JRD

SALIVARY RESERVOIR DESIGNS FOR PATIENTS WITH XEROSTOMIA: A REVIEW

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ABSTRACT

Aim: The present paper aims to review the literature available on various approaches to salivary reservoir designs, the functional aspects, cleansibility, type of attachments used, and different techniques used for the fabrication of salivary reservoirs in patients suffering from xerostomia.

Material and Methods: A search in the National Library of Medicine's Pub Med database, Google search and Science Direct was performed to include all case reports and reviews on prosthodontic rehabilitation of dentulous/partially edentulous/edentulous patient with xerostomia.

Results: Out of the 35 articles found in the database search, 18 articles were included based on the designs they adopted for fabrication of salivary reservoirs.

Conclusions: The various designs available in literature enable an operator to choose the most suitable reservoir design based on specific patient requirements. Innovations in reservoir design promise a more customized prosthesis for every patient. Further research and innovation will enable increasingly efficient salivary substitute delivery systems for the xerostomic patient.

KEYWORDS: salivary reservoir, denture reservoir, xerostomia, functional reservoir, attachment for reservoir

INTRODUCTION

Saliva is one of the most important components of the stomagnathic system and is secreted from the exocrine salivary glands. It is of great importance for the maintenance of health and function of the system. Mean daily salivary output ranges from 500 to 1500 ml and the average volume of saliva present in the oral cavity is approximately one ml[1]. The percentage contributions of unstimulated saliva are 20% from parotid, 65% from submandibular, 7% to 8% from sublingual, and less than 10% from numerous minor glands[2]. The accepted normal flow for unstimulated saliva is anything above 0.1 ml/min; any unstimulated flow rate below 0.1 ml/min is considered to be hypofunction[3].

Many of the signs of oral imbalances like increased caries incidence; susceptibility to oral candidosis; burning mouth; sore tongue (glossodynia); difficulties with speech, mastication, and swallowing; altered taste sensation (dysgeusia); and halitosis are either due to decreased salivary flow or alteration in salivary composition[1]. Xerostomia is the subjective symptom or sensation of dry mouth; defined as dryness of mouth due to lack of normal secretion of saliva[1].

Causes of xerostomia can be categorized into: (1) developmental

disturbances in the glands; (2) water or metabolite loss; (3) iatrogenic causes including medication and radiotherapy; (4) systemic disease including sjogren syndrome, diabetes, etc; (5) local factors including smoking, mouth breathing etc[1,2].

The treatment options of xerostomia are categorized into: (1) general management (etiological management) which focus on treating the main etiology of xerostomia which can be drugs, low salt diets, radiotherapy, etc; (2) preventive measures which include frequent checks for maintenance of stomagnathic system (eg: frequent dental visit, fluoride application, etc); (3) measures to increase salivary flow including sialogogues; (4) management of underlying systemic disease; (5) use of saliva substitute which are categorized into glycerine and lemon based, carboxymethyl cellulose based, and mucin based; (6) use of oral lubricating device which includes salivary reservoirs.

An ideal salivary reservoir is a device which should not impede normal oral functions and should be simple to use and easy to clean[4].

LITERATURE REVIEW

CLASSIFICATION

In literature a classification for salivary reservoirs does not exist. A classification of salivary reservoir is proposed here based on the designs found during the search, to simplify understanding and communication.

1. Based on the arch into which the salivary reservoir is incorporated: (a) maxillary salivary reservoir; (b) mandibular salivary reservoir.
2. Based on cleansibility of salivary reservoir: (a) cleansable salivary reservoir - reservoir which has a removable lid and can be cleaned from inside under direct vision; (b) non-cleansable salivary reservoir - reservoir which cannot be cleaned under direct vision as the lid is permanently fixed and cannot be separated.
3. Based on functional aspect of stomagnathic system: (a) functional salivary reservoir - reservoir where the patient can control the release of saliva by functional movement of the structures of the oral cavity like movement of tongue[4], sucking[5] and swallowing[6,7]; (b) nonfunctional salivary reservoir - reservoir where release and flow rate are not under the control of patient (eg: release of saliva due to gravity only).

This article reviews in English literature published from 1984- 2014 with various approaches for the fabrication of a salivary reservoir.

A search in the National Library of Medicine's Pub Med database, Google scholar and Science Direct was performed to include all case reports and reviews on prosthodontic rehabilitation of dentulous/edentulous patients suffering from xerostomia where treatment included incorporation of salivary reservoir into prosthesis. The inclusion and exclusion criteria were described in table 1.

Table 1. Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
PubMed indexed articles	Non PubMed indexed articles
Written in English language	Written in language other than English
Full text availability	Abstract

Out of the 35 articles found in the database search, 18 articles were included based on whether they described new designs for fabrication of salivary reservoirs. The key words used for the search were salivary reservoir, denture reservoir and xerostomia.

RESULTS

The various articles are categorized as follows (Table 2).

DISCUSSION

Out of the eighteen articles found in literature, three designs[5-7] were found to be functional salivary reservoirs while thirteen designs[8-11] were found to be nonfunctional salivary reservoirs in the complete denture category[12-18]. In removable cast partial dentures, three designs[8,19,20] were found to be in the nonfunctional category, while in removable partial dentures one design[4] was found in functional salivary reservoir category and two[9,21] were found in nonfunctional salivary reservoir category.

FUNCTIONAL SALIVARY RESERVOIRS

Have an advantage over nonfunctional salivary reservoir as controlled release of saliva can be achieved[4-7] by the functional movements of oral cavity like movement of tongue[4], sucking[5] and

swallowing[6,7]. Upadhyay et al.[6] had used swallowing movements for the release of salivary substitute which leads to less outlet clogging and helps in sustained release of saliva[6]. These articles report that flexible materials have been used for the fabrication of the lid of the reservoirs.

Table 2. Articles used in the review.

COMPLETE DENTURE RESERVOIRS									
Author	**Arch**	**Functional/ non-functional**	**Cleansibility**	**Type of attachment**	**Reservoir space maintained by**	**Salivary substitute used**	**Filling of salivary reservoir**	**Drainage of salivary reservoir**	**Remarks**
Vissink et al[5]	Maxillary	functional	Cleansable	Mechanical interlocking between Co-Cr plate and acrylic	Optosil (Bayer, Leverkuse, West Germany)	N.A	Two holes of 1.5 mm in diameter in anterior and posterior region of metal base (intaglio surface)	1 hole in the center of the acrylic resin lid (polished surface)	Beeswax was used for palatal contouring, metal base of Co-Cr was used, which was 0.45mm thick in center and 1mm in the region where met the acrylic. Latex membrane (Penrose drain, Argyle, Tullamore, Ireland) was fixed with cyanoacrylate at the opening, a punch hole was made in it for the flow of saliva by sucking activity
Upadhyay et al[6]	Maxillary	functional	Non-cleansable	Fixed with autopolymerising resin	Both components were fabricated separately	Saliva Orthana(AS Pharma, Andover, UK)	1 mm in the anterior part (lowest part of reservoir floor)	1 mm in anterior part (lowest part of reservoir floor)	Acrylic based resilient liner((Permasoft; Dentsply, New Delhi, India) was used for functional flow of saliva, activated by tongue movements
Shah et al[7]	Maxillary	functional	Cleansable	Friction lock attachment	A mixture of 50% pumice and 50% plaster	N.A	By removing the flexible lid	1 mm releasing hole at the most dependent point on the lid	Functional palatogram assessment using tissue-conditioning material (Visco-gel; Dentsply Ltd., Weybridge, UK) lid: 2-mm thick flexible BIOPLAST(Scheu Dental GmbH,Germeny) material used for functional flow of saliva
Toljanic et al[8]	Maxillary	Non fuctional	Non- cleansable	Fixed with autopolymerising resin	Plaster	Xero-lube (Scherer Laboratorie, Inc., Dallas, Texas).	3 holes in anterior region along the outer edge of cap with number 1 round bur	3 holes in anterior region along the outer edge of cap with number 1 round bur	Co-Cr palate and meshwork was used to reduce overall thickness of the denture base
Vissink et al[9]	Maxillary	Non fuctional	Cleansable	Mechanical interlocking between Co-Cr plate and acrylic	Optosil (Bayer, Leverkuse, West Germany)	Mucin (Salivamm Orthana, Orthana Ltd., Copenhage, Denmark).	Two holes of 1.5 mm in diameter in anterior and posterior areas of the metal base (intaglio surface)	0.1-0.2 mm hole which was 5mm palatal to the anterior tooth	Co-Cr plate was 0.45mm thick in the center and 1mm at the junction of acrylic resin denture base and Co-Cr. Palatal contouring was carried out by functional movement of the tongue and recorded by soft wax
Singh et al[10]	Maxillary	Non fuctional	Cleansable	Mechanical interlocking with 1mm slot below the polished surface of palate	N.A	wetmouth	By sliding open the lid	By seepage of salivary substitute	Lid fabricated with flexible denture material (Lucitone).
Debnath et al[11]	Maxillary	Non fuctional	Cleansable	Rhein 83 attachment of 2mm diameter	Modeling clay (Jingjing, china)	Wetmouth ICPA	0.5 mm hole in the intaglio surface of the metallic framework	Escape path was made by using a cellophane sheet in the posterior part of the lid	0.45 mm Co-Cr intaglio surface with vertical wallsfor the reservoir and spheres for OT caps were cast together
Vissink et al[9]	Mandibular	Non fuctional	Cleansable	Sliding frictional lock between the metal track and block of acrylic resin posterior teeth	Denture made in two parts by using interchangeable flask and fix with autopolymerising resin	N.A	By sliding the posterior tooth section on its metallic track	0.1 -0.2 mm on the lingual surface of the midline of denture	The stainless steel metallic track was 25 mm long, 2.8 mm high, and 7 mm wide at the base, and 4.5 mm wide at the top. Lid on top of it was made with a block of acrylic resin that slid into the metal track
Sinclair, Frost and Walter[12]	Mandibular	Non fuctional	Cleansable	Magnets, two 4 mm cobalt samarium magnets [Magnet Development Ltd., Swindon, England] posteriorly for attachment and one 1.2 mm stainless steel strut anteriorly for bracing action	Mixture of 80%plaster and 20%pumice	KY jelly (Johnson and Johnson Ltd. Maidenhea, Berkshire, England)	By removing the occlusal lid from the reservoir	1.3 mm release hole in the fit surface, one in each 2nd premolar region	The magnets used had a breakaway force of 400 gm. Magnetic force is lost under shear force so to avoid that,an anterior rod was used which prevents the shearing force
Mendoza and Tomlinson[13] And Dabas et al[14]	Mandibular	Non fuctional	Cleansable	Three double-toothed LegoTM (LEGO, LEGO Korea Co Ltd, Seoul, Korea) blocks were used, one in anterior region and two in posterior region	Space for reservoir was cut in recall appointment by maintaining a minimum thickness of 2mm of acrylic for reservoir walls		By separating the two parts of the split denture	0.5 mm diameter on the inferior aspect of lingual flange	
Burhanpurwala et al[15]	Mandibular	Non fuctional	Cleansable	Stainless steel press on button in the molar region	Putty	Wet Mouth, ICPA	Labially in between two central incisor of diameter of 19 gauge needle	3 outlet holes on each side in retromylohoid region of diameter of 26 gauge needle	

Pattanaik and pattanaik[16] Ladda et al[17]	Mandibular	Non fuctional	Cleansable	six metal rods 3mm in length and 2mm in diameter having a groove at one end for retention and were made of Ni-Cr alloy (Bellabond Plus, Bego, Bremen, Germany) and placed parallel to each other while 5 metal rods were used by ladda et al	Clay Putty (ladda et al)	Methyl cellulose	Lingually in between two central Incisors in the upper section containing the teeth	The hole is made by # 8 straight fissure bur on the inferior surface of the lingual aspect on either side	Precision is required to place the metal rods parallel to each other and adequate acrylic is necessary around the metal rod
Hallikerimath and jain[18]	Mandibular	Non fuctional	Cleansable	Six mechanical interlocking by custom made attachments	Space for reservoir was made rectangle in premolar to molar region using straight fissure bur	Customized artificial saliva	The reservoirwas filled with the help of a syringe	Lingual aspect of the base of the reservoir	
Debnath et al[11]	Mandibular	Non fuctional	Non-cleansable	Fixed with autopolymerising resin using 3 V shaped notches as reference	Modeling clay (Jingjing, china)	Wetmouth ICPA	A hollow plastic cap and the hub of 2ml disposable syringe was used	0.2 mm diameter in anterior lingual aspect of the denture	
REMOVABLE CAST PARTIAL DENTURE									
Toljanicet al[8]	Maxillary	Non fuctional	Non- cleansable	Fixed with autopolymerising resin	Plaster	Xero-lube (Scherer Laboratories, Inc., Dallas, Texas)	3 holes in the anterior region with no 1 round bur	3 holes in the anterior region with no 1 round bur	Intaglio surface was Co-Cr and the lid was of autopolymerising resin
Agarwal et al[19]	Maxillary	Non fuctional	Cleansable	Stainless steel snap button	Plaster	Xero-Lube	2 mm in diameter in the mid palatal region of the polished surface of the reservoir	2 holes of 1mm diameter in premolar region	The lid was fabricated with autopolymerising resin
Modgi et al[20]	Maxillary	Non fuctional	Cleansable	Precision attachment- 5mm x 2.8 mm was used (MINICON V 37580, BEGO GERMANY)	Lab putty	E-saliva	The denture was filled with the help of a syringe	2 holes of 0.7 mm diameter in the posterior region of reservoir	Palatogram analysis was carried out with tissue conditioner
REMOVABLE PARTIAL DENTURE									
Vissink et al[9]	Maxillary	Non fuctional	Cleansable	Mechanical interlocking between Co-Cr plate and acrylic	Optosil (Bayer, Leverkuse, West Germany)	Mucin (Saliva Orthana, Orthana Ltd., Copenhage, Denmark).	Two holes of 1.5 mm diameter in the anterior and posterior position of the metal base	0.1-0.2 mm, location of the hole was 5mm palatal to the anterior tooth	Co-Cr plate was 0.45mm thick in center and 1mm at the junction of acrylic resin and Co-Cr.
Frost et al[21]	Maxillary	Non fuctional	Non cleansable	Two layers of EVA resin was pressed with water dispensable medium like mixture of plaster and pumice sandwiched in between	Plaster and pumice	K-Y jelly		Holes of 2 mm diameter	EVA resin (EVA resin (Erkoflex)) Erkodent, Erich Kopp GmbH, Siemensstrasse 3,D — 72285 Pfazgrafenweiler, Germany) was used for the fabrication of the prosthesis
Kam et al[4]	Maxillary	Fuctional	Non cleansable	Fixed with autopolymerising resin	Dental stone	Oral Balance gel (Laclede Inc., Rancho Dominguez, CA, USA)	By locating device and syringe specially designed for refilling	A ball valve, with an opening of 4-5 mm diameter 6mm diameter stainless steel ball attached with 0.7 mm stainless steel wire with an elastic diaphragm to control flow	Functional reservoir in which patient can control the release of saliva through the ball valve opening using tongue movement and intra oral pressure

Upadhyay et al.[6] preferred to use an acrylic resin based heat polymerizing liner material which they claimed can be polished, has high durable bond strength, and is less susceptible tocolonization with candida *albicans*[22]. However the main disadvantage of this material is that it loses its resiliency in 12-18 month and requires replacement[6]. Shah et al.[7] used a 2mm thick ethylene vinyl acetate, which does not lose its resiliency over time but requires special equipment for its fabrication. Vissinik et al.[5] used rubber dam material which allows slow release of saliva but its integration onto the prosthesis is technique sensitive and durability is questionable.

CLEANSIBILITY

Cleansibility of a reservoir becomes an important consideration as it can harbor pathological microorganisms particularly in xerostomic patients and other patients predisposed to infection, especially to candidial infection. A reservoir can be rendered cleansable by separating two parts of the reservoir, so that it's cleaning can be performed under direct vision. Some designs in literature advocate cleaning by forcibly injecting a cleaning agent from one opening and discharging it from the other, but the effectiveness of this type of cleaning of the reservoir is less than

adequate at best as the operator/ patient does not have direct access to clean all the surfaces of the reservoir thoroughly especially with the presence of particulate matter and biofilms within the cavity.

ARTIFICIAL SALIVA

Ideally saliva substitutes should be pleasant to taste, nontoxic, non-addictive, economical and must exhibit good wetting of the tissue surface of denture[23]. Studies have shown that in the absence of thickening agent in artificial saliva, the use of water to moisten and lubricate the oral mucosa is less effective[23,24] when used inside a reservoir. Therefore the use of artificial saliva in salivary reservoirs is recommended.

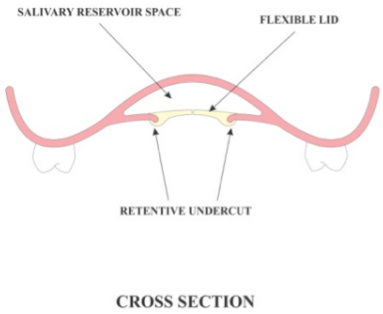
Artificial saliva substitutes are broadly categorized into two groups carboxymethyl cellulose based and mucin based, though mucin based saliva substitutes have shown better wettability of oral tissue than carboxymethyl cellulose based artificial saliva but because of their porcine or bovine origin, mucin based artificial saliva are likely to be objectionable in some parts of world[23].

ATTACHMENTS

1. Mechanical interlockin [5,7,9,10,18]: the advantages of these attachments include reduced costs and reduced weight of prosthesis, but the disadvantages are that they are very technique sensitive. Precision is required for the precise fit and they tend to have lengthy and complicated lab procedures (Figure 1).

2. Rhein 83[11]: the advantages of this attachmentis its availability in a variety of intensities of retention, but disadvantages are increased weight of the prosthesis, parallelism of attachment component is critical to achieve, increased costs and the possible encroachment into the tongue space especially in a lower prosthesis which may adversely affect speech and comfort.

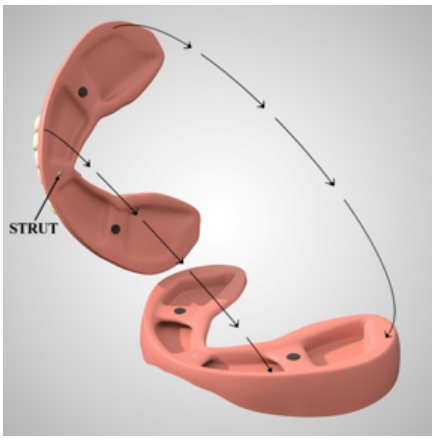
Figure 1. Cross section of maxillary functional reservoir with mechanical attachment.



3. Magnets[12]: used cobalt samarium magnets which were 4mm in diameter and had a breaking force of 400 gms. The main problem with magnets as attachment is the loss of magnetic bonding, which occurs under a shearing load. It also requires exhaustive laboratory steps, results in and precision for proper placement, so care must be taken to eliminate the shearing force which results in a separation of the two parts of the denture. In the design described by Sinclairone anterior strut was used to prevent this shearing force. While selecting a magnet for this application one should ensure that the bonding system is strong enough to withstand the parting forces of sticky food substances. Iron neodyum boron magnets are also available in small sizes and can produce a greater attachment force[12] (Figure 2).

4. Double tooth lego blocks[13,14]: it is known that it is important to place them parallel to each other when more than one block is used for efficient use, other disadvantages include need of manual dexterity to separate and rejoin the two segments of the split denture, accurate reseating of the processed denture becomes difficult if large undercuts are present so case selection becomes important while selecting this type of attachment system, only cases of sufficient vertical dimension and thickness are suitable for these attachment[13] and they also cannot be used universally for all cases (Figure 3).

Figure 2. Magnetic attachment with anterior strut.



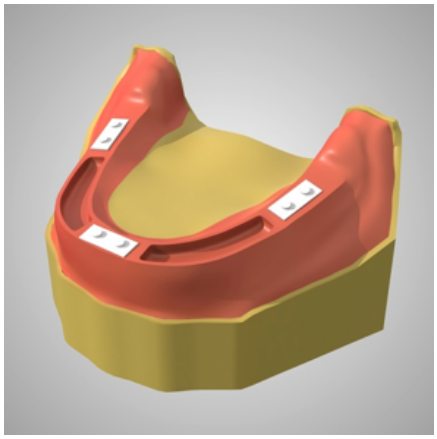
5. Stainless steel press on buttons [15,19]: these are buttons that are adapted from textile industry. Their precise fit with these is questionable at best and seepage of saliva may occur [15,] stainless steel press on buttons need replacements as they loosen with time [17] and their resistance to corrosion is not known.

6. Metal rods [16,17]: of Ni-Cr alloy have been used as attachments which have a groove at one end that fits a fabricated counterpart on the denture. Using them as attachments requires at least two mm of acrylic around each, but giving two mm of acrylic around all metal rods ultimately leads to a decrease in reservoir space.

7. Precision attachment[20]: these are frictional grip slide attachments.Male and female

components make it precise and it utilizes less space thus providing more volume for the reservoir. Disadvantages include the cost and difficulties is achieving parallelism between attachments.

Figure 3. Lego® block attachment with reservoir space.



CONCLUSIONS

The volume of an average salivary reservoir ranges from 2.3-5.3 ml and the duration of flow ranges from 2-5 hours. An ideal salivary reservoir should not impede normal oral function, should be simple to fabricate and must be easy to use and clean. In a maxillary prosthesis the reservoir should be determined by using a palatogram assessment and appropriate palatal contouring should carried out based on the records generated by the patient. Metallic bases should be selected in cases of shallow palatal vaults to minimize the thickness of the base and to increase the space for the reservoir. A transparent lid should be planned as it helps the patient to visualize the amount of artificial saliva present. In maxillary salivary reservoirs mechanical interlocking or frictional fit should be used as methods to retain the reservoir lid as they decrease the weight of the prosthesis.

For a mandibular salivary reservoir it is better to determine the potential area for the salivary reservoir by carrying out a neutral zone recording. In cases of split dentures it is important to keep a minimum of three mm acrylic below the artificial teeth and two mm acrylic for the reservoir wall for strength. In mandibular salivary reservoirs attachments can be considered. Selection of attachments depends on the personal choice and experience, the space for salivary reservoir should be made at the time of acrylization as making space after acrylization leaves rough internal surfaces which may be difficult to polish and can lead to bacterial colonization.

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