas Gerais - UFMG) is the first device to degree tongue strength advanced in Brazil. The main diagnosed drawback within the device was the problem to seal the tubes that precipitated some leak that encouraged the measurements and created air bubbles within the system.

In an overall view, most of the devices measure pressure in only one direction. However, tongue activity throughout the features entails a combination of dynamic and static forces because the tongue is oriented in the diffusion of varied positions. The employment of quantitative strategies to measure tongue force facilitates the skilled in the analysis of orofacial physiology, creating the diagnosing of tongue force additional reliable, particularly in those subjects with a small strength deficit that is difficult to be noted by clinical evaluation. However, it is far more crucial to remember that the quantitative assessment needs to not be used to substitute the qualitative, rather complement it, because skilled expertise is vital to understand the pathology of the affected person.

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Conflicts of interest

There are no conflicts of interest.

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