COMPARATIVE EVALUATION OF RETENTION AND STABILITY OF IMPLANT SUPPORTED MANDIBULAR OVERDENTURE USING LOCATOR ATTACHMENT AT DIFFERENT IMPLANT POSITIONS - AN IN VITRO STUDY

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CHENNAI

In partial fulfillment for the degree of

MASTER OF DENTAL SURGERY

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MAY - 2019

CERTIFICATE - I

This is to certify that the dissertation titled **'COMPARATIVE EVALUATION OF RETENTION AND STABILITY OF IMPLANT SUPPORTED MANDIBULAR OVERDENTURE USING LOCATOR ATTACHMENT AT DIFFERENT IMPLANT POSITIONS - AN IN VITRO STUDY'** is a bonafide work done by **DR.S.V.SHANMUGA PRIYA**, Post Graduate Student (2016-2019), during the course of the study for the degree of "Master of Dental surgery" in Department of **PROSTHODONTICS AND CROWN AND BRIDGE**, KSR Institute of Dental Science and Research, Tiruchengode during the period of 2016-2019, under our supervision and guidance.

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To

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Your dissertational study titled "COMPARATIVE EVALUATION OF RETENTION AND STABILITY OF IMPLANT SUPPORTED MANDIBULAR OVERDENTURE USING LOCATOR ATTACHMENT AT DIFFERENT IMPLANT POSITIONS – AN IN VITRO STUDY" presented before the ethical committee on 16th Dec. 2016 has been discussed by the committee members and has been approved.

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Signature of Member Secretary
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DECLARATION BY THE CANDIDATE

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PLACE OF STUDY	K.S.R Institute of Dental Science & Research
DURATION OF COURSE	3 years
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LIST OF ABBREVIATIONS

SIROD	Single implant retained overdenture
IOD	Implant overdenture
NaCl	Sodium chloride
LIA	Locator implant attachment
LBA	Locator bar attachment
CD	Complete denture
mm	Millimeter
cm	Centimeter
N	Newton
D	Diameter of an implant
L	Length of an implant
3D	Three dimensional
MDF	Maximum dislodgement force

TERMINOLOGIES

DENTAL IMPLANT - a prosthetic device made of alloplastic material(s) implanted into the oral tissues beneath the mucosal and/or periosteal layer and on or within the bone to provide retention and support for a fixed or removable dental prosthesis; a substance that is placed into and/or on the jaw bone to support a fixed or removable dental prosthesis.

OVERDENTURE - any removable dental prosthesis that covers and rests on one or more remaining natural teeth, the roots of natural teeth, and/or dental implants; a dental prosthesis that covers and is partially supported by natural teeth, natural tooth roots, and/or dental implants.

RETENTION - that quality inherent in the dental prosthesis acting to resist the forces of dislodgment along the path of placement.

STABLILITY – the quality of a complete or removable partial denture to be firm, steady, or constant, to resist displacement by functional horizontal or rotational stresses.

IMPRESSION TRANSFER COPING - that component of a tooth or dental implant system used to provide a spatial relationship of a tooth or endosteal dental implant to the alveolar ridge and adjacent dentition or other structures; open tray impression transfer copings can be retained in the impression; closed tray impression transfer copings require detachment from the implants intraorally and replacement into the impression after attaching the analogs or replicas.

IMPLANT-SUPPORTED DENTURE - dental prosthesis, such as fixed complete denture, fixed partial denture, removable complete overdenture, removable partial overdenture, as well as maxillofacial prostheses, which can be supported and retained in part or whole by dental implants.

INTRODUCTION

Edentulism is a chronic condition and therapy is palliative which is aimed to improve function and quality of life. At present, total edentulism is considered as a condition that consists of severe dysfunction of the whole dentomaxillary system with serious comorbidities involving the entire body. According to surveys, approximately 7% of the patients are not able to wear their dentures due to severe atrophy of the alveolar bone and are considered as "Dental Cripples."[1] Deteriorating muscle strength and coordination in elderly patients may lead to problems fabricating complete dentures, as well as difficulty in achieving and maintaining acceptable denture retention and stability.[2]

One therapeutic approach to improve oral function in elderly edentulous patients is the use of overdentures. Most patients who are seeking improvement in the retention and stability of the mandibular denture do not have objections to removable prosthesis type and do not desire complete fixed prostheses and their implied difficult oral hygienic procedures.[3]

More recently, osseointegrated implants have been used to improve denture support, stability, and retention. Implant overdentures increase the masticatory function and improve satisfaction by making up for insufficient retention and stability of conventional dentures. Through a literature review, Batenburg et al. reported a high implant success rate in implant overdentures.[3] Removable prosthesis with few implants offer a less expensive option for an edentulous patient.

During the first three years after teeth extraction, the alveolar bone level usually decreases considerably. Later the process of resorption slows a bit, but never stops completely. The average rate of mandibular ridge resorption, in such situations, is about 0.2 mm per year and especially in the anterior mandible it is about 0.4 mm.[4]

But with implant overdenture, the long term bone resorption remains at 0.1 mm annually in the anterior mandible.[5]

According to the McGill consensus statement regarding overdentures, evidence exists suggesting that a two-implant retained overdenture should become the standard of care for treatment of the edentulous mandible.[6] Three advantages of the overdenture concept are: a reduced number of implants, an easier surgical procedure and an easier restorative technique by using pre-fabricated attachments. The high success rate of inter-foraminal implants used to support mandibular overdentures has been well documented in the literature.[7]

As implant overdentures are widely used clinically and understanding about implant overdentures has become higher, the types of implant attachment systems and their application methods have been diversely developed.[8] Although speculative, the faster the attachment releases from the abutment, the greater the stress shielding function. The retentive forces of most attachment systems are in the range of about 20 N. It is also assumed that forces of around 20 N are probably sufficient for overdentures in the edentulous mandibles.[9]

The choice of attachment system is an important step in the construction of overdentures and it depends on the amount of retention required, arch morphology, patient expectation, cost and load distribution to the implants and their surrounding tissue. Locator attachments are widely used today as attachment systems for implant overdentures. Advantages of Locator attachments are minimal height, self-alignment, dual (inner and outer) retention and correction of problems related to implant angulation. In addition, repair and replacement are easy and fast.[10]

STATEMENT OF PROBLEM

The treatment of the edentulous mandible with two-implant retained overdenture is a well accepted treatment with a long-term successful outcome. The prosthetic factors including attachment system for successful mandibular implant overdentures have been extensively reported in the literature. The location of dental implants and the choice of retentive attachments for implant retained overdentures are based on the amount of retention required, arch morphology, patient expectation, cost, load distribution to the implants and finally, the clinician's preference. Locator attachment systems are widely used nowadays for implant retained overdentures. However, limited information is available regarding implant positions and the effect on the retention and stability of two-implant retained mandibular implant overdentures especially using locator attachment systems.

AIMS AND OBJECTIVES

AIM

The aim of this in-vitro study was to evaluate and compare the effect of different locations of implants on the retention and stability of two-implants supported overdenture with locator attachments.

OBJECTIVES

1. To evaluate and compare the effect of vertically directed dislodging forces on the retention between locator attachment retained mandibular overdenture supported by implants placed in the “B&D” and “A&E” positions, in a test specimen.

2. To evaluate and compare the effect of oblique rotational dislodging forces on the stability between locator attachment retained mandibular overdenture supported by implants placed in the “B&D” and “A&E” positions, in a test specimen.

3. To evaluate and compare the effect of posterior rotational dislodging forces on the stability between locator attachment retained mandibular overdenture supported by implants placed in the “B&D” and “A&E” positions, in a test specimen.

NULL HYPOTHESIS

1. There will be no significant difference in retention between the mandibular overdentures retained by locator attachments supported by implants when placed either in the “B & D” or “A & E” positions, in a test specimen, when vertically directed dislodging forces are applied on them.

2. There will be no significant difference in stability between the mandibular overdentures retained by locator attachments supported by implants when placed either in the “B & D” or “A & E” positions, in a test specimen, when oblique rotational dislodging forces are applied on them.

3. There will be no significant difference in stability between the mandibular overdentures retained by locator attachments supported by implants when placed either in the “B & D” or “A & E” positions, in a test specimen, when posterior rotational dislodging forces are applied on them.

REVIEW OF LITERATURE

Meijer HJA, Starmans FJM, Steen WHA, Bosman F (1994)[26] showed that the tensile stress was approximately 50% greater in two-implant model under an oblique force, but this did not account for the other force directions. It also appeared that the largest compressive stress were generally found in the models that represented the most extreme resorption. The 10º lingual inclination would cause more stress in the bone around the implants than would a 4º lingual inclination. This 3D finite element analysis concluded that there was no reduction of the principal stress if the load was distributed by increasing the number of implants.

Bergendal T (1998)[12] evaluated the implant survival rate, clinical function and long term prognosis of overdentures in the maxilla and the mandible using two different attachment systems with a limited number of supporting implants. It considered that the long term follow up of overdentures in both the jaws, supported by limited number of implants revealed that the long-term prognosis in the mandible was excellent. The implant survival rate in the maxilla was lower than in the mandible because of bone morphology and loading conditions. He concluded that to reduce stress distribution to the implants, the lever arm should be kept as short as possible by using short abutments.

Batenburg RHK, Meijer HJA (1998)[3] found out that when a narrow mandibular arch existed, there is a tendency for gradual stress increase and so, a straight bar between two implants would likely be situated over the floor of the mouth rather than over bone, limiting the function of tongue. Using an angulated bar in a more labial position would induce stress in the bone and the placement of 2 implants closer together would result in a smaller bar with insufficient retention for the overdenture.

Therefore, four implants for a narrow mandibular arch and bar connection were needed, while single attachments were indicated for a narrow mandibular arch provided with two implants.

Burns DR (2000)[41] reviewed the literature and addressed some of the current issues regarding implant overdentures (mandible) and distinguished between the areas of consensus of opinion and controversy. Areas of controversy included the following (1) the number of implants required to provide adequate mandibular implant overdenture treatment outcome (2) the necessity for rigid interconnection between implants in the anterior mandible (3) negative influence of mandibular implant overdenture treatment on the anterior maxilla (combination syndrome) (4) the necessity for placements of dental implants in attached keratinized gingiva rather than alveolar mucosa.

Sadowsky SJ (2001)[5] considered the following clinical treatment concepts (1) The mandibular overdenture retained by implants in the inter-foraminal region appeared to maintain bone in the anterior mandible. (2) In younger patients or those for less than 10 yrs, a fixed implant denture would preserve posterior bone better than an implant overdenture in the mandible. (3) Occlusal schemes with no anterior contact in the centric relation position and minimal anterior contact in excursions would reduce the combination syndrome effect. (4) Multiple implants could be recommended for the mandibular overdenture when sensitive jaw anatomy increased occlusal forces, or high retention needs were present or when implant length is < 8 mm or implant width is < 3.5 mm.

Chung KH, Chung CY, Cagna DR, Cronin RI, (2004)[2] designed a study to investigate the magnitude of retentive force in implant overdentures using a variety of attachment systems. The study revealed that many attachments systems with patrix and matrix configuration have a relatively low strain-at-dislodgement value. It was also found out that for the relatively high strain-at-dislodgement group, high distortion of the retentive elements would happen during dislodgement.

Pascinta M, Grossmann Y, Finger IM (2005)[42] described the use of low-profile attachments systems to accommodate limited inter-arch space for a mandibular implant retained overdenture. This clinical report demonstrated that using low-profile attachments for mandibular implant-retained overdentures with limited inter-arch space provided a valuable prosthetic option, the prosthetic treatment included a maxillary CD and mandibular implant retained overdenture. The incorporation of the attachments significantly contributed to denture retention and stability.

Trakas T, Michalakis K (2006)[9] revealed a mean marginal bone loss of 0.3mm within the first year of implants with bars and clips. Up-to-date evidence from the literature indicated that peri-implant soft tissue health was not affected by either ball or bar attachments. However, there was published evidence that showed a higher plaque index associated with magnet type attachments. Studies confirmed that ball attachments provided higher stability with the load more evenly distributed on to the residual ridges on both sides of the dental arch. Compressive stresses were reduced if the implants were not connected. Literature concluded that patients rehabilitated with magnet retained overdentures were not satisfied. It can probably be concluded that there was no difference between the bar and ball attachment methods.

Alsabeeha NHM, Payne AGT, Swain MV (2008)[14] investigated the retentive force or wear features of different attachment systems, specifically for mandibular two implants-retained overdentures using an unsplinted prosthodontic design. Ball attachments with larger patrices were found to achieve higher retentive forces compared to similar attachments of smaller dimensions. A 30º implant angulation was reflected in a reduction of retentive force up to 25%. The clinical relevance of recording the retentive force of attachment systems under paraxial dislodging forces was considered to be a measure of stability of overdentures. The findings here implied that better stability for the overdenture would be expected from ball attachments compared to magnetic.

Evtimovska E, Masri R (2009)[43] examined early changes in the retentive values of implant overdenture attachments during multiple pulls. The result showed that there was a significant difference in the percent reductions in peak load to dislodgement between the attachments after the first pull and after the final pull. The yellow hader clips exhibited the least percent reduction in peak load to dislodgement after the first pull, followed by the white locator attachments. The result demonstrated that locator attachments had higher retentive values than yellow hader clips and they should be used when greater retention was needed. The reduction was peak load to dislodgement for the locator attachments were more apparent when they were used for non parallel implants.

Sadig W (2009)[15] evaluated the effect of connector type and implant number and location on the retention and stability of implant supported overdentures by measuring retentive forces during vertical and 2 types of rotational dislodgment (oblique rotational dislodging forces and posterior rotational dislodging forces). In this study, the results obtained with the posterior dislodging forces were higher than the other 2 tested forces which could be attributed to the anteriorly placed canine implants that offer indirect resistance. It was concluded that the locator connectors provide the highest retention and stability of the implant-supported overdentures followed by ball connectors and then magnets.

Dene L (2010)[44] reported a case with the symphyseal height of the anterior mandible 10 mm and patient had cardiovascular complications and in addition he was on anticoagulants. So, the INR was made to bring down 1-1.5 prior to surgery. The mandible was restored with four narrow platform implants. Using locator attachments, a mandibular overdenture was fabricated with good retention and stability. This improved the patient's quality of life. This report demonstrated the successful use of endosteal implants together with locators in the mandibular symphyseal area.

Kleis WK, Kammerer PW, et al (2010)[16] compared a self aligning attachment system with two traditional ball abutments for two implant retained overdentures in the edentulous mandible in 1 year of clinical use. The locator group showed 75.5% loss of retention because of the wear of the male parts and thus change of these parts at regular intervals become necessary. In comparison to dal–ro and TG-O-ring the locator needed a noticeable higher effort to position. According to the results, the use of the self aligning attachment system accounted for more prosthodontic maintenance than the use of the traditional ball abutments.

Cakarer S, Can T (2011)[17] evaluated the comparison of the bar, ball and locator attachment system with regard to a clinical point of view. In this study, 15.7% of the patients in the ball group and 55.5% of the patients in the bar group had complications associated with the attachments including replacement of attachment components and attachment fracture. No retention problem was recorded in the locator group. No complications associated with post insertion maintenance or implants were observed in the locator group. Also this study demonstrated that retentive values of the locator attachments were reduced significantly after multiple pulls. It was concluded that all the attachment systems were useful. No significant difference was observed between the attachment systems regarding the implant failure.

Mackie A, Lyons K, Thomson WM, Payne AGT (2011)[18] research found out that the resilient locator nylon matrix loses retention frequently but was easily replaced, incurring minimal clinical time. Specific to the locator attachment system was the nuisance factor of the regular packing of food debris or plaque accumulation within the undercut. It was concluded that no significant differences were found between the overall number of prosthodontic maintenance events required for mandibular implant overdentures using either the locator or southern attachment system over 3years. Prosthodontic success rates were 90% in the locator nylon group, 88% in the southern plastic group and 75% in the straremann gold group.

Yang T-C, Maeda Y, Gonda T, Kotecha S (2011)[19] evaluated the retentive force and lateral force of an implant with various types of attachments for overdentures in relation to implant inclination. This study concluded that the retentive force of the locator blue and ball attachments remained constant as the implant inclination increased up to 30°, whereas the same conditions stimulated an increase in the lateral force to the implant. The magnetic attachments did not present a higher retentive force, but the changes in the retentive force and lateral force were minimal in relation to implant inclination, especially in the self-adjusting magnetic attachment, which allowed vertical and rotational movements.

Cheng T, Ma L, Liu XL, et al, (2012)[20]compared the clinical outcomes of single mandibular implant retained overdentures versus that of complete dentures. Single implants were placed in the anterior area of the mandible for the following reasons (1) thicker cortical bone (2) lowered surgery risk by avoiding the inferior alveolar nerve (3) a larger tissue- supporting area to prevent overloading on the implant. The author concluded that the single implant retained mandibular overdenture with locator and magnet attachment achieved better patient satisfaction and promoted chewing efficiency than those reported with conventional mandibular dentures.

El-Sheikh AM, Shihabuddin OF, Ghoraba SMF (2012)[22] compared the treatment outcome and prosthodontic maintanence requirements of two versus three narrow-diameter bone level implants with locator attachments supporting mandibular overdentures. With the limited observation period and the number of patients included in this study, it was concluded that the use of narrow diameter bone level implants appeared to be predictable if clinical guidelines were followed and appropriate prosthetic restorations were provided. It was also concluded that there were was need to insert more than two-narrow diameter implants with locator attachments in cases of atropic mandible to support an overdenture, since there were no significant differences with regard to any of the studied clinical or radiographic parameters of the peri-implant tissues between the two groups.

Kim MS, Yoon MJ, Huh JB, Jeon YC, Ieong CM, (2012)[45] suggested that in case of inter-occlusal space the usage of bar might cause a denture fracture, prosthesis over-contour or poor hygiene. Attachment like ERA attachment, multiple clip with different directions, friction pin and swivel latchet had the disadvantage of retention loss due to the wear caused by the repeated insertion and removal of the denture. In case of wear, plastic male part could be replaced and metal female parts require manufacturing of the prosthesis. To solve this problem, locator was used with bar as it had the lowest vertical height and enabled the metal female part to be replaced using the drill and tapping technique. The biggest advantage of drill and tapping technique was that it achieved total retrievability by just replacing new metal female part.

Sadr SJ, Saboury A, Hadi A, Mahshid M (2012)[21] compared the effect of different implant locations (ABDE,6AE6,6BD6) on the retention and stability of mandibular implant supported overdenture with ball attachments. The results of the study showed that the retention of the overdenture at 6BD6 implant position and the lateral stability of the overdenture at 6AE6 implant position against oblique force were the highest. On the other hand, the amount of lateral stability of overdenture against anteroposterior force was the highest in 6BD6 implant position. This study also demonstrated that the more posterior the location of distal implant, the higher the retention and stability.

Celik G, Uludag B (2013)[7] found out that the resultant stresses were greater on the side of the load application for vertical orientation of the implants. Among the 4 attachment systems, the single anchor attachment (ERA) transferred less stress to the implants. This result was in agreement with previous studies. The bar with the distally placed extra coronal rigid attachment design caused the highest stress pattern when comparing these results to the results of inclined oriented implants, similar stress patterns were observed.

Elsyad MA, et al (2013)[23] evaluated and compared the effect of three different positions on strain developed around four implants supporting a mandibular overdenture with rigid telescopic attachments. The study concluded that Quadrilateral design showed the lowest peri-implant strain compared to curved or linear designs. This design might be recommended when rigid telescopic crowns were used to connect mandibular overdentures to four implants .The curved design recorded the highest strain values for all load applications. The highest strain values were observed at distal sites of the posterior implants.

Mahajan N, Thakkur RK (2013)[46] reported a case that showed the procedure that allowed the fabrication of lower overdenture with locator attachments, which had the highest retention and stability followed by ball and then finally magnets as recommended. After 6 months of the osseointegration period, a definitive prosthodontic therapy was started by exposing the cover screws of implants and healing abutments were placed for 2 weeks. In the above procedure, chair side pick-up procedure with autopolymerising resin was performed and blue male inserts were given to the patients for initial few months. The retention could be increased gradually by changing to higher retentive caps according to patient's usage and needs.
Oettle AC, Fourie J, Baron BH, Van AW (2013)[47] determined the position and occurrence of the midline mandibular canal in the various age, sex, population and dentition groups. It was found that the MLC (mandibular lingual canal) situated more superior, progressed in an antero-inferior direction, while those canals located inferior showed an antero-superior direction. Also dentate males seemed to have adequate height of alveolar bone needed for dental implants in the midline without endangering the vessels of the MLC. Edentulous female patients were at most risk to injury of the vessels of the MLC during dental implant surgery in this area.

Scherer MD, Glumphy EAM, Seghi RR (2013)[24] investigated the effect of implant distribution and number on the retention and stability of a simulated prosthesis using different types of attachment systems. The study concluded that the resistance to vertical dislodging forces of a simulated overdenture prosthesis increased with additional widely distributed implants and the resistance to oblique dislodging forces of a simulated overdenture prosthesis also increased with additional widely distributed implants. Resistance to antero-posterior dislodging forces of a simulated overdenture prosthesis increased with additional widely distributed implants except in the four implant groups.

Bansal S, et al (2014)[25] described that according to Taylor, for a 2-implant retained mandibular overdenture, placement of implants in the lateral incisor area rather than the canine position offered a mechanical advantage providing better stability for the overdenture. By moving the implants from the canine to the lateral incisor position, the effective anterior lever arm could be reduced, thus minimizing the tipping forces on the overdenture.

Ionescu C, Gabinasu BM, et al (2014)[4] reported a case of 53 yr old patient who was completely edentulous and was rehabilitated with four implants supported mandibular overdentures using locator attachment. In this case, the author had chosen locator attachment because of insufficient restorative space available, which was less than 9 mm. Also, he considered the fact that in time it was possible to lose an implant or two, a condition that could be remedied without much need of the laboratory help with refurbishing the denture accordingly to Mc Gills consensus.

Meghea DM, Preoteasa CT &Preoteasa E (2014)[26] conducted a narrative review on studies reporting data on the attachments systems for implant overdentures, considering aspects as design and biomechanical consequences The selection criteria for the attachment were given as (1) the number, the position and the angulation of the implants (2) the prosthetic features like vertical prosthetic space, the resilience of the oral mucosa, occlusal loading (3) the normal dexterity of the patient (4) biological conditions and therapeutic expectations , as the splinting of implants by choosing bar systems provided a more uniform distribution of occlusal forces and (5) financial and time resources of the patient.

Passia N, Brezavseek M, Fritzer E, Kappel S (2014)[48] designed a study as a prospective multi-centre randomized controlled clinical. The patients received one median implant in the edentulous mandible which retained the existing complete dentures using ball attachments. Loading of the median implant was either immediately after implant placement or delayed by 3 months of submerged healing at second stage (control group). The primary outcome measure was non- inferiority of the implant success rate of the experimental group compared to the control group. The secondary outcome measured clinical, technical and subjective variables. This multi-centre clinical trial gave information on the ability of a single median implant to retain a complete mandibular denture when immediately loaded.

Patel U, Walmsley D (2014)[27] outlined the use of implant placement in the edentulous mandible which resulted in the successful provision of a complete overdenture. The patient was advised rehabilitation of the mandibular arch with a removable prosthesis supported by four implants. A temporary prosthesis was made by copying the patient’s current lower denture and modification done to allow space for the healing abutment. Inter-occlusal space analysis revealed limited space between occlusal plane and mandibular denture bearing area. So, a stud attachment such as the locator system (low profile stud) was used. The cuff of the locator abutment must stand atleast 1mm higher than the level of the mucosa. The processed denture was delivered and the retentive level of the nylon insert was chosen based on how early the denture was displaced in the mouth during function.

Scherer MD, Mcglumphy EA, et al (2014)[28] used four different types of attachments. And this study concluded that the interactions between attachment systems, direction of force and implant location were statistically significant. The vertical retention and horizontal stability of a simulated overdenture prosthesis increased with distal implant location up to the second premolar. Anteroposterior stability increased when the implant location was placed distally. Ball and locator attachments reported the highest levels of retention and stability.

Sethi T, Kheur M, Harianawala H, et al (2014)[28] informed that the use of a single implant to support an overdenture was first documented by Cordioli. The authors of this report concluded that single implant supported magnet retained mandibular overdentures significantly improved the oral health related quality of life of completely edentulous patients. The authors have treated multiple patients with this protocol and have found it to be a successful option. This method used an implant abutment with a customised coping that harboured the keeper for magnet. The placement of the coping and picking up of the magnet in self cure resin could be done chair side and did not require additional laboratory times.

Tabatabian F, Saboury A, Sobhani ZS, Petropoulos VC (2014)[29] assessed the effect of inter-implant distance on the retention and resistance of mandibular implant - tissue supported overdenture. Three pairs of implants with 4 mm diameter and 12 mm length were inserted with inter-implant distances of 10, 25 and 35 millimetre and at the approximate locations of laterals, canines and first premolars namely positioned as A, B and C respectively. Based on the results of this study, placing implants with more inter-implant distance could be advantageous in increasing the resistance against anterior-posterior functional forces.

Daou EE (2015)[30] did a review to help the clinician in selecting the most adapted stud attachments according to evidence based dentistry. The greatest reported value for the peak load was for the Zest Advanced Generation (ZAAG) attachment compared to the Nobel Biocare ball, the zest anchor and the strengold ERA. The ZAAG attachment exhibited significantly the highest retentive values under dislodging tensile forces applied to the housings in two directions simulating function: vertical and oblique.

Srinivasan M, Schimmal M, Kobayashi M, Badond (2015)[31] evaluated the influence of an artificial saliva lubricant on the retentive force of a stud type attachment (locator) for implant overdentures. The raw data revealed that the retentive forces for locator attachments were lower while conducting the tests in artificial saliva as compared to testing with 0.9% NaCl solution, but this was not statistically significant. The results of this pilot study did not evince that the retentive force of locator attachments with blue inserts was influenced by different lubricants during in-vitro cyclic dislodging, when the implants were parallel to one another.

Topkaya T, Solmaz M.Y (2015)[32] evaluated the effects of the number and configuration of the implants in lower jaw overdentures supported by ball anchor connectors using finite element method. It was concluded that in all models loading on the first molar tooth produced the highest stress on the implant. The stress in 4 implant supported models were lower than the stresses in the 2 implant supported models in all loading conditions. In the 2 implant supported models, the stress in the 2 premolar model in which the implant were inserted in the first molar sites were lower compared to the other 2 implant supported models.

Elsyad MA, Elhaddad AA &Khirallah AS (2016)[33] evaluated and compared axial and non-axial retentive properties of 0-ring and locator attachments that were used to retain maxillary implant over dentures. Within the limitations of this in-vitro study, it was concluded that the locator medium recorded the highest initial and final retention (during vertical, anterior and lateral dislodging) compared to other types of attachments. O-ring attachments recorded the highest initial and final retention during posterior dislodging. And the lowest initial retention was recorded with locator extra-light and the lowest final retention was recorded with recorded with the O-ring attachment. During lateral and anterior dislodging, the lowest initial and final retentions were recorded with the O-ring attachments.

Kaneko T, Nakamura S, Hino S, Horie N And Shimoyama (2016)[34] reported a case and the author evaluated the masticatory function which revealed significant improvements in oral function with two-IOD treatment as compared with the conventional complete dentures. In these cases, he used locator attachments for the reasons: locator attachment system used a lower height than a ball anchor and were self aligning, providing dual retention. Also, the locator attachments for the IOD were associated with less deformations of the mandibular denture base over the implants compared to ball attachments. The locator system recorded higher compressible strains and provided excellent settlement of the denture base without fulcrum formation.

Mahoorkar S, Bhat S & Kant R (2016)[50] analysed systematically the literature on single implant supported mandibular overdenture. The authors concluded that the single implant retained overdenture (SIROD) could be an economic alternative for an octogenarian patient. Nine studies reported success rates of nearly 100% without any complications or failures. Implant survival rate seemed to be high with the SIROD and no association was found between the implant failures and the type of surgery, implant type and dimensions of implants. Some studies reported SIROD to be at par with the two implant retained overdentures in terms of patient satisfaction and prosthodontic complications.

Nischal K & Chowdhary R (2016)[1] concluded that early loaded single implant overdenture reinforced with meta mesh was a reliable treatment option in prosthetically maladaptive edentulous patients and in patients for whom cost was a major issue of concern. It could provide a beneficial outlay over a 2-year observation period. According to Carl. E. Misch Prosthetic classification, RP5 prosthesis was subjected to more bone loss posteriorly in comparison to RP4 prosthesis. Therefore a single implant overdenture should be relined over a period of time for better prognosis in the future.

Oda K, Kanazawa M, et al (2016)[35] evaluated the denture movement of mandibular implant retained overdentures anchored by different numbers of implants. Three implant positions were prepared at the anterior midline (1-IOD), the lateral incisor regions (2-IOD) and the middle and canine regions (3-IOD). Loading tests were performed and the study concluded that the use of 2 implants for anchoring an implant overdenture resulted in easier rotation of the denture base during mastication with the anterior teeth than the use of 1 or 3 implants. The horizontal movements of implant retained overdentures were small compared with the vertical movements. Denture movement under occlusal force in the molar region was small compared with that in the anterior region.

Patil PG, Seow LL and Tagore M (2016)[36] designed a study to test the hypothesis that the implant success and satisfying masticatory performance could be obtained by single median implant used in the edentulous mandible to retain a complete mandibular denture. From a biomechanical point of view during mastication, the occlusal forces on the posterior teeth of the two implant retained mandibular overdentures caused maximum movement of the denture around the fulcrum line joining two attachments; Hence the freedom of movement was limited to around one axis. In single implant retained mandibular overdenture cases, the denture was free to move in all directions and effective stress concentration around the crestal bone might be reduced when compared to two implants.

Reda KM, El-Torky IR, El-Gendy MN (2016)[51] compared the retention force of three different types of overdenture attachment systems used in implant retained mandibular complete overdentures. Retention forces were calculated three times (initially, after 3000 and 5500cycles). It was concluded that regardless of the initial retention level of overdenture attachment, gradual loss of retention values was inevitable. However, the rate of retention loss in overdenture attachments was higher in types which comprised of plastic parts within their components, rather than those totally made up of noble metals.

Seo Y-H, Bae E-B, Kim J-K (2016)[8] evaluated the clinical findings and patient satisfaction on implant overdenture designed with locator implant attachment (LIA) or locator bar attachment (LBA) in mandibular edentulous patients. When compared to the LBA group, the LIA group showed a higher incidence of complications and among them loss of retention occurred most frequently. The frequency of patrix replacement for restoration of retention was higher in the LIA group than in the LBA group. The LIA group and LBA group both showed high levels of satisfaction and there was no significant difference.

Sia PKS, Masri R, Driscoll CF & Romberg E (2016)[37] evaluated the effect of the differential heights of pairs of locator abutments on the retention of overdentures after 6 months of simulated function. The results showed that a statistically significant difference was found between the various groups tested, suggesting that the differences in the height of locator abutment pairs might influence the retention of overdentures. The peak load-to-dislodgement group 6mm was significantly higher than that of group 0 mm and 2 mm. The enhanced retention observed in this study as the difference in locator height increased might be due to increased friction or a rotational path of dislodgement or both. The tallest locator abutment of 6 mm had the largest surface area in contact with the intaglio surface of the denture compared with the shorter locator abutments of 0, 2 or 4 mm.

El-Anwar MI, El-Taftazany EA, Hamed HA, Abdelhay MA (2017)[38] compared the stresses generated by using two or four root form dental implants supporting mandibular overdentures that were retained with ball and locator attachments. The result showed that the locator attachment showed less von mises stress values than the ball attachment with vertical as well as oblique loading conditions in implant–abutment complex, supporting alveolar bone and the resilient caps. It was concluded that locator attachments might provide an adequate attachment system when two implants were to be used to support an overdenture when compared to the ball and socket attachments.

Elsyad MA, Abdehamid M, Dayekh& Khalifa AK (2017)[10] evaluated and compared the retention and stability of dolder bar and locator attachments used to retain maxillary implant overdentures. For all dislodging forces, locator transparent recorded the highest forces, followed by locator pink and locator blue, with bars recording the lowest forces. Posterior dislodging forces recorded significantly higher stability for all attachments. Locator attachments were recommended to retain maxillary overdentures over dolder bar attachments, as locator attachments were associated with high retention and stability after wear simulation with minimal retention loss. After wear simulation, the retention and stability of locator transparent and pink inserts only were still above the minimum required retention needed to achieve good patient satisfaction.

Tehini G, Baba NZ, Berber A, Majzoub Z, Bassal H (2017)[39] assessed and compared the effect of simulated mastication on the retention of white, pink and blue locator inserts for overdentures retained by 2 implants. In this study, all the specimens were subjected to biaxial cyclic loading for a total of 100,000 cycles in dry conditions at room temperature. The blue inserts, showed a significant loss of retention (-37%) following simulated function, while pink and transparent components maintained their retention values after biaxial load.

Yoo JS, Kwon KR, Noh K, et al (2017)[40] evaluated the level of strain deformation with the locator attachment was smaller than that with the bar/clip attachment and this could be explained by the fact that the vertical pressure was absorbed by the deformation of the components of the locator attachment and the denture. Based on these results, it was concluded that the maximum extension of the denture base provided a favourable prognosis for the implants.

MATERIALS

MATERIALS

1. Modelling wax (Hindustan, Chapel road, Hyderabad, India) (Fig. 2)
2. Implants (Myriad plus, Equinox, Amersfoort, Netherlands – D 3.8mm * L 11mm) (Fig. 3)
3. Impression copings – Snap on type along with abutments (Myriad plus, Equinox, Amersfoort, Netherlands) (Fig. 21)
4. Implant analogs (Myriad plus, Equinox, Amersfoort, Netherlands) (Fig. 3)
5. Plaster of paris (Type 2 gypsum, SBM, Sri Balamurugan industries, Tuticorin, India) (Fig. 16)
6. Dental stone (Type 3 gypsum – Gold stone, Asian chemicals, Rajkot, India) (Fig. 17)
7. Heat cure denture base acrylic resin (DPI – pink, Dental products of India, Wallace street, Mumbai, India) (Fig. 6)
8. Condensation silicone light body (Zetaplus soft, Zhermack, Badia Polesine (Rovigo) - Italy)
9. Addition silicone putty and light body (Neosilk, Calmed Invest kft., Busan, Korea) (Fig. 12)
10. Self cure denture base acrylic resin (DPI – pink, Dental products of India, Wallace street, Mumbai, India) (Fig. 5)
11. Locator attachments (Equinox, Amersfoort, Netherlands) – abutments with 3 mm of gingival cuff height, metal housings and transparent nylon male caps (Fig. 9 & 10)
12. Polyether impression material (Impregum^{TM}-soft, 3M ESPE, Deutschland, Neuss-Germany) (Fig. 11)
13. Tray adhesive (Polyether adhesive, 3 M, Deutschland GmbH, 41453 Neuss,

Germany) (Fig. 15)

14. Acrylic Teeth set (Medilux, Meadway dentals Pvt. Ltd., New Delhi, India) (Fig. 4)
15. Beading wax (Giriraj dental products, Mumbai, India) (Fig. 14)
16. Cold mould seal (DPI, Dental products of India, Wallace street, Mumbai, India)
17. Sand paper

ARMAMENTARIUM

1. Lower edentulous model former (Fig. 1)
2. Surveyor (Ney surveyor, Neytech, Dentsply, USA) (Fig. 28)
3. Flasks and clamps
4. Laboratory lathe (Fig.25)
5. Carbide burs (Fig. 26)
6. Locator abutment driver and Wrench (Locator Core Tool & Locator Torque Wrench, Zest Anchors LLC) (Fig. 20 & 23)
7. Acrylic trimmers (Fig. 26)
8. Straight fissure bur (Meisinger straight fissure carbide FG bur, HM31-010, Germany) (Fig. 26)
9. Sand paper mandrel (Fig. 26)
10. Cotton rag wheel
11. Internal hex driver (Myriad plus, Equinox, Amersfoort, Netherlands) (Fig. 23)
12. Spirit lamp (Fig. 27)
13. Chip blower (Fig. 27)
14. Wax knife (Fig. 24)
15. Wax carver (Fig. 24)

16. Metal scale (Fig. 27)
17. B.P blade no. 15 with handle (Fig. 24)
18. Rubber bowl (Fig. 24)
19. Stainless steel spatula (Fig. 24)
20. Divider (Fig. 24)
21. Hot plate spatula (Fig. 24)
22. Wax spatula (Fig. 24)
23. Acrylic mixing jar
24. Dental flasks and clamps
25. Prefabricated metal hooks (Fig. 13)
26. Stainless steel metal chains (Fig. 19)
27. Metal plate with nails and bolts (Fig. 18)
28. Universal testing machine (Kalpak industries, Pune, Maharashtra, India) (Fig. 29)
29. Curing water bath (Delta, Gurgaon, Haryana, India) (Fig. 22)
30. Spirit columns (Fig. 27)

METHODOLOGY

1. Fabrication of test specimens

A. Preparation of mandibular edentulous wax model

Modelling wax (Hindustan, Chapel road, Hyderabad, India) was cut in to pieces and melted in a hot water bath (Delta, Gurgaon, Haryana, India) using a stainless steel vessel. Then, the melted wax was allowed to flow into the mould space of a mandibular edentulous model former till the wax completely filled the mould. The wax was allowed to cool and harden. The model former with the wax was left for 2 hrs at room temperature, to ensure complete solidification of the wax. Later, the wax model was retrieved from the model former (Fig.30). For the purpose of giving soft tissue replica with silicone in the acrylic test model, grooves of 3 mm (equivalent to the locator abutment cuff height) depth were made in the wax model using a wax spatula. Depth of 3 mm was ensured by having a marking in the wax spatula (Fig.31). Then, till the depth of the grooves, the wax model was completely scraped with a wax carver (Fig.32).

B. Incorporation of implants into the wax model

Four implants (Myriad plus, Equinox, Amersfoort, Netherlands) of diameter 3.8 mm and length 11 mm were placed in the wax model after ensuring parallelism with the help of a surveyor (Ney surveyor, Neytech, Dentsply, USA) by the following method. The wax model was locked in the surveying table in such a way that it was parallel to the surveying platform. Two markings were made with a permanent marker for the implants to be placed in B and D positions with an inter implant distance of 16 mm[56] between them and another two markings were made for the implants to be placed in A and E positions with an inter implant distance of about 35 mm between them[29] (Fig.33).

Impression coping was attached to the implant with the help of an internal hex driver (Myriad plus, Equinox, Amersfoort, Netherlands) and the complex was attached to the surveying arm of the surveyor. Then, the surveying arm was lowered on to the wax model and made to contact the ridge area corresponding to the markings made (Fig.34). The wax in that area was softened with a heated wax knife and the surveying arm was further lowered in to the wax model, thereby submerging the implants in to the wax model. It was ensured that the surface of the implant was at the level of the crest of the ridge. Once the wax hardened, the impression coping & the implant complex which was attached to the surveyor arm was then detached from the surveyor. Similarly, all the other 3 implants were placed and thus, a wax model with four implants in A,B,D & E positions was obtained (Fig.35). The impression copings were kept attached to the implants till the wax model was processed in acrylic. These impression copings helped in maintaining the position of the implants during the processing of the test specimen.

C. Processing of the test specimen with implants

The wax model was processed in heat cure pink acrylic resin using conventional flasking & lost wax technique.[15] Once the wax model was processed in acrylic, the impression copings were removed. The acrylic model was then trimmed with acrylic and carbide burs & then smoothened with sand paper. Polishing was done on a dental lathe with cotton rag wheel and pumice. Thus, acrylic test model with four implants in A,B,D & E positions was obtained (Fig.36).

D. Simulation of soft tissue with silicone liner

1. To simulate the soft tissue, a silicone liner was given on the ridge surface for about 3 mm thickness matching the gingival cuff height of the locator abutments.[7] This was done by first placing the locator abutments (Zest Anchors) into the implants in the acrylic model using abutment driver (Locator Core Tool, Zest Anchors LLC) and then, tightened to 30 Ncm with a wrench (Locator Torque Wrench, Zest Anchors LLC) following the manufacturer's instructions[37](Fig.37). Two thickness base plate wax (Hindustan, Chapel road, Hyderabad, India) of about 3 mm thickness was then adapted on the ridge surface of the acrylic model surrounding the abutments (Fig.38). Flasking was done in a conventional method. After the setting of the plaster, the flask was opened & the test model was removed from the mould cavity. Then, the wax layers were removed from the model. Addition silicone light body (Neosilk, Calmed Invest kft., Busan, Korea) was mixed and placed in that mould cavity. Then, counter part of the flask along with the model was placed over that. Then the flask was tightened with the clamp. After setting of the addition silicone, the model was retrieved from the flask. Thus, the test specimen with a resilient silicone soft liner was fabricated (Fig.39).

E. Fabrication of custom trays and impression making

Custom tray was fabricated for making closed tray impression. The locator abutments were then removed and the impression copings along with snap on attachments (Myriad plus, Equinox, Amersfoort, Netherlands) (Fig. 42) were attached to the implants in the acrylic model using an internal hex drive (Myriad plus, Equinox, Amersfoort, Netherlands) (Fig.43). Two sheets of wax were adapted over the acrylic model ie., around & above the impression copings with snap on and rest of the ridge. Two tissue stoppers were given in the molar region on both the sides. Special tray for closed tray impression technique was fabricated with auto-polymerising resin (DPI – pink, Dental products of India, Wallace street, Mumbai, India) using dough method and a handle was placed in the anterior region (Fig.40 & 41). Wax spacer was removed from the custom tray and tray adhesive (Polyether adhesive, 3 M, Deutschland GmbH, 41453 Neuss, Germany) was applied to the tray. Polyether medium body impression material (Impregum™ soft, 3M ESPE, Deutschland, Neuss-Germany)[57,58] was mixed. Then, the custom tray was loaded with the impression material and the impression was made by correctly seating the tray in position. After ensuring that the material had set, the tray was removed from the model and thus, the snap on attachments were embedded in the impression in their respective positions (Fig.44).

F. Fabrication of stone casts

The impression copings were then removed from the test specimen and attached to the implant analogs (Myriad plus, Equinox, Amersfoort, Netherlands) (Fig.45). The complexes were positioned correctly within the snap on attachments (Fig.46). The impression was beaded using beading wax (Giriraj dental products, Mumbai, India). To get soft tissue mollage, condensation silicone light body was mixed and injected around the impression copings in the impression. Then, stone cast was poured with type 3 gypsum (Gold stone, Asian chemicals, Rajkot, India). On retrieval of the stone cast from the impression, the implant analogs got incorporated into the stone cast. The impression copings were then removed and the cast was trimmed and shaped.

G. Attaching locator attachment sets on the stone model

The locator abutments were then screwed into the implant analogs in the stone model using abutment driver (Locator Core Tool, Zest Anchors LLC) and then, tightened to 30 Ncm with a wrench (Locator Torque Wrench, Zest Anchors LLC) (Fig.47). Complex of attachment metal housings & black processing units were attached to the locator abutments.

H. Fabrication of record base and occlusion rim

Permanent record base was constructed on the stone cast by adapting a modelling wax sheet, flasking, dewaxing and packing with heat cure acrylic resin (DPI – pink, Dental products of India, Wallace street, Mumbai, India). Curing was carried out according to the manufacturer's instructions. Metal housings with black processing units were embedded in the intaglio surface of the denture base (Fig.48). Occlusion rim was constructed with modelling wax to an anterior height of 18 mm and a posterior height corresponding to the 2/3rd of the retromolar pad. It had a width of about 5 mm anteriorly and 8 mm posteriorly.

I. Fabrication of trial denture

Teeth arrangement was done following the principles of teeth setting for the lower teeth using acrylic teeth set (Medilux, Meadway dentals Pvt. Ltd., New Delhi, India). Wax up and polishing was done (Fig.49).

J. Processing of the denture

The waxed up denture was then flasked and dewaxing was done. The permanent denture base with the housings was retained in its position in the flask, after the dewaxing procedure. Heat cure acrylic material (DPI – pink, Dental products of

India, Wallace street, Mumbai, India) was packed and curing was carried out. Thus, processed denture with metal housings in A,B,D & E positions was obtained. It was then trimmed and polished (Fig.50).

K. Removal of attachment housings from the processed denture

The metal housings were then removed from the denture using straight fissure bur (Meisinger straight fissure carbide FG bur, HM31-010, Germany) before duplication and vent holes were formed in all the four A,B,D & E positions (Fig.51). Such vent spaces were created for attaching the attachment housings in the test dentures after duplication. The advantage of creating exact space for housing was that it would prevent change of angulation of housings in the test dentures during the attachment of metal housings procedure.

L. Duplication of test dentures

A regular dental flask was used for the fabrication of duplicate dentures. Addition silicone putty (Neosilk, Calmed Invest kft., Busan, Korea) was mixed and placed inside the body portion of the flask and the occlusal surface of the denture was invested into the putty. The putty was adapted along the entire border of the denture including the lingual side. Petroleum jelly was applied as a separating medium over the putty to prevent adhesion of the second layer of putty. Addition silicone light body (Neosilk, Calmed Invest kft., Busan, Korea) was mixed and placed in the intaglio surface of the denture and again addition silicone putty was mixed and kept over it and in the base of the flask. The flask was closed after ensuring the proper seating of the base. After the setting of addition silicone, the test denture was removed from the flask leaving a mould space (Fig.52,53 & 54).

Auto-polymerising resin (DPI – pink, Dental products of India, Wallace street, Mumbai, India) was mixed as per manufacturer's instructions and poured in to the mould space. Then, the flask was closed properly and allowed for curing of the resin. After the completion of curing of the resin, deflasking was done & the duplicated denture was retrieved from the mould and kept in pressure pot maintained at a pressure of 20 psi for 20 min[52]. Then the duplicated denture was trimmed and polished. Similarly, twenty duplicated dentures were fabricated for both the groups (Fig.55). As there was tearing of the addition silicone material after removal of about 3 duplicated test dentures, the material was changed ie., the flasking procedure was repeated after duplication of 3 duplicated test dentures.

M. Incorporation of locator attachments in all test dentures

After the completion of the processing work, the locator abutments were removed from the analogs in the stone model and were screwed into the acrylic test specimen using the abutment driver (Locator Core Tool, Zest Anchors LLC) and then, tightened to 30 Ncm with a wrench (Locator Torque Wrench, Zest Anchors LLC). For the first group (group A), metal housings with black processing units were placed in B and D positions of the locator abutments in the test specimen (Fig.56) and the test denture was checked for adaptation by placing it on the test specimen to ensure complete seating of the denture. Then, auto-polymerising resin was added to the location of vent holes (B & D positions) in the test denture and placed over the housings in the test specimen. Thus, the attachment housings were picked up in B & D positions and the remaining vent holes in A and E positions in the test denture were closed using auto-polymerising resin (Fig.57). In the same way, ten dentures were made for group A specimens (Fig.58). Similar procedure was done in a vice-versa manner for the attachment of housings in A and E positions for the group B specimens (Fig.59,60 & 61).

The black attachments were then replaced by transparent Locator attachments (Locator medium retentive caps) using a Locator Core Tool (Zest Anchors LLC). Transparent Locator attachments were tested in this experiment, as they were considered the most retentive nylon caps[10] (Fig.62 & 63).

2. Evaluation of retention and stability using Universal testing machine

A. Attachment of hooks in the test dentures

The retention and stability was tested by subjecting the dentures to tensile forces in different directions. The tensile force was applied to the dentures by attaching chains to hooks attached to dentures on one side and the tensile load cell of the Universal testing machine (Kalpak industries, Pune, Maharashtra, India) on the other side. Four preformed metal hooks with a radius of 3 mm were attached to each of the test dentures. Two hooks were attached in the cingulum portion of canine teeth on either side and other two hooks were attached in the occlusal surface (central fossa) of second molar on either side. The hooks were attached in the denture using auto-polymerising resin. The hooks were attached in such a way that the top surface of the hooks were all at the same level. This was verified by placing a glass plate with spirit columns over the hooks (Fig.64). Thus, 4 hooks were attached to all the test specimens (Fig.65).

B. Tests for retention and stability

The test was done in a Universal testing machine (Kalpak industries, Pune, Maharashtra, India). The test specimen with the test denture was placed in the cast holder of the testing machine (Fig.66). The test specimen was positioned in the cast holder in such a way that the hooks were all in the same plane. The test specimen was also positioned in such a way that the load cell was equidistant from all hooks. A chain of 15 cm length was attached to each of the hooks. The other end of the chain was attached to the load cell of the Universal testing machine (Kalpak industries, Pune, Maharashtra, India) by means of a metal plate. The metal plate had 4 hooks facing downwards in the bottom side and a central hook in the top side. The 4 chains from the denture were attached to the corresponding hooks in the bottom side of the metal plate and one more central chain from the central hook in the top side of the metal plate was connected to the load cell of the machine.

The chains were adjusted to increase or decrease in length by tightening the screws connected to the plate before each measurement to reduce slackness to a minimum. A tensile force was applied on the denture with a cross head speed of 51 mm/min. Each test denture was subjected to 3 tests. The load at which the dentures detached from the test specimen was considered as the dislodging force and it was recorded in Newton (N).

Test no. 1 – Effect of Vertically directed dislodging forces

It was done to determine the retention of the locator attachment when subjected to vertical tensile forces. All the 4 chains were attached to the loading cell of the testing machine and the test was conducted (Fig.67). It was repeated for 5 times for each denture. So, 5 values were obtained for each denture.

Test no. 2 – Effect of Oblique rotational dislodging forces

This test was conducted to evaluate the stability of the denture when subjected to oblique forces. It simulated the clinical condition when there will be a displacement of the denture upon lateral excursion. For this test, only the chains attached to the anterior and posterior hooks on one side of the denture were attached to the loading cell of the testing machine (Fig.68). The test was conducted similarly as in the retention test. It was repeated 5 times for each test denture. So, 5 values were obtained for each test denture.

Test no. 3 – Effect of Posterior rotational dislodging forces

This test was conducted to evaluate the stability of a denture when subjected to anteroposterior forces. It simulated the clinical condition where there will be a displacement of the denture in protrusive movement, when the lower anterior teeth are thrust against the upper anterior teeth. For this test, only the chains attached to the 2 hooks on the posterior regions of the denture were attached to the loading cell of the testing machine (Fig.69). It was repeated 5 times for each test denture. So, 5 values were obtained for each test denture.

3. Results and statistical evaluation

The retention and stability values were recorded through a computer connected to the Universal testing machine and the values were recorded in Newton (N). The computer prompted the order for initiation of tensile force with crosshead speed of 51 mm/min. The tensile force was continued till the complete dislodgement of overdenture from the acrylic model. The diagram of the applied force until complete dislodgement was drawn using the computer. Finally, the greatest figure for applied force (N) was indicative of the maximum dislodgement force (MDF) which was then recorded in the Tables. The mean and the standard deviation for each specimen in the test were calculated and the results were subjected to statistical evaluation.

COLOUR PLATES

COLOUR PLATES

Fig.1 Lower edentulous model former

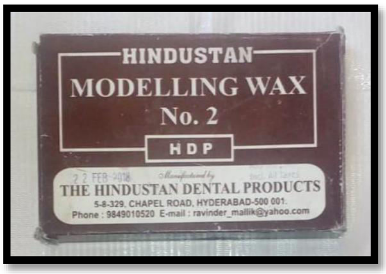

Fig.2 Modelling wax

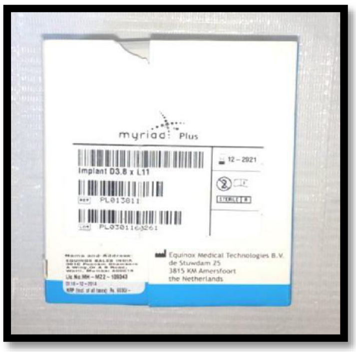

Fig. 3 Endosseous implants (D 3.8 mm* L 11 mm)

Fig.4 Acrylic resin teeth set

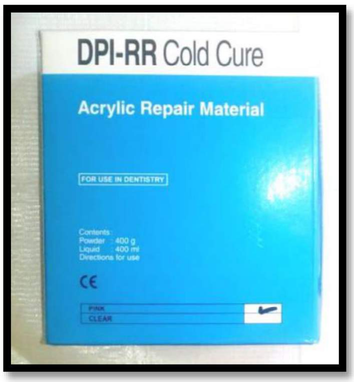

Fig.5 Denture base self cure acrylic resin

Fig.6 Denture base heat cure acrylic resin

Fig.7 Locator abutments with metal housings and nylon male caps (transparent, blue & pink)

Fig.8 Locator attachment - Metal housings with nylon caps

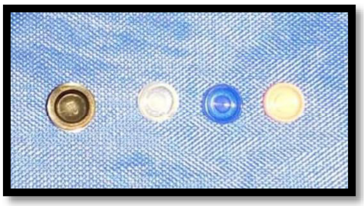

Fig.9 Metal housing with black processing unit & nylon caps

Fig.10 Locator abutment, transparent nylon male cap & metal housing

Fig.11 Polyether impression material (medium body)

Fig.12 Addition silicone putty and light body

Fig.13 Metal hooks

Fig.14 Beading wax

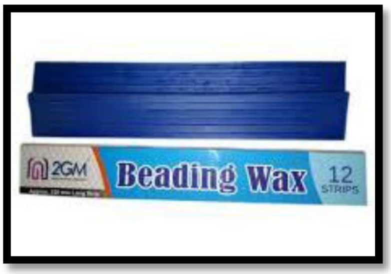

Fig.15 Polyether adhesive

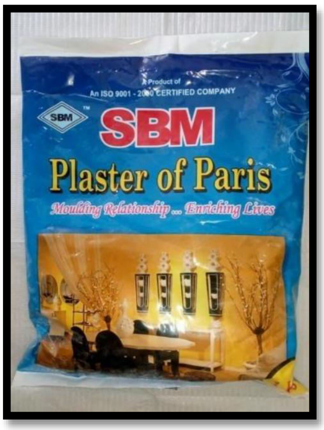

Fig.16 Plaster of paris (Type 2 gypsum)

Fig.17 Dental stone (type 3 gypsum)

Fig.18 Metal plate with hooks in the bottom side corresponding to the hooks in the denture and one hook in the top side to be attached to the load cell of the universal testing machine

Fig.19 Metal chains

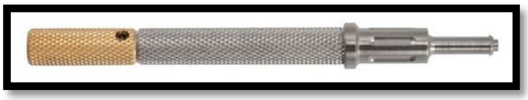

Fig.20 Locator core tool

Fig.21 Snap on attachment & impression coping

Fig.22 Curing water bath

Fig.23 Torque wrench and hex drives

Fig.24 Rubber bowl, spatula, BP blade no. 15 with handle, divider, wax knife, wax carver, wax spatula

Fig.25 Dental lathe

Fig.26 Acrylic trimmers, straight fissure bur & sand paper mandrel

Fig.27 Metal scale, chip blower, glass plate, spirit columns, spirit lamp, universal plier

Fig.28 Ney dental surveyor

Fig.29 Universal testing machine

Fig.30 Edentulous Wax model

Fig.31 Grooves of about 3 mm in depth placed in the wax model

Fig.32 Wax model scraped till the depth of the grooves

Fig.33 Four markings were made in A,B,D and E positions

Fig.34 Wax model mounted on the dental surveyor

Fig.35 Wax model with implants in A,B,D & E positions

Fig.36 Acrylic specimen with implants in A,B,D & E positions

Fig.37 Acrylic specimen with locator abutments attached to the implants

Fig.38 Wax spacer that equals gingival cuff height of locator abutment (3 mm) given for silicone liner

Fig.39 Silicone liner that simulates soft tissues

Fig.40 Custom tray fabricated for making closed tray impression

Fig.41 Custom tray showing tissue stops

Fig.42 Snap on attachment fixed to impression coping

Fig.43 Snap on attachment with impression coping attached to the Implants

Fig.44 Impression made with polyether showing the snap on attachment embedded in it

Fig.45 Impression coping attached to lab analog

Fig.46 Impression made with polyether with impression coping and lab analog placed within the snap on attachment

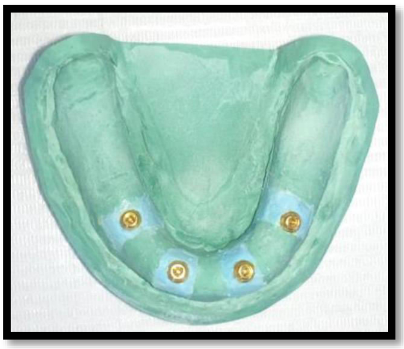

Fig.47 Master cast with locator abutment attached to the lab analog

Fig.48 Intaglio surface of the denture base showing all the housings with black processing units

Fig.49 Waxed up denture

Fig.50 Processed denture

Fig.51 Vent holes for the attachments seen in the intaglio surface of the denture

Fig.52 Flasking done with addition silicone putty & Intaglio surface of the denture filled with light body

Fig.53 Cast for duplication obtained with addition silicone light body

Fig.54 Mould space seen after the removal of the denture

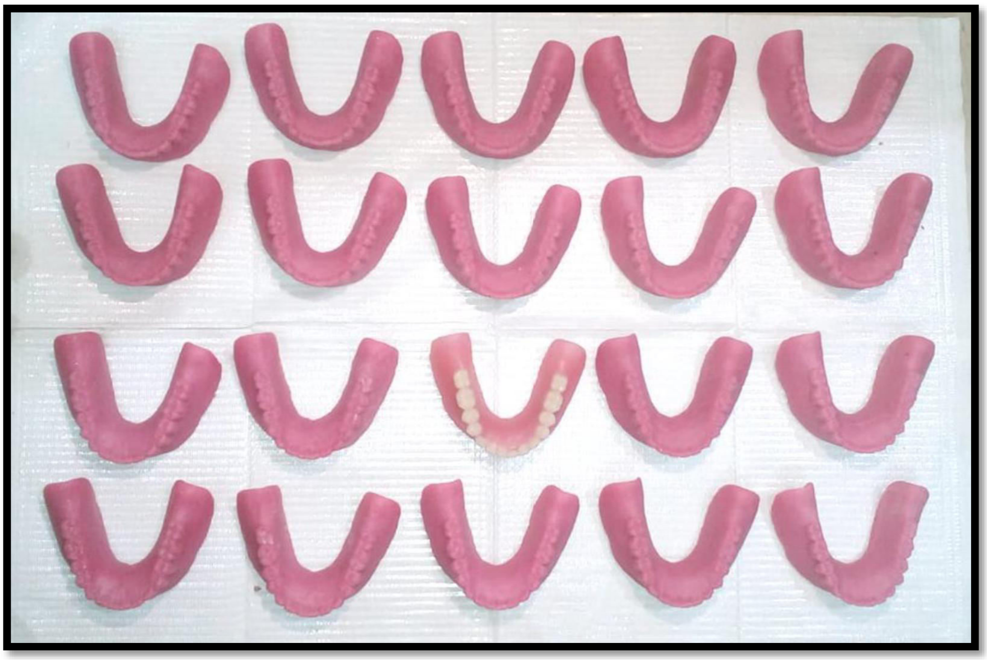

Fig.55 Duplicated autopolymerising resin test dentures

Fig.56 Specimen with metal housings on the locator abutments in B & D positions

Fig.57 Intaglio surface of the denture showing black processing unit in B & D positions

Fig.58 Duplicated test dentures – Intaglio surfaces with metal housings in B and D positions

Fig.59 Specimen with metal housings on the locator abutments in A & E positions

Fig.60 Intaglio surface of the denture showing black processing unit in A & E positions

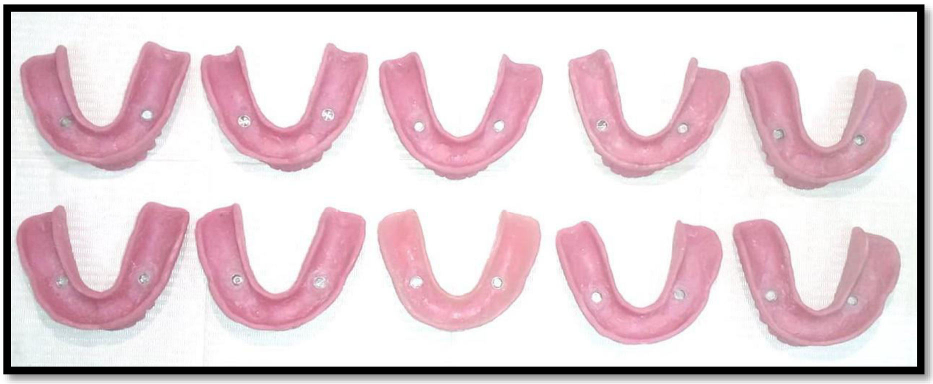

Fig.61 Duplicated test dentures – Intaglio surfaces with metal housings in A and E positions

Fig.62 Transparent nylon caps placed within the housings in B & D positions

Fig.63 Transparent nylon caps placed within the housings in A & E positions

Fig.64 Level of hooks verified with spirit columns

Fig.65 Hooks attached to all the test dentures

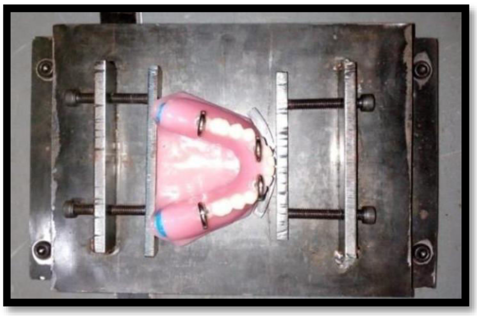

Fig.66 Test model attached to the fixed base set up of the testing machine

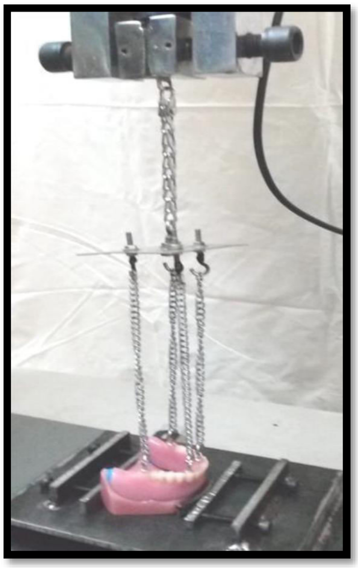

Fig.67 Vertical dislodgment test

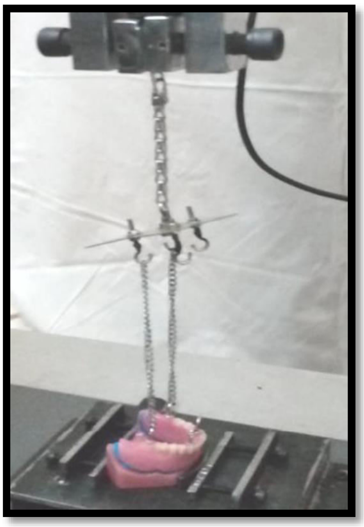

Fig.68 Posterior rotational dislodgement test

Fig.69 Oblique rotational dislodgment test

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RESULTS

The present in-vitro study was conducted to comparatively evaluate the effect of location of implants on the retention and stability of locator retained implant supported mandibular overdenture.

Each test denture was subjected to three different tests on an universal testing machine. Test No. 1 was conducted to evaluate the effect of vertically directed dislodging forces. Test No. 2 was conducted to evaluate the effect of oblique rotational dislodging forces and Test No. 3 was conducted to evaluate the effect of posterior rotational dislodging forces. The force at which the denture detached from the specimen was recorded in Newton (N). Each test was repeated 5 times for each denture and the mean was obtained.

The following results were drawn from the study:

Table 1 shows the mean values obtained for the ten test dentures in group A for all the 3 tests. Table 2 shows the mean values obtained for the ten test dentures in group B for all the 3 tests.

Table 3 shows the test for significance within group A and B for the Test no. 1. Table 4 shows the test for significance within group A and B for the Test no. 2. Table 5 shows the test for significance within group A and B for the Test no. 3.

Graph 1 shows the mean values obtained for all the test dentures in group A and B for the Test no. 1. Similarly, Graph 2 shows the mean values obtained for all the test dentures in group A and B for the Test no. 2 and Graph 3 shows the mean values obtained for all the test dentures in group A and B for the Test no. 3.

Graph 4 compares the overall mean value of all the specimens in group A with group B for the Test no.1. Similarly, Graph 5 compares the overall mean value of all the specimens in group A with group B for the Test no.2 and Graph 6 compares the overall mean value of all the specimens in group A with group B for the Test no.3.

Also annexture 1 and 2 shows all the basic values obtained for all the test dentures.

Table 1: Mean values (N) of all the test specimens in group A for all the three tests along with the overall mean values (N)

S.No	Vertical dislodgement forces (N)	Oblique dislodgement forces (N)	Posterior dislodgement forces (N)
1	32.49	15.63	19.87
2	33.12	15.75	18.83
3	33.50	15.01	20.54
4	29.96	11.89	18.84
5	22.59	14.73	17.90
6	33.50	11.89	19.87
7	32.49	14.73	20.54
8	22.59	15.75	18.83
9	29.96	15.63	17.90
10	33.12	15.01	18.84
Mean	30.33	14.60	19.20

Table 2: Mean values (N) of all the test specimens in group B for all the three tests along with the overall mean values (N)

S.No	Vertical dislodgement forces (N)	Oblique dislodgement forces (N)	Posterior dislodgement forces (N)
1	25.28	18.34	22.06
2	25.93	18.60	22.55
3	25.74	18.04	22.62
4	30.06	17.84	24.57
5	27.50	14.72	19.24
6	30.06	18.60	22.62
7	25.28	17.84	19.24
8	25.74	14.72	22.06
9	27.50	18.04	22.55
10	25.93	18.34	24.57
Mean	26.90	17.51	22.21

Table 3: Test for significance within group A and B for the test no. 1 (vertically directed dislodging forces)

Group	N	Mean	Standard Deviation	Standard Error Mean	P Value
A	10	30.33	4.28	1.35	0.032
B	10	26.90	1.84	0.58	

Table 4: Test for significance within group A and B for the Test no. 2 (oblique rotational dislodging forces)

Group	N	Mean	Standard Deviation	Standard Error Mean	P Value
A	10	14.60	1.48	0.47	0.00
B	10	17.51	1.49	0.47	

Table 5: Test for significance within group A and B for the Test no. 2 (posterior rotational dislodging forces)

Group	N	Mean17.51	Standard Deviation	Standard Error Mean	P Value
A	10	19.20	0.97	0.31	0.00
B	10	22.21	1.81	0.57	

INFERENCE:

To compare the effect of different forces on retention and stability between the two groups, the results were analysed using student's T – test and SPSS software version 20 at the level of significance (p value) as 0.05.

The overall mean value of the specimens in group A for the Test No. 1 (Vertical dislodgement test) was 30.33 and the overall mean value of the specimens in group B for the Test No. 1 was 26.90 (Tables 1 & 2).

Similarly, the overall mean value of the specimens in group A for the Test No. 2 (Oblique dislodgement test) was 14.60 and the overall mean value of the specimens in group B for the Test No. 2 was 17.50 (Tables 1 & 2).

And the overall mean value of the specimens in group A for the Test No. 3 (Posterior dislodgement test) was 19.19 and the overall mean value of the specimens in group B for the Test No. 3 was 22.21 (Tables 1 & 2).

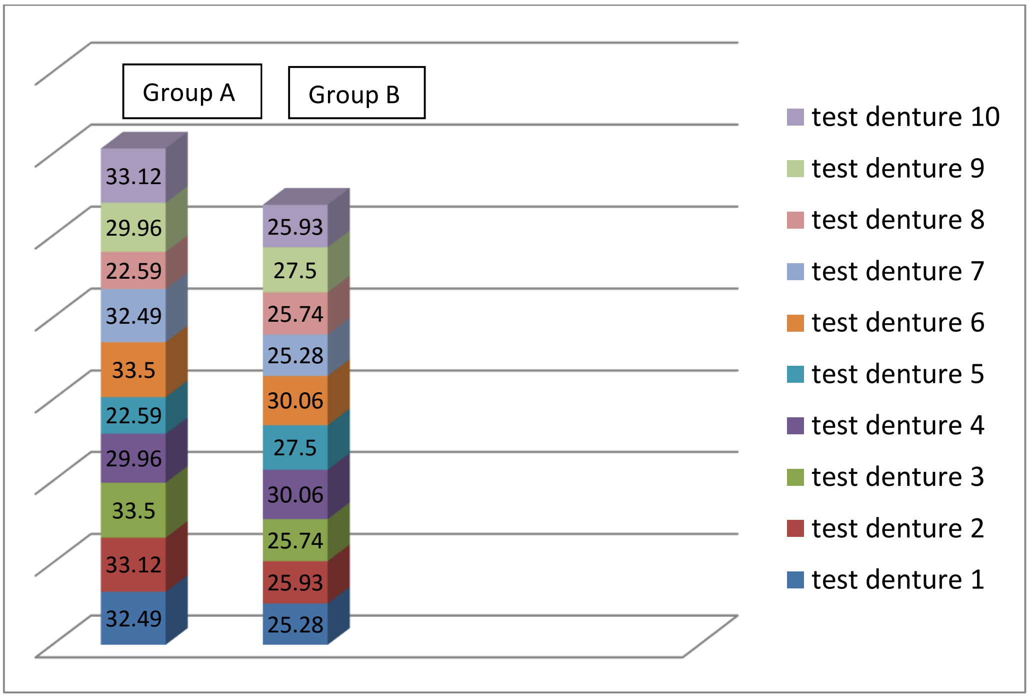
On comparison between group A and B for the Test No. 1, the results were found to be statistically significant (p value 0.032) (Table 3).

On comparison between group A and B for the Test No. 2, the results were found to be statistically highly significant (p value 0.00) (Table 4).

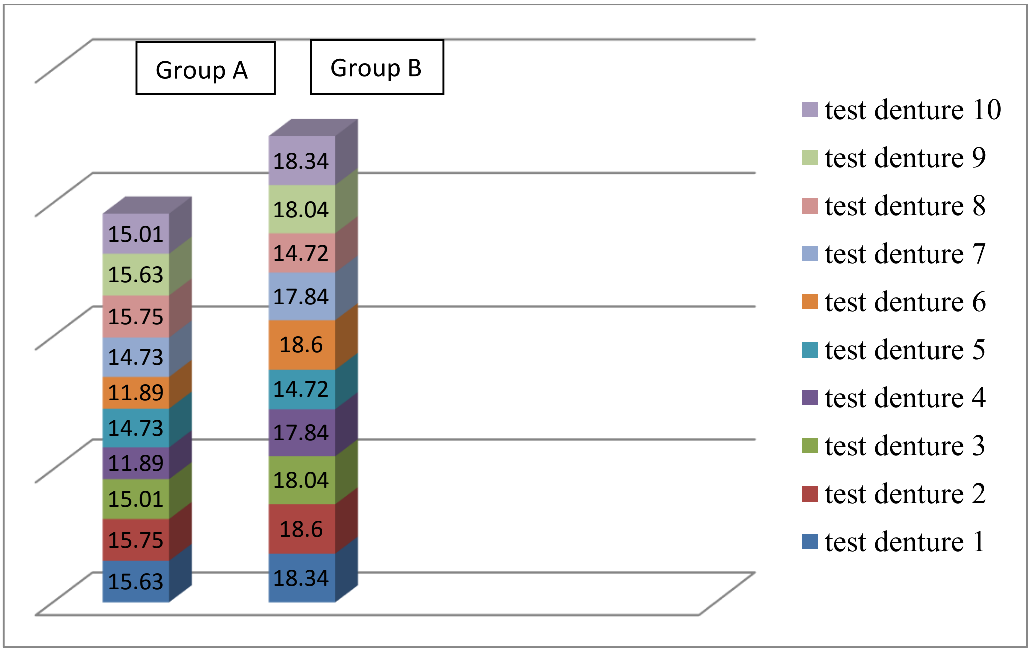
On comparison between group A and B for the Test No. 3, the results were found to be statistically highly significant (p value 0.00) (Table 5).

Also, in the present study on comparative evaluation of the results of Test no. 1, Test no. 2 and Test no. 3 of the specimens in group A and B, it was seen that the resistance to vertically directed forces was more followed by posterior rotational dislodging force and oblique rotational dislodging force.

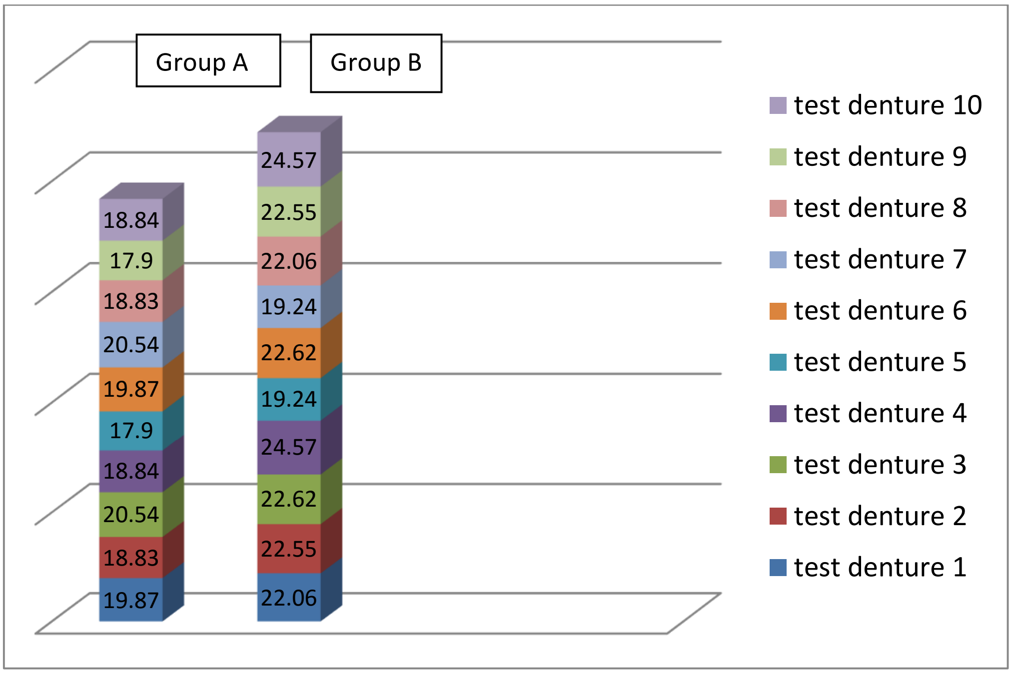
Graph 1: Mean values of all the test specimens in group A and B for the Test no. 1 (Vertical dislodgement test)



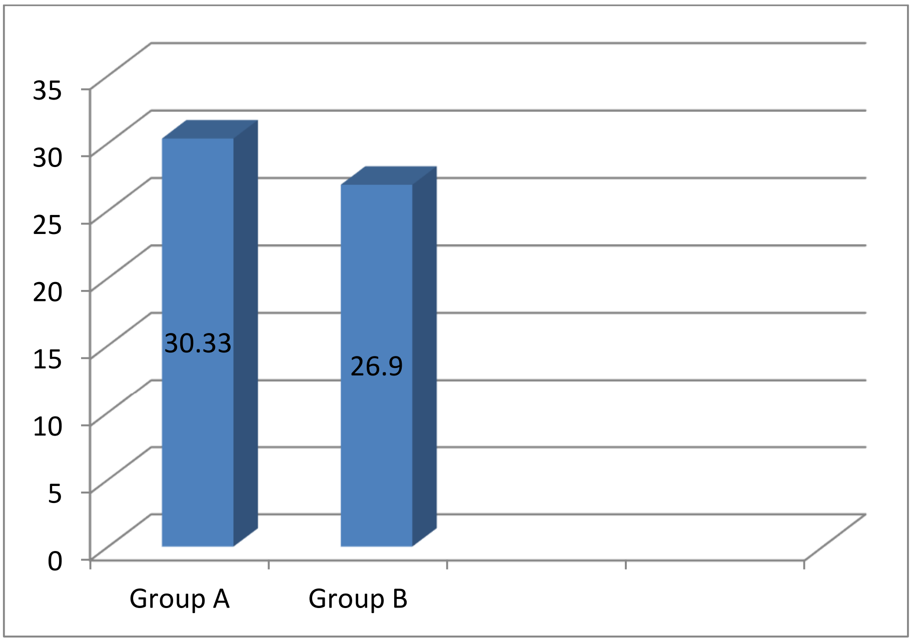
Graph 2: Mean values of all the test specimens in group A and B for the Test no. 2 (Oblique dislodgement test)



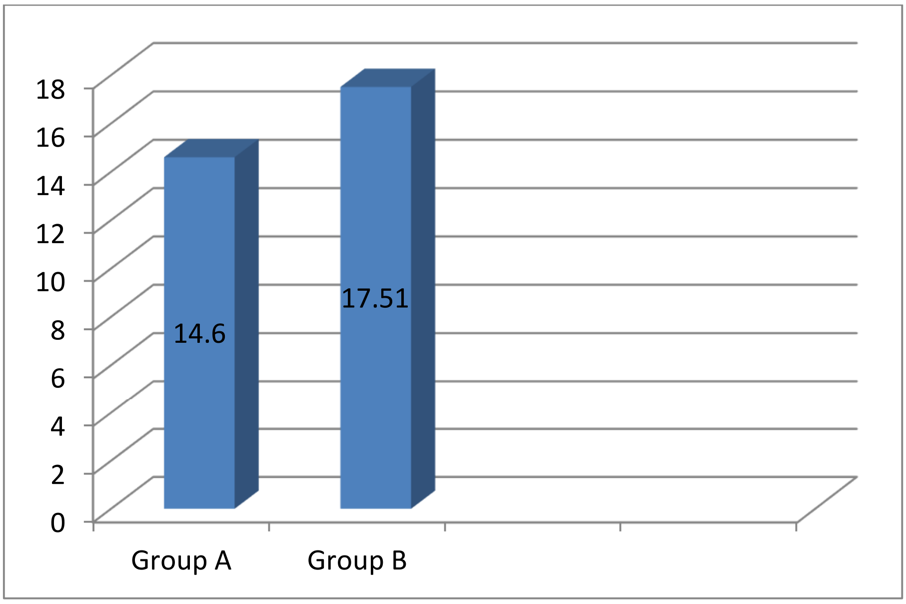
Graph 3: Mean values of all the test specimens in group A and B for the Test no. 3 (Posterior dislodgement test)



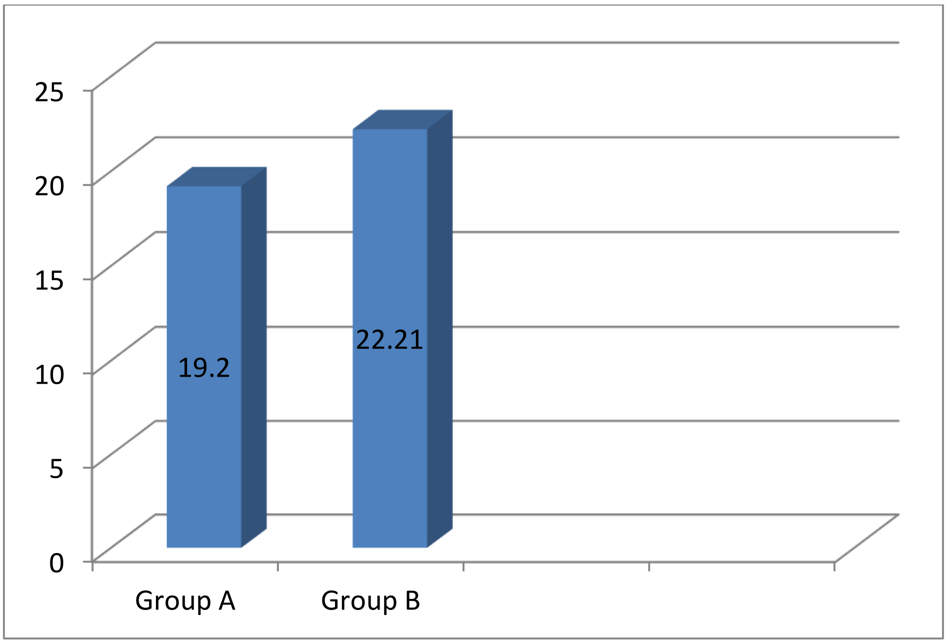
Graph 4: Comparison of overall mean values of all the test specimens in group A and B for the Test no. 1



Graph 5: Comparison of overall mean values of all the test specimens in group A and B for the Test no. 2



Graph 6: Comparison of overall mean values of all the test specimens in group A and B for the Test no. 3



DISCUSSION

Certain mechanical, biological and physical factors determine the retention, stability and support of the prosthesis, which influence the success of the treatment. Both retention and stability are influenced by ridge height and surface area. In conditions of reduced retention and stability, there is an associated reduction in masticatory efficiency and disturbance in phonetics, which can lead to a feeling of insecurity, low self-esteem and dissatisfaction with the complete denture. The reduction in retention and stability is more commonly seen in the mandibular denture than the maxillary denture. Numerous methods like vestibuloplasty, bone grafting, ridge augmentation, neutral zone concept, special impression procedure and denture adhesives have been reported in the dental literature to improve the retention and stability. Also, attachment systems (like ball, bar, locators, ERA and magnets) have been historically employed as a means of improving the retention and stability of tooth supported overdentures in edentulous or nearly edentulous arches.

More recently, osseointegrated implants have been used to improve denture support, stability, and retention. Treatment of the edentulous patient with implant-retained overdentures has been shown to provide predictable and successful results. With regard to number of implants required for retention of mandibular overdentures, there is a consensus (Mc Gill consensus, 2002) that states that two implants in the inter-foraminal region of the mandible are sufficient and two implants retained overdentures are considered the standard of care for the edentulous patients.[6,15] The compact bone in the symphysis region between the mental foramina seems to be sufficient to ensure excellent results over long periods.[12]

Many studies and literature favours for implant supported overdentures (IOD) using limited number of implants. Van steenberghe et al were among the first authors who proposed the placement of two implants in the advantageous sites rather than placing many implants.[3,5] So, when anatomic restrictions or other patient-related complicating factors are involved, the fabrication of an overdenture supported by two implants with solitary attachments may be preferable.[3] So, considering the financial aspect and minimal invasive technique, two implants were used in this study.

Some authors highlighted the importance of vertical restorative space and its management in patients with overdentures. In this respect, there is a classification system for ridges namely: arch type Class I –restorative vertical space equal to or greater than 15 mm; arch type Class II – space between 12 and 14 mm, arch type Class III – space between 9 and 11 mm and arch type Class IV – space less than 9 mm. Ionescu et al stated that "When the space between the arches is inadequate there are some problems such as: over-contouring of the dentures, excessive vertical dimension of occlusion, fracture of the adjacent teeth, loosening of the overdenture, denture fracture and general patient dissatisfaction".[4]

In this regard, since 2001, a new product has been released in the market: the Locator, a new resilient connector whose abutment and attachment system's height is only 3.17 mm. The system can be applied in a limited inter-ridge space. Also, Locator attachment system uses a lower height than ball anchor.[34] In this way, the patient is pleased with the aesthetic result obtained, and in addition, the system achieves greater retention and greater stability for the prosthesis.[4] It consists of a metal matrix and a resilient plastic element that is placed on latch embedded directly into the prosthesis. Because of the unique design of the Locator, the patrix (male) is the replaceable nylon insert on the under surface of the overdenture. The matrix (female) is by virtue, again of its unique design, the overdenture abutment on the implant. The manufacturer stated that because of the self-positioning design, the insertion of the prosthesis becomes easy and quick. Hence, abrasion and damaging of the attachment can be largely avoided.

Locator attachment system consists of three types of nylon patrices– Locator extra-light retention, blue (680 g, REF 386-524-00), Locator light retention, pink(1.365 g, REF 386-522-00),and Locator medium retention, transparent (2.270g, REF 386-520-00).[10] So, originally consisting of three matrices with different retentive values (clear : 5 lb, pink: 3 lb and blue: 1.5 lb), they are all composed of 4.7 mm diameter resilient nylon liners attached to 4.0 mm diameter titanium alloy, titanium nitride coated abutments.[18] Locators disengage the abutments more slowly than bar attachments during non-axial dislodging, as they have a dual retention property, which comes from friction between the inner and outer surface together due to dimensional misfit between the slightly oversized nylon patrix insert and the smaller diameter of the inner ring of the matrix abutment.[19] The design of locator attachment allows the ability to compensate for implant angulations about the vertical plane of up to 20° which equals to 40° divergence between two implants eliminating the need for positioning of angled abutments.[38]

Elsyad et al found that Locator - medium (transparent nylon caps) recorded the highest initial retention compared to other types of Locator and O-ring attachments. Uludag et al concluded that Locator attachments provided better retention than Hader bar yellow clip attachments for 3-implant-retained mandibular overdentures.[56]Sadig found that Locator attachments provided the greatest level of retention for implant-supported overdentures, followed by ball and magnet attachments.[15] Chung et al noted that transparent Locator attachments provided higher retentive forces than Hader bar metal clips.[2] Evtimovska et al found that transparent Locator attachments showed higher mean peak load-to-dislodgement than Hader clips.[43] Elsyad et al found out that after wear simulation, the highest final retentive force was noted with Locator transparent, followed by Locator pink, Locator blue, and the bar attachment.[10] Similarly, Evtimovska et al concluded that Locator transparent attachments have higher retentive values than yellow Hader clips after 20 consecutive pulls, and they should be used when greater retention is needed.[43]

During the connection of the attachment, the Locator attachment system has a space of 0.2mm between the abutment top and nylon patrix for the retention disk. This allows vertical resilience and 8° hinging in any direction. Elsyad et al., using an acrylic model covered with resilient silicone mucosal simulation, studied deformation of the mandibular denture base with Locator and ball attachments for two implants supported overdenture (IOD). That study found that during bilateral load application to the prosthesis, Locator attachments for the IOD were associated with less deformation of the mandibular denture base over the implants compared to ball attachments. The Locator system recorded higher compressible strains and provided excellent settlement of the denture base without fulcrum formation. This mechanical condition without fulcrum formation could thus be considered to behave like the denture base of conventional mandibular complete dentures, and result in good prognosis for both implants and prostheses, and might contribute to long-term stability of the IOD.[34]

Minimum space requirement for ball attachment is 10-12 mm and for locators is 8.5 mm. The implants act as a fulcrum with 2 potential lever arms: (1) From the fulcrum to the posterior extension of the denture and (2) from the fulcrum anteriorly to the incisal edge. Forces on either lever arm will produce rotation.

However, the primary and secondary stress bearing areas of the overdenture will resist occlusal forces placed on the posterior lever arm, but forces on the anterior lever arm, such as incisive movements, may cause more noticeable rotation. By moving the implants from the canine to the lateral incisor position, the effective anterior lever arm is reduced, thus minimizing the tipping forces on the overdenture.[25]

The most common prosthetic complication reported with the use of the Locator system is loosening of the retentive mechanism. Plastic deformation, wear, and surface abrasion are all possible causes for the loss of retention.[39] Several factors affecting the retention of Locator attachments have been identified, including repeated insertion-removal cycles of the prosthesis, implant location, diverging implant angulations, Locator abutment height, overdenture immersion in denture cleansers, exposure to high water temperatures, and direction of tensile force in the retention tests.[39]

Implant retained overdentures using the Locator show a high implant success rate of over 94.5%. In addition, it requires low maintenance as compared to the other solitary type attachments due to its average life of 22.6 months. According to the study by Mackie *et al*. as a result of comparing the replacement frequency of the Locator patrix and ball attachment matrix in implant overdentures by using two implants, there was no significant difference. In a 5-year clinical study of Akce et al, the Locator showed less bone resorption and on the other hand, Krennmair et al reported that the satisfaction with the implant retained overdentures by using the Locator was higher than that of the conventional dentures.[8] Also, the attachment system is supposed to satisfactorily maintain retention for up to 56,000 cycles.[16]

Another advantage of using the Locator attachment system is that when a gasket replacement is needed, it is not mandatory to remove the entire device within the denture base.[4] Many experimental researches have shown that a wider mucosal band (> 2 mm) was associated with less mucosal recession and periodontal attachment loss compared with a narrow (< 2 mm) band. The absence of adequate keratinized mucosa around implant retained overdentures was associated with higher plaque accumulation, gingival inflammation, bleeding on probing, and mucosal recession. So, it is considered that keratinised mucosa > 2mm is necessary for long term results.[61,62] Hence, locator with 3 mm height of gingival collar was chosen as the attachment system in this study.

The implants were placed in the anterior area of mandible. This region is the preferred site in implant retained overdenture for the following reasons: thicker cortical bone, lowered surgery risk by avoiding the inferior alveolar nerve and blood vessels and finally, a larger tissue-supporting area available in the posterior regions to prevent overloading on implant.[20] The inter-implant distance was defined as the straight distance between the centres of the paired implants.[29] So, in this study, two implants were placed in the inter-foraminal region with inter-implant distance between B & D positions as 16 mm[56] and between A & E positions as 35 mm.[29]

Also in this study, the mucosa was simulated by using soft liner, as the resiliency of soft tissue may increase the load on the attachments and therefore can affect their retentive values. Moreover, the overdenture contact with the mucosa may alter the way attachments disconnect, particularly during non-axial dislodging, as the denture base periphery may pivot on the soft liner.[10] Although the experimental model reproduces the oral mucosa, it is not the same with actual intraoral soft tissue. The thickness of the soft tissue differs among people, and even in the same person, different regions have different thickness. Such changes in soft tissue thickness can increase or decrease the stress around the implant because the deformation of the denture base is affected by the underlying soft tissue.[40]

The methodology carried out in this study was similar to the fabrication of a conventional denture. Four hooks were attached to the test dentures in canine and 2nd molar positions on each side using autopolymerising resin. Each test denture was subjected to 3 forces into 3 directions - vertical (for the evaluation of retention), oblique (for the evaluation of stability) and antero-posterior (for the evaluation of stability) direction. Tension was used for the assessment of all the 3 forces. Retention is defined as that quality inherent in the dental prosthesis acting to resist the forces of dislodgment along the path of placement and stability is defined as the quality of a complete or removable partial denture to be firm, steady, or constant, to resist displacement by functional horizontal or rotational stresses.

FACTORS AFFECTING COMPLETE DENTURE RETENTION AND STABILITY[60,63,64,65 & 66] :

The factors that contribute to retention and stability are interrelated and the highly constant interaction between retention and stability often makes them indistinguishable. Stability ensures the physiologic comfort of the patient while retention contributes to psychologic comfort. The factors that contribute to retention include adhesion, cohesion, interfacial surface tension, gravity, intimate tissue contact, border seal, atmospheric pressure and neuromuscular control. And the factors that contribute to stability include ridge height and conformation, base adaptation, residual ridge relationships, occlusal harmony, and neuromuscular control.

ADHESION :

Adhesion is the physical force involved in the attraction between unlike molecules. A drop of water introduced on the surface of a solid glass plate will resist movement away from the glass in proportion to the adhesion between the unlike materials.

COHESION :

Cohesion is the physical factor of electromagnetic force acting between molecules of the same material. A molecule within a fluid has an attraction exerted on it on all sides by neighbouring molecules. The same molecule exerts an attractive force on the neighbouring molecules equal in magnitude but opposite in direction. Forces of cohesion are responsible for maintaining the continuity of a water droplet when placed in contact with another material.

INTERFACIAL SURFACE TENSION :

In review the phenomenon of surface tension is defined as the force that maintains the surface continuity of a fluid. Interfacial surface tension refers to the forces involved in maintaining the attraction of two opposed ground solid plates with an intervening fluid film that resists displacing forces applied at right angles to the fluid film surface. Interfacial surface tension operates by virtue of a thin fluid film between two intimately contacted objects.

GRAVITY

This physical force primarily concerns the mandibular prosthesis.

INTIMATE TISSUE CONTACT :

Intimate tissue contact is the biologic factor that refers to the close adaptation of the denture base to the underlying soft tissues. The impression technique will determine the degree of intimate tissue contact obtained with the tissues at rest and during function.

BORDER SEAL AND DENTURE EXTENSION

Border seal is the biologic factor that involves intimate contact of the denture borders with the surrounding soft tissue. The seal encompasses the circumference of the denture and includes features such as beading and posterior palatal seal to enhance its effectiveness. Also the denture base should cover the posterior extension of the firmly bound keratinised tissue of the pear shaped pad in the lower arch. The contour and inferior extension of the lingual flange are dependent on the action and anatomy of the mylohyoid muscle.

ATMOSPHERIC PRESSURE

Atmospheric pressure is the physical factor of hydrostatic pressure due to the weight of the atmosphere on the earth's surface. This phenomenon creates a pressure gradient across the meniscus seen in the borders of the denture. The smaller the film thickness, the greater the pressure difference and therefore the greater the force required to achieve separation.

NEUROMUSCULAR CONTROL

Neuromuscular control refers to the functional forces exerted by the musculature of the patient that can affect retention. This is primarily a learned biologic phenomenon. Certain characteristics can be incorporated into the external contours of the denture base to promote neuromuscular control. Older patients have more difficulty in adapting themselves to new complete dentures which results from progressive cerebral atrophy that affects related neurologic systems.

TIME :

The amount of separation of denture and mucosa that can occur depends on the duration of the application of any force. If a reseating force is applied before detachment has occurred, such as in chewing, the displacement will only be transitory and may never reach the point of collapse.

The factors that contribute to stability include ridge height and conformation, base adaptation, residual ridge relationships, occlusal harmony, and neuromuscular control. These factors can be condensed into the following categories:

1. The relationship of the denture base to the underlying tissues
2. The relationship of the external surface and border to the surrounding orofacial musculature
3. The relationship of the opposing occlusal surfaces

The heart of a material testing laboratory is the universal testing machine, as this device can evaluate several characteristics of dental restorative materials and even of the finished prostheses, such as: compressive strength, flexure strength, tensile strength and shear strength. Tensile strength (ultimate tensile strength or ultimate strength) is the maximum stress a material can withstand while being stretched or pulled before failing or breaking. Tensile strength is usually established by a tensile test, also known as tension testing, which is a fundamental material science test in which a sample is subjected to controlled tension until failure.[59] So, Universal testing machine was used for tensile pulling. To account for the weight of the experimental overdenture and chains, the machine was calibrated and balanced using a computer algorithm.[33] A crosshead speed of 50.8 mm/min was used because it is the average speed at which the patients remove implant overdentures from their fixtures. However, patients may remove their dentures at different rates, which in turn may affect retention.[37]

Mandibular implant overdentures, when in place in the oral environment, move in complex ways – typically in six directions: occlusal, gingival, mesial, distal, facial and lingual. Although true unidirectional dislodging forces rarely occur in clinical scenarios, a directional pull testing is an effective way of measuring the retention and stability of a prosthesis during in-vitro laboratory evaluation. Vertical tensile force was similar to the force applied when chewing a sticky food which applies a force opposite to the path of insertion. Oblique tensile force was similar to unilateral chewing, and anterior-posterior tensile force was similar to the situation where food is being chewed by the posterior teeth or when something is bitten by the front teeth. Anteroposterior dislodging or lifting force has been reported as an indirect measure of incisor function of a mandibular overdenture.[21]

The occlusal plane was set parallel to the horizontal plane, and the models were secured to the base of a universal connector unit using metallic screws. Four braided chains (15 cm long) along with eye bolts & metal plate were used to connect the hooks of the denture to the load cell of the testing machine. The length of the chains were adjusted to minimize slack and then calibrated to account for the weight of the chains to assure precise axial loading. The load cell was calibrated before conducting the experiments and the maximum retentive force (N) was extracted from the computer-generated files. All the 4 chains were evenly pulled to determine the vertical dislodging force (N). Also, two aspects of stability were tested in this study: (1) influence of para-axial forces, for which 2 chains were attached to one side (canine and molar hooks) of the test denture to test lateral stability and (2) posterior dislodging forces, for which 2 chains were attached to the hooks in the molar regions on both the sides of the test denture. The chains were adjusted to reduce slackness and then calibrated to account for the weight of the chains as described previously. The dislodging forces were applied until displacement or separation of the specimens occurred. The maximum peak to dislodgment load in Newtons (N) was calculated. For each test and each denture the tensile pulling test was done for 5 times.

The results were analysed using student's t – test and SPSS software version 20 at the level of signicance (p value) as 0.05. The overall mean value of the specimens in group A for the Test No. 1 (Vertical dislodgement test) was 30.33 and the overall mean value of the specimens in group B for the Test No. 1 was 26.90 (Table 1 & 2 and Graph 4). Similarly, the overall mean value of the specimens in group A for the Test No. 2 (Oblique dislodgement test) was 14.60 and the overall mean value of the specimens in group B for the Test No. 2 was 17.50 (Table 1 & 2 and Graph 5). And the overall mean value of the specimens in group A for the Test No. 3 (Posterior dislodgement test) was 19.19 and the overall mean value of the specimens in group B for the Test No. 3 was 22.21 (Table 1 & 2 and Graph 6) .

On comparison between group A and B for the Test No. 1, the results were found to be statistically significant (p value 0.032) (Table 3). On comparison between group A and B for the Test No. 2, the results were found to be statistically highly significant (p value 0.00) (Table 4). And on comparison between group A and B for the Test No. 3, the results were found to be statistically highly significant (p value 0.00) (Table 5).

A retentive force of around 20 N has been recommended as adequate minimum retentive force required for an overdenture by many studies.[9,15,28] The results of the present study also shows that the specimen A and B samples have a retentive force more than the recommended value suggesting that placing implants in either of these positions provide adequate retention. The retentive values obtained for vertical tensile force were in accordance with the values obtained in in-vitro studies conducted by Scherer in 2013, Tabatabaian in 2014 and Sadr in 2012.[24,29 &21] It was found out that the vertical force required for the dislodgement of the denture was greater for group A where implants are placed in B and D positions compared to group B where implants were placed in A and E positions. Whereas, the horizontal rotational forces (oblique dislodgement and posterior dislodgement forces) required for the dislodgement of the denture was greater for group B with implants in A and E positions than group A with implants in B and D positions.

According to Carl E. Misch, positioning of the implants in the B and D positions is a better prosthetic option than in A and E positions to avoid unfavourable rocking leverages ie., the anterior movement of the prosthesis is reduced by placing the implants in B and D positions for an overdenture. Also the two implants should be equidistant from the midline. Otherwise the more distal implant will act as fulcrum causing instability and ultimately leading to wearing of the attachments.[56] The result obtained for Test no.1 (Vertical dislodgement test) was in favour of Misch CE.

Scherer et al compared the retention and stability of two implant-retained overdentures based on implant location and found out that in all the attachment systems tested, a general trend was determined that an increased resistance to dislodgement occurred as the implant location was moved distally.[28] According to Michelinakis and Doukas, the retention was increased by increasing the inter-implant distance for IOD retained by two implants with ball attachments.[69,70]

But in this study, an increased resistance to dislodgement occurred as the implant location was moved distally for oblique and posterior rotational dislodging forces. Whereas for the vertical dislodgment test, an increased resistance was seen with implants in B & D positions.

Also, in the present study, on comparative evaluation of the results of Test no. 1, Test no. 2 and Test no. 3 of the specimens in group A and B, it was seen that the resistance to vertically directed forces was more followed by posterior rotational dislodging force and oblique rotational dislodging force. The lower vertical height of the Locator attachment (2.5 mm) could be responsible for the minimal resistance of the Locator attachment to lateral dislodging forces.[10] The higher rate of vertical force was also mentioned in studies conducted by Petropoulos et al in 2002 and Tabatabaian et al in 2010.[29,68]

The advantage of placing the implants in A and E positions, which showed the highest resistance of overdenture to antero-posteriorly directed dislodging forces, can be explained in physics and mechanics by the torque formula:

$$\tau = rF\sin\phi$$

τ : Torque force

r : Distance from force to axis of rotation

F : Force

ϕ : Angle between F and r vectors

In different implant positions (B & D and A & E), the amounts of $'F'$ and $'\phi'$ are constant while the amount of $'r'$ is variable depending on implant positions. In position A & E, the axis of rotation, a virtual line that passes through the centers of the implants, moves backward and the amount of $'r'$ for posterior forces is minimal. According to the above-mentioned formula, $'\tau'$ is minimal, thus the resistance against posterior forces is at its highest level as the results of the current investigation revealed.[29]

The results of this in-vitro study indicated that the inter-implant distance had a significant effect on the retention and stability of a simulated implant overdenture prosthesis, thus rejecting the null hypothesis.

LIMITATIONS OF THE STUDY:

This study has several limitations. The attachments were not tested under simulated function, and thermal cycling was not performed. Also, this in-vitro study did not consider the effects of variable fluid experiments, multidirectional force application and effect of fatigue on the test specimen. The presence of saliva and constant occlusal load may have an additional influence on the amount of wear in the attachments. Moreover, measurement of overdenture stability using oblique dislodging forces is somewhat simplistic and does not present a true reflection of the in-vivo off-axial dislodging forces to which the denture base is subjected.[10] The testing conducted was directed at limited, specific and expected mechanical conditions and this in-vitro protocol falls short of clinical reality. Therefore, long-term randomized clinical trials by studying the masticatory efficiency and performances are recommended to evaluate the retention and stability characteristics of Locator with different implant locations and future clinical studies are needed to shed more light on this aspect.

SUMMARY AND CONCLUSION

The present study was conducted to compare and evaluate the effect of different location of implants on the retention and stability of two implants-supported overdenture with locator attachment. An acrylic test specimen was fabricated with implants in four positions – A,B,D and E. Over that an acrylic test denture was constructed in the conventional way with vent holes for all the metal housings corresponding to the four implant positions. The same test denture was duplicated using autopolymerising resin to get the remaining samples. For group A, ten test dentures were fabricated with metal housings in B and D positions and the vent holes in A and E positions were sealed using autopolymerising resin. Similarly, for group B, ten test dentures were fabricated with metal housings in A and E positions and the vent holes in B and D positions were sealed using autopolymerising resin. To all the test dentures, four hooks were attached in canine and molar regions on both the sides and were subjected to tensile forces using Universal testing machine. Each test denture was subjected to three different tests. Test No. 1 was conducted to evaluate the effect of vertically directed dislodging forces. Test No. 2 was conducted to evaluate the effect of oblique rotational dislodging forces. Test No. 3 was conducted to evaluate the effect of posterior rotational dislodging forces. The force at which the denture detached from the specimen was recorded in Newton (N). Each test was repeated 5 times for each denture and the mean was obtained. The results of the present study showed a significant difference between the two groups and thus rejected the null hypothesis.

So, within the limitations of this in-vitro study, it was concluded that on comparison between the two groups (group A with implants in B and D positions and group B with implants in A and E positions)

(1) Statistically significant difference (p value 0.032) was found with vertically directed dislodging forces with higher value seen in relation to group A.

(2) Highly Statistically significant difference (p value 0.00) was found with oblique rotational dislodging forces with higher value seen in relation to group B.

(3) Highly Statistically significant difference (p value 0.00) was found with posterior rotational dislodging forces with higher value seen in relation to group B.

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ANNEXURE - 1

ANNEXURE - 1

BASIC VALUES AND MEAN VALUES (N) OF THE TEST SPECIMENS IN GROUP A FOR THE VERTICAL, OBLIQUE & POSTERIOR DISLODGEMENT TESTS

Table 1: Basic values and mean value (N) of the test denture 1 for the 3 different tests

Pull No	Test No. 1(N)	Test No. 2(N)	Test No. 3(N)
1	32.51	15.74	19.47
2	32.70	15.21	18.86
3	32.65	16.08	20.10
4	31.96	16.45	20.25
5	32.65	14.66	20.65
Mean	**32.49**	**15.63**	**19.87**

Table 2: Basic values and mean value (N) of the test denture 2 for the 3 different tests

Pull No	Test No. 1(N)	Test No. 2(N)	Test No. 3(N)
1	33.14	15.64	18.91
2	33.18	15.85	18.73
3	32.95	15.65	18.76
4	33.05	15.49	18.94
5	33.28	16.12	18.80
Mean	**33.12**	**15.75**	**18.83**

Table 3: Basic values and mean value (N) of the test denture 3 for the 3 different tests

Pull No	Test No. 1(N)	Test No. 2(N)	Test No. 3(N)
1	33.16	14.98	20.06
2	33.18	15.15	20.81
3	33.24	14.88	20.67
4	34.10	14.96	20.52
5	33.81	15.04	20.62
Mean	**33.50**	**15.01**	**20.54**

Table 4: Basic values and mean value (N) of the test denture 4 for the 3 different tests

Pull No	Test No. 1(N)	Test No. 2(N)	Test No. 3(N)
1	30.29	13.06	20.17
2	31.75	11.84	18.62
3	31.04	11.98	18.80
4	29.27	11.63	17.41
5	27.47	10.96	19.18
Mean	**29.96**	**11.89**	**18.84**

Table 5: Basic values and mean value (N) of the test denture 5 for the 3 different tests

Pull No	Test No. 1(N)	Test No. 2(N)	Test No. 3(N)
1	25.55	11.01	18.18
2	20.61	16.82	17.92
3	21.64	16.08	16.16
4	22.86	16.15	18.24
5	22.40	13.59	19.10
Mean	**22.59**	**14.73**	**17.90**

Table 6: Basic values and mean value (N) of the test denture 6 for the 3 different tests

Pull No	Test No. 1(N)	Test No. 2(N)	Test No. 3(N)
1	33.24	11.84	18.86
2	33.16	11.98	19.47
3	33.81	13.06	20.10
4	34.10	11.63	20.65
5	33.16	10.96	20.25
Mean	**33.50**	**11.89**	**19.87**

Table 7: Basic values and mean value (N) of the test denture 7 for the 3 different tests

Pull No	Test No. 1(N)	Test No. 2(N)	Test No. 3(N)
1	32.70	11.01	20.81
2	32.65	16.82	20.06
3	32.65	13.59	20.67
4	31.96	16.08	20.52
5	32.51	16.15	20.62
Mean	**32.49**	**14.73**	**20.54**

Table 8: Basic values and mean value (N) of the test denture 8 for the 3 different tests

Pull No	Test No. 1(N)	Test No. 2(N)	Test No. 3(N)
1	25.55	15.64	18.73
2	21.60	15.65	18.91
3	22.84	15.85	18.76
4	22.46	15.49	18.80
5	20.61	16.12	18.94
Mean	**22.59**	**15.75**	**18.83**

Table 9: Basic values and mean value (N) of the test denture 9 for the 3 different tests

Pull No	Test No. 1(N)	Test No. 2(N)	Test No. 3(N)
1	31.75	15.74	18.18
2	31.04	16.08	17.93
3	29.27	15.21	16.17
4	27.47	14.66	18.25
5	30.29	16.45	19.15
Mean	**29.96**	**15.63**	**17.90**

Table 10: Basic values and mean value (N) of the test denture 10 for the 3 different tests

Pull No	Test No. 1(N)	Test No. 2(N)	Test No. 3(N)
1	33.18	15.15	18.62
2	33.14	14.98	20.17
3	33.05	14.88	17.41
4	33.28	15.04	19.18
5	32.95	14.96	18.80
Mean	**33.12**	**15.01**	**18.84**

ANNEXURE - 2

ANNEXURE - 2

BASIC VALUES AND MEAN VALUES (N) OF THE TEST SPECIMENS IN GROUP A FOR THE VERTICAL, OBLIQUE & POSTERIOR DISLODGEMENT TESTS

Table 11: Basic values and mean value (N) of the test denture 11 for the 3 different tests

Pull No	Test No. 1(N)	Test No. 2(N)	Test No. 3(N)
1	25.55	18.31	22.83
2	24.90	18.02	21.77
3	26.15	17.92	21.96
4	24.86	18.86	21.88
5	24.92	18.60	21.86
Mean	**25.28**	**18.34**	**22.06**

Table 12: Basic values and mean value (N) of the test denture 12 for the 3 different tests

Pull No	Test No. 1(N)	Test No. 2(N)	Test No. 3(N)
1	25.93	18.42	22.61
2	25.84	18.56	22.45
3	25.94	18.92	22.64
4	25.69	18.55	22.64
5	26.23	18.49	22.42
Mean	**25.93**	**18.60**	**22.55**

Table 13: Basic values and mean value (N) of the test denture 13 for the 3 different tests

Pull No	Test No. 1(N)	Test No. 2(N)	Test No. 3(N)
1	25.46	17.65	22.45
2	25.91	17.96	22.75
3	25.84	18.12	22.81
4	25.69	18.09	22.68
5	25.82	18.18	22.41
Mean	**25.74**	**18.04**	**22.62**

Table 14: Basic values and mean value (N) of the test denture 14 for the 3 different tests

Pull No	Test No. 1(N)	Test No. 2(N)	Test No. 3(N)
1	30.48	18.31	24.74
2	30.14	18.02	24.90
3	29.86	17.20	24.51
4	29.28	18.86	24.73
5	30.53	16.83	23.96
Mean	**30.06**	**17.84**	**24.57**

Table 15: Basic values and mean value (N) of the test denture 15 for the 3 different tests

Pull No	Test No. 1(N)	Test No. 2(N)	Test No. 3(N)
1	27.36	13.21	18.35
2	28.35	15.08	20.77
3	26.38	16.06	19.66
4	27.47	14.53	18.49
5	27.93	14.74	18.91
Mean	**27.50**	**14.72**	**19.24**

Table 16: Basic values and mean value (N) of the test denture 16 for the 3 different tests

Pull No	Test No. 1(N)	Test No. 2(N)	Test No. 3(N)
1	24.90	18.56	22.41
2	26.15	18.92	22.81
3	25.55	18.42	22.68
4	24.92	18.49	22.75
5	24.86	18.55	22.45
Mean	**25.28**	**18.60**	**22.62**

Table 17: Basic values and mean value (N) of the test denture 17 for the 3 different tests

Pull No	Test No. 1(N)	Test No. 2(N)	Test No. 3(N)
1	30.14	18.02	18.35
2	30.48	18.31	20.77
3	29.28	17.20	19.66
4	29.86	16.83	18.49
5	30.53	18.86	18.91
Mean	**30.06**	**17.84**	**19.24**

Table 18: Basic values and mean value (N) of the test denture 18 for the 3 different tests

Pull No	Test No. 1(N)	Test No. 2(N)	Test No. 3(N)
1	25.91	13.21	22.83
2	25.46	15.08	21.96
3	25.84	14.53	21.77
4	25.69	14.74	21.86
5	25.82	16.06	21.88
Mean	**25.74**	**14.72**	**22.06**

Table 19: Basic values and mean value (N) of the test denture 19 for the 3 different tests

Pull No	Test No. 1(N)	Test No. 2(N)	Test No. 3(N)
1	27.36	17.65	22.64
2	28.35	18.12	22.64
3	27.47	17.96	22.45
4	27.93	18.09	22.61
5	26.38	18.18	22.42
Mean	**27.50**	**18.04**	**22.55**

Table 20: Basic values and mean value (N) of the test denture 20 for the 3 different tests

Pull No	Test No. 1(N)	Test No. 2(N)	Test No. 3(N)
1	25.84	18.86	24.90
2	25.93	18.02	24.51
3	25.94	18.31	24.73
4	26.23	17.92	23.96
5	26.69	18.60	24.74
Mean	**25.93**	**18.34**	**24.57**