# COMPARATIVE EVALUATION OF THE EFFECT OF LOCATION AND NUMBER OF IMPLANTS ON THE RETENTION AND STABILITY OF MAGNETICALLY RETAINED IMPLANT SUPPORTED MANDIBULAR OVERDENTURE -AN IN VITRO STUDY

*Dissertation Submitted to*

**THE TAMILNADU DR. M.G.R. MEDICAL UNIVERSITY**

*In partial fulfillment for the Degree of*

## MASTER OF DENTAL SURGERY

**BRANCH I**

**PROSTHODONTICS AND CROWN & BRIDGE**

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# CERTIFICATE

This is to certify that the dissertation titled **"COMPARATIVE EVALUATION OF THE EFFECT OF LOCATION AND NUMBER OF IMPLANTS ON THE RETENTION AND STABILITY OF MAGNETICALLY RETAINED IMPLANT SUPPORTED MANDIBULAR OVERDENTURE -AN IN VITRO STUDY "** is a bonafide record work done by **Dr. SUDARSON .K** under our guidance and to our satisfaction during his post graduate study period between 2008 – 2011.

This Dissertation is submitted to **THE TAMILNADU DR. M.G.R. MEDICAL UNIVERSITY**, in partial fulfillment for the Degree of **MASTER OF DENTAL SURGERY – PROSTHODONTICS AND CROWN & BRIDGE, BRANCH I.** It has not been submitted (partial or full) for the award of any other degree or diploma.

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# INTRODUCTION

Restoration of function and esthetics in completely edentulous patients has been traditionally achieved with optimal success using conventional complete dentures. Certain mechanical, biological and physical factors affect the outcome of complete denture treatment. These factors determine the retention, stability and support of the prosthesis, which in turn influence the success of the treatment.[19,20,21]

Retention of complete dentures is determined by physical factors like adhesion, cohesion and interfacial surface tension, mechanical factors like undercuts, anatomic factors like ridge height and surface area and biologic factors like intimate tissue contact, amount and quality of saliva. Stability on the other hand is affected by factors like ridge height, occlusal harmony, residual ridge relationships and the presence of undercuts. Both retention and stability are influenced by ridge height and surface area. In situations of long standing edentulousness there is usually a reduction in ridge height and surface area as a result of resorption and consequently there is a reduction in retention and stability.[5,19,20]

In conditions where there is a reduction of retention and stability there is an associated reduction in masticatory efficiency and disturbance in phonetics. All these contribute to a feeling of insecurity, low self esteem and dissatisfaction with the complete denture. Higher incidence of maladaptation to dentures has been shown to occur with mandibular dentures than with maxillary dentures.[24,25,31]

Various studies have suggested different surgical and non surgical methods to improve the retention and stability of mandibular dentures, like magnets implanted in the jaw, incorporation of neutral zone concept in denture construction, special impression procedures, retaining and modifying natural teeth to provide stability to the denture (overdenture) and dental implants with attachments. In the literature the use of attachment systems to improve the retention and stability of tooth and implant supported overdentures have been reported.[9,12,20,24,31]

A retentive force high enough to prevent denture displacement has been identified as an essential requirement for a successful attachment system. Currently, a universal accepted threshold value of retentive force for attachment system remains elusive in the literature. However some investigators came to the conclusion that attachments with retention forces more than 3N is sufficient to enhance denture performance. The retentive force is gained from mechanical and frictional contacts, as in a ball, bar and locator attachments or from magnetic forces of attraction between the patrix and matrix of magnetic attachments.[2, 8]

The advantages of magnetic attachment include ease of cleansing, ease of placement, constant retention, as well as self seating property. Hence magnetic attachments were introduced as a simple attachment modality for implant supported overdentures, which is considered as one of the treatment option for atrophic edentulous mandible.[4,32]

Numerous reports regarding the number of implants required while using a ball, bar or locator attachments can be found in the literature. The effect of the number of implants with one of the above attachments and also the effect of the implant location on the retention and stability of the prosthesis have been extensively studied.[36,37,42] But studies aimed at the number and location of implants with magnetic attachment system to retain a mandibular overdenture are very few.

Misch has discussed in depth regarding the options for mandibular overdentures with respect to the number and location of implants and also the type of attachments. He has divided the available bone in the anterior region into five equal columns of bone serving as potential implant sites. These sites have been labelled as A, B, C, D, E starting from the patient's right side. The A and E site corresponds to the first premolar on either side. The B and D site corresponds to the canine position on either side and the C site corresponds to the midline of the mandible. Five different options, utilising 2, 3, 4 or 5 implants with either a bar or a ball attachments placed in these sites has been proposed. Using magnetic attachments with implants placed in these sites is also being proposed in recent literature as an additional option to retain a mandibular overdenture. [26,41]

According to the Macgill consensus, two implants in the interforaminal region of the mandible is sufficient to retain, stabilise and support an overdenture. These two implants are preferably placed in the B and D positions owing to the abundance of bone and also the location which resists the rocking of the restoration. It has also been suggested that the A and E position can be prospective sites for placement of two implants. But this option has been considered a less favourable than the option of placing implants in the B and D position as they allow greater amplitude of rocking of the restoration which in turn can lead to excessive lateral forces on the implant. Whereas while using a magnetic attachment the rocking of the prosthesis does not transmit any detrimental forces on to the implant, as the magnet has the ability to detach itself and get separated. But at the same time the self seating property of the magnet allows itself to be reattached thereby still provide retention and stability to the prosthesis. So magnetic attachments on implants placed in the A and E position can still be a viable option in those patients where implants cannot be placed in the B and D positions. Whether placing implants with magnetic attachments in the A and E position will have an effect on the outcome of the treatment needs to be answered.[3, 26, 28]

However despite the proposal that mandibular two implant supported overdenture is sufficient, it still remains inaccessible to many edentulous patients in several developing countries due to financial constraints. An alternative solution is the use of a mandibular overdenture retained by a single implant placed in the midline. Information from case reports and prospective studies have demonstrated the possibility of a successful outcome with this approach as well. Studies have indicated adequate retention and stability and thereby comparable satisfaction with overdentures retained by one implant. There is also a considerable decrease in the treatment duration and cost as compared with mandibular overdenture retained by two implants.[2, 3, 17] Information regarding the retention and stability of mandibular overdenture retained by magnetic attachment placed on a single implant is lacking in literature.

Studies which have tested the retentive quality of attachments have tested the attachments ability to resist vertically directed dislodging force. Similarly studies which have tested the stability of the attachments have tested the attachments ability to resist lateral dislodging force and posterior dislodging force. Hence it is necessary to evaluate the effect of forces in these directions to evaluate the retentive and stabilising quality of a magnetic attachment system placed on implants.[36,42]

In view of the above factors it is necessary to evaluate if the change in location of the implant location from B and D to A and E will affect the retention and stability of a magnetically retained mandibular implant overdenture and also compare the retention and stability of magnetically retained two implant supported mandibular overdenture with that of magnetically retained one implant supported mandibular overdenture.

Hence this in vitro study was aimed to comparatively evaluate the effect of location and number of implants on the retention and stability of magnetically retained implant supported mandibular overdenture.

The objectives of the study include the following:

1. To evaluate the effect of vertically directed dislodging forces on the retention of magnetically retained mandibular overdenture supported by two implants placed in the B and D position.
2. To evaluate the effect of vertically directed dislodging forces on the retention of magnetically retained mandibular overdenture supported by two implants placed in the A and E position.
3. To evaluate the effect of vertically directed dislodging forces on the retention of magnetically retained mandibular overdenture supported by one implant placed in the C position.

4. To compare the effect of vertically directed forces on the retention of magnetically retained mandibular overdenture between the three test specimens with implants placed at, “ B&D”, “A&E” & “C” locations respectively.
5. To evaluate the effect of oblique rotational dislodging forces on the stability of magnetically retained mandibular overdenture supported by two implants placed in the B and D position.
6. To evaluate the effect of oblique rotational dislodging forces on the stability of magnetically retained mandibular overdenture supported by two implants placed in the A and E position.
7. To evaluate the effect of oblique rotational dislodging forces on the stability of magnetically retained mandibular overdenture supported by one implant placed in the C position.
8. To compare the effect of oblique rotational dislodging forces on the stability of magnetically retained mandibular overdenture, between the three test specimens with implants placed at “ B&D”, “A&E” & “C” locations respectively.
9. To evaluate the effect of posterior rotational dislodging forces on the stability of magnetically retained mandibular overdenture supported by two implants placed in the B and D position.
10. To evaluate the effect of posterior rotational dislodging forces on the stability of magnetically retained mandibular overdenture supported by two implants placed in the A and E position.

11. To evaluate the effect of posterior rotational dislodging forces on the stability of magnetically retained mandibular overdenture supported by one implant placed in the C position.
12. To compare the effect of posterior rotational dislodging forces on the stability of magnetically retained mandibular overdenture, between the three test specimens with implants placed at “B&D”, “A&E” & “C” locations respectively.
13. To comparatively evaluate the effect of vertically directed, oblique rotational, and posterior rotational dislodging forces on the retention and stability of magnetically retained mandibular overdenture supported by two implants in the B and D position.
14. To comparatively evaluate the effect of vertically directed, oblique rotational and posterior rotational dislodging forces on the retention and stability of magnetically retained mandibular overdenture supported by two implants in the A and E position.
15. To comparatively evaluate the effect of vertically directed, oblique rotational and posterior rotational dislodging forces on the retention and stability of magnetically retained mandibular overdenture supported by one implant in the C position.

# REVIEW OF LITERATURE

**Ron Highton et al (1986)**[18] in a study determined the retentive characteristics of Six commercially available magnets. Of the magnetic systems chosen for five were closed field systems and one was an open field system. The blocks with the magnet and the keepers were placed on an Instron test machine and breakaway force was determined. Then 0.1mm plastic strips were placed at the periphery of the blocks to provide an air gap between the magnets and the keepers. The testing continued by increasing air gap 0.5mm increments and breakaway forces were determined for all the magnet-keeper systems at the various air gaps. The maximum retention was obtained when the magnet and keeper were in apposition. However, as the air gap increased in 0.1mm increments, the breakaway force diminished rapidly initially and then began to taper off at 0.2mm and 0.3mm.

**Lewandowski et al (1988)**[22] in their study investigated two rare earth magnetic systems , the CoSm paired type & Nd paired type, by measuring grip force and reseating force. Two speeds of separation were conducted. The slow speed (2mm/min) allowed measurement of maximum attraction force. A faster separation (50mm/min) approximated the speed of movement of the mandible away from the denture and its magnet during chewing. To measure reseating forces, different air gaps were introduced between the magnets and its keeper by placing paper with 0.01mm and 0.20mmand 0.50mm thickness. The neodymium magnet had better grip force and reseating force compared with cobalt samarium magnets.

**Akaltan et al (1995)**[1] The study determined the retentive characteristics of one open-field and two closed-field commercial dental magnetic systems. The effect of speed of separation and the space between the magnet and its keeper on the retention force were evaluated. The magnets and their respective keepers, embedded in acrylic resin blocks, were tested with fast and slow speeds of separation. The maximum retention values of the magnetic systems were tested with slow speed of separation. The fast speed of separation was designed to reflect mandibular movement. Various spaces were developed between the magnets and their respective keepers, and magnetic systems were tested only in slow speed of separation. The fast speed of separation dramatically lowered the retention force of each magnetic system. As the space increased between the magnet and keeper, the retention values diminished rapidly. While closed-field systems demonstrated higher retentive forces than the open-field system, the open-field system was less affected by the various spaces.

**Breeding et al (1996)**[11] The study recorded and compared the retention of one- and two-clip retained simulated mandibular complete denture prostheses before and after simulated function. Cast metal Hader bars and clip holders were used to make 10 one-clip and 10 two-clip specimen pairs. Tensile removal values before and after simulated function were recorded and compared by repeated-measures analysis of variance and Student tau tests (significance level 0.05). The results revealed that the use of two clips instead of one significantly increased retention of the simulated prosthesis. It was also found that there was a significant loss of retention after the specimens were placed on the bars and then removed once for both the one- and two-clip groups. Simulated function did not cause a significant change in retention for either group.

**Cohen et al (1996)**[13] The study tested two precision overdenture attachment designs for retention. A nylon overdenture cap system and a new cap and keeper system. The new cap and keeper system were designed to reduce the time involved in replacing a cap worn by the conditions of the oral environment. Six groups were tested at two different angles and retentive failure was examined at two different angles (26 and 0 degrees). Failure was measured in pounds with a force gauge over a 2000 pull cycle. The amount of force required to remove caps for two overdenture caps and a replaced cap for the metal keeper system was determined. The results indicated a significant difference between cap types ($p < 0.0001$) with respect to the relative force required to remove the cap. There was no effect of angle. The nylon cap design required less force for removal but showed more consistency in the force required over the course of the 2000 pulls when compared with the keeper with cap insert.

**Petropoulos et al (1997)**[28] The study compared the retention and release periods of the Nobel Biocare bar and clip (NBC), Nobel Biocare ball (NB), Zest anchor (ZA), Zest magnet (ZM), and Sterngold ERA (SE) attachments on an implant-retained overdenture model. Each attachment had one part embedded in a denture-like housing, and the other part screwed into the implants. Dislodging tensile forces were applied to the housings in two directions simulating function:

vertical and oblique. Eight tests were done in two directions with three samples of each attachment. The dislodging forces generated measurements of the peak load, break load, and displacement at peak load and break load. Results showed the NBC to be significantly most retentive for the break load when subjected to vertical and oblique forces. He concluded that the NBC could be selected when a higher degree of retention and fast release period are desired.

**Fromentin et al (1999)**[16] determined the influence of mechanical fatigue on four varieties of implant overdenture stud type attachments (Supra-Snap, O'Ring, TSIB, ZAAG). Measurements of the initial vertical retentive force and the weight of the implant abutment were recorded. The same procedure was performed after the equivalent of 2 months, 6 months, and 12 months of clinical wear. For the four attachments, weight variation of the abutment between 0 and 1,080 cycles demonstrated no significant difference. Results indicated the TSIB to be significantly most retentive; next most retentive was the O'Ring, followed respectively by Supra-Snap and ZAAG.

**Setz et al (2000)**[38] The study compared the effects of different types of attachments on the mobility of implant-stabilized overdentures in vitro, designing a measurement device that could also be used in vivo. On an acrylic model with 2 implants in the canine areas, magnets were fixed to one of the implant abutments. Four Hall-effect devices were attached to the denture opposite the magnet, which allowed contact-free measurements of denture movements. The results showed very small, largely insignificant differences in denture mobility when different were used.

**Williams et al (2001)**[44] The study evaluated the initial retention characteristics of 5 implant maxillary overdenture designs under in vitro dislodging forces. A simulated edentulous maxilla was fabricated with 4 screw-type 3.75 x 13-mm implants anteriorly. Five overdenture designs with the following attachments were evaluated. 4 plastic Hader clips with an EDS bar; 2 plastic anterior Hader clips with an identical EDS bar; 2 Hader clips with 2 posterior ERA attachments; 3 Zaag attachments on a bar; and 4 Zaag attachments with on a bar. Overdentures were fabricated with full palatal coverage. Each design was subjected to 10 consecutive retention pulls on a universal testing machine. Data were subjected to analysis of variance and t tests to determine differences. The highest average value after 10 pulls was 19.8 lb for the combination ERA and Hader clip design. The lowest retentive values were recorded for the 2 and 4 Hader clip designs (5.08 +/- 0.89 lb and 5.06 +/- 0.67 lb, respectively). Retention decreased over the course of consecutive pulls for all designs, especially for the most retentive designs. The smallest retention decrease occurred with the least retentive designs.

**Petropoulos et al (2002)**[29] compared the retention and stability of the Nobel Biocare standard ball (NBS), Nobel Biocare 2.25-mm-diameter ball (NB2), Zest Anchor (ZA), Zest Anchor Advanced Generation (ZAAG), Sterngold ERA orange (SEO), and Sterngold ERA white (SEW) attachments on an implant-retained overdenture model. Dislodging tensile forces were applied to the housings in 3 directions simulating function: vertical, oblique, and anterior-posterior. Eight tests were done in 3 directions with 6 samples of each attachment. The dislodging forces generated measurements of the peak load. Results showed the ZAAG attachment to be the most retentive for the peak load measurement when subjected to vertically directed forces. For anterior-posteriorly directed forces, results showed the NBS had the highest measured retentive force.

**Tokuhisa et al (2003)**[40] compared the stress patterns generated around implants and denture movement among Ball/ O-ring, bar/clip, magnetic attachment systems. Two root-form implants were anchored in a mandibular model made of resin, and a removable overdenture on which all experiments were performed was fabricated. The surface of the model was covered with a layer of impression material to simulate oral mucosa. A vertical force was applied to the left first molar and gradually increased from 0 to 50 N in 5-N steps. The resultant stress distribution and denture movement were evaluated. The ball/O-ring attachment transferred the least stress to both implants and produced less bending moment than the bar/clip attachment.

**Svetlize et al (2004)**[39] The study evaluated the retention on two or four implants of eight resilient and nonresilient retentive anchors used in overdentures. Eight groups of retentive anchors were used: Dyna and Shiner (magnets); Dalla Bona and O-Ring (balls); Ceka Revax and Zaag attachments (studs); the cast bar (Dolder type) system with plastic clips; and the milled bars system. These specimens with their respective overdentures were prepared on two similar acrylic resin models with four implants (3.75 x 13 mm). Ten tensile strength tests (Instron) were performed on each group at a speed of 3 mm per minute. The milled bar system was the most retentive anchor, with the Dalla Bona, Ceka Revax, Hader Bar, Zaag attachment, and O-Ring groups being the second most retentive. The least retentive groups were the Shiner and Dyna magnets. The authors concluded that proper abutment placement in the mandible and the correct selection of the retentive anchor will improve overdenture retention.

**Chung et al (2004)**[12] The study compared the retention characteristics of various overdenture attachment systems commonly used to retain overdentures to dental implants. The attachments evaluated were the Hader bar & metal clip, Locator LR pink, Locator LR white, Spheroflex ball, Shiner magnet, Maxi magnet, Magnedisc magnet, ERA white, and ERA gray. Each apparatus was tested with 5 specimens per attachment system. Peak load-to-dislodgement was measured. Results suggest that the attachment systems evaluated may be grouped into high (ERA gray), medium (Locator LR white, Spheroflex ball, Hader bar & metal clip, ERA white), low (Locator LR pink), and very low (Shiner magnet, Maxi magnet, Magnedisc magnet) retention characteristics.

**Rutkanas et al (2004)**[34] evaluated and compared retentive and stabilizing properties of stud (ERA Overdenture (orange and white), Locator Root (pink) and OP anchor # 4) and magnetic attachments (Hyperslim 4513, Hyperslim 4013, Magfit EX600W, Magnedisc 500 and Magfit-RK) by measuring maximum retentive force and retentive energy during linear and rotational dislodgments. For each type of dislodgement10 measurements were recorded by universal testing machine (AGS-H, Shimadzu Co., Kyoto, Japan) with 50 mm/min cross head speed. Results showed that studs provided higher retention and stability than magnetic attachments. As for rotational dislodgements maximum retentive force of magnetic attachments decreased in following order – anterior > lateral >

posterior; whereas of studs – posterior > anterior > lateral. Magnetic attachments had considerably lower retentive energy values for all types of dislodgements.

**Cune et al (2005)**[14] aimed to study to determine patient satisfaction with implant supported mandibular overdentures using magnet, bar clip, and ball-socket attachments and to assess the relation between the maximum bite force and patient satisfaction. Eighteen patients were selected and the attachment types were changed 3 months, in random order. Patients were asked to express their satisfaction and preference through a questionnaire regarding their satisfaction and preference at the end of the treatment. The results showed that patient preferred bar-clip attachments and ball-socket attachments over magnet attachments.

**Rutkanas et al (2005)**[33] compared the retentive force of overdenture attachments after their reach stable retention. He determined minimum number of cycles required to reach stable retention.  Three specimens of each type of attachment were used stud ERA Overdenture (orange and white), Locator Root (pink) and OP anchor # 4) and magnetic (Magfit EX600W. Micromaterial testing machine (MMT-250NB-10, Shimadzu Co.Tokyo, Japan) with a sensor interface PCD-320 and software package PCD-30A (Kyowa Electronic Instruments Co., Tokyo, Japan) was used to performe 2000 insertion-removal cycles with 50 mm/min cross head speed. Maximum retentive force was measured initially and after each 40 Cycles. Results showed that before and after fatigue simulation statistically significant differences existed among the five types of attachments. Decrease of retention was characteristic for all attachments except OP. After fatigue LRP was most retentive. Magnetic attachments preserved maximum amount of retention measured at the baseline (98%). EO and EW attachments have preserved only 25% and 37% of initial retention respectively. He concluded that due to fatigue overdenture attachments gradually loose their retention. Stud attachments are more susceptible to fatigue than magnets. Eight hundred cycles are required to achieve relatively stable retention of overdenture attachments.

**Michelinakis et al (2006)[25]** evaluated the interimplant distance and the type of attachment on the retention of mandibular overdentures on two implants. Two implant analogues were embedded at distances of 19mm, 23mm and 29mm.Hader bar, ball abutments and magnet attachment were compared. Forty five groups of paired attachments were tested for vertical peak tensile load at the three interimplant distances. Results showed that interimplant distance played only a significant role only in the retention produced by bar attachments. At 19 and 23 mm, statistically was more retentive than the yellow clips, white clips and magnets but not compared to the red clips. Regarding magnetic attachments the retentive values in 29mm was highest followed by 19mm and 23mm.They concluded that interimplant distance can affect the initial retention of mandibular overdentures on two implants depending on the type of attachment used.

**Bayer et al (2007)[6]** The objective of the study was to quantify wear processes by measuring the retention force changes and the fitting tolerance at different prefabricated attachment systems to estimate the wear constancy and applicability in clinical practice. Seven prefabricated attachment systems (Dalbo-Classic, Dalbo-PLUS, Dalbo-Z, Mini-Gerber-PLUS, Stufenexzenter, SpharoLock, and Degussa-Kugelankersystem) with different construction and alloy composition were tested. Twenty samples of each system were subjected to 10,000 insertion-separation cycles in a wear simulator with a periodontium-simulating specimen holder. The simulator was designed to record the force needed to insert and to separate the attachment and the distance moved during the insertion and separation cycles. Results indicated that all types of anchors showed wear that led to a loss or to an increase in retention force at the beginning of the wear simulation. Anchors with a plastic retention insert showed the slightest changes in retention force. The wear does not have an effect on the fitting tolerance. The author concluded Anchor systems that possess an adjustable matrix should be preferred. They allow decreasing or increasing the retention force of an anchor if this force is changed by wear. There is no risk of a loss of support if forces in occlusal direction are exerted because there is no clinically relevant change in the fitting tolerance.

**Rutkanas et al (2007)**[35] evaluated and compare retention of two-teeth (implant) supported mandibular overdenture with either stud or magnetic attachments during linear (axial) and rotational (paraxial) dislodgements. He also compared the retentive properties before and after wear simulation. Retention in axial direction was evaluated on the model by measuring maximum retentive force (N) and range of retention (mm) during the linear dislodgement. Retention in the paraxial direction was evaluated on mandibular-overdenture model by measuring the maximum retentive force (N) during three types of rotational dislodgements – anterior, lateral and posterior. The minimum number of cycles required to simulate wear was determined by special wear test. The wear was simulated in the test group, and retention in axial and paraxial directions was measured again. Initially, studs had higher retention (4–11 N) than magnets (4·5–6 N) in axial direction. After the wear simulation, it had decreased from 76% to 48% for some of the studs and had become similar to the retention of magnetic attachments. Magnets had lower retention range (0·2–0·3 mm) than studs (0·5–1·1 mm). Studs provided similar or higher retention in paraxial directions than magnetic attachments both before and after wear simulation. Retentive properties of magnets decreased mostly with posterior rotational dislodgement. Retentive properties of stud overdenture attachments were less constant.

**Boeckler et al (2008)**[10] investigated reviewed and compared maximum retentive forces and characteristic curves for magnetic attachments indicated for use as root anchors and on implants. Twenty-four samarium-cobalt (SmCo) and neodym-iron-boron (NeFeB) magnetic attachments (12 tooth- and 12 implant-borne) were evaluated. Five magnet pairs of each product and each combination were tested 10 times in a calibrated universal testing machine using a nonmagnetic test device. Maximum retentive forces for root keepers ranged from 1.4 to 6.6 N. Maximum retentive forces for magnetic attachments on implants ranged from 0.7 to 5.8 N.

**Wahab et al (2008)**[42] compared the effect of location and number of implants on the retention and stability of magnetically retained mandibular overdenture. Four groups of such prostheses were classified according to number and position of the implants in the canine, premolar or molar regions. Significance difference in retention were observed when 6 magnets were used, whereas the lowest retention was obtained with 2 magnets. Only oblique stability improved significantly when the number of implants was increased.

**Pigozzo et al (2009)**[30] The study evaluated retentive strength and fatigue resistance of 4 overdenture bar-and-clip attachment systems. Forty bar-and-clip attachment system specimens were tested: Conexão Bar Clip (polymer clip), Sterngold Hader Bar (polymer clip), 3i Gold Hader Type Clip (metal clip), or SIN Clipo (metal clip). Specimens immersed in artificial saliva were tested to 5500 cycles at 0.8 Hz using a servohydraulic universal testing machine. Retention strength values (N) were recorded initially and after 1100, 2200, 3300, 4400, and 5500 insertion and removal cycles during the tensile test using a speed of 1 mm/min and a load cell of 1 kN. An increase in retention strength values was observed during the fatigue test after 5500 cycles of insertion and removal. No significant difference in retentive strength was observed in the groups using polymer clips (Conexão Bar Clip and Sterngold Hader Bar) and with metal clip systems (SIN Clipo and 3i Gold Hader Type Clip). The SIN Clipo system demonstrated the smallest retention strength values, which were significantly different from the other 2 attachment systems, the Sterngold Hader Bar ($P<.01$) and the Conexão Bar Clip ($P<.01$). Although the 3i Gold Hader Type Clip did not differ significantly, in terms of retentive strength, from the Sterngold Hader Bar ($P=.258$), its retentive strength was significantly lower than the retentive strength of the Conexão Bar Clip system ($P=.030$). The systems evaluated demonstrated satisfactory retention for all time periods tested, as retention strengths from 5 to 7 N should be sufficient to stabilize overdentures. No component fracture or compromise in retention was found for any of the systems tested.

**Sadig et al (2009)**[36] 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. Two model designs were selected based on the number and location of the inserted implants: In a first setup, 2 implants were placed in the canine regions; in a second setup, 2 implants were placed in the canine regions and 2 in the premolar regions. Three types of connector were used in each model: magnets, balls, and locators; 10 resin bases were fabricated and 3 hooks fixed at tripodal locations for chain testing. Vertical dislodging forces and 2 aspects (oblique and posterior rotational dislodging forces) of stability were tested. Locator connectors provide significantly higher retention and stability of implant-supported overdentures, followed by ball connectors and then magnets. The 2-implant design offers less retention and stability than the 4-implant model. Number of implants and type of connector significantly affected retention and stability of implant-supported overdenture.

**Bayer et al (2009)**[8] evaluated the retention force changes of different prefabricated attachment systems for implant-supported overdentures to estimate the wear constancy and applicability in clinical practice. Four prefabricated attachment systems were tested Group SG: retentive ball attachment with gold matrix, Group ST: retentive ball attachment with titanium spring matrix, Group IB: UNOR i-Ball with Ecco matrix and Group IMZ: IMZ-Twin Plus ball attachment with gold matrix. Results showed that attachments with a plastic retention insert or gold matrices underwent the smallest changes in retention force. The titanium spring system showed the largest changes in retention force and a greater variation between the different cycles and specimen. He concluded that attachment systems which possess a male and female component of different material composition are preferable.

**Alsabeeha (2009)**[3] reviewed the literature on mandibular single-implant overdenture and present surgical and prosthodontic perspectives of a novel approach for this treatment option. A limited number of reports were identified on mandibular single implant overdenture. The methodology revealed specific anatomical and vascular dangers of the mandibular midline symphysis and described a novel approach using a currently available short wide diameter tapered implant. In addition, the prosthodontic rationale for mandibular single denture overdenture was described. The review reveals that there is a lack of published clinical trials using mandibular single-implant overdentures.

**Alsabeeha et al(2009)**[4] The study reviewed the published literature on in vitro articles investigating the retentive force or wear features of different attachment systems, specifically for mandibular two-implant overdentures using an unsplinted prosthodontic design. These articles provided evidence that the majority of attachment systems for mandibular two-implant overdentures demonstrate a reduction in their retentive force under in vitro conditions. Wear was unquestionably implicated as the etiologic factor for the loss of retention; however, the specific mechanisms involved in the wear process have not been researched adequately. Findings from the literature have also implicated several factors that influence the retentive force of the attachment system and its wear features; compelling evidence on its precise role however, is still lacking. Further in vitro investigations of the factors involved in the retention and wear of attachment systems for mandibular two-implant overdentures are still needed. These factors must be investigated separately under well-controlled conditions to limit the influence of confounding variables on their outcome.

**Walton et al (2009)[43]** The study tested the hypotheses that there are no difference in patient satisfaction, component costs or treatment and maintenance times when mandibular overdentures are retained by one or two implants. Subjects wearing conventional complete dentures were randomized to receive either one midline or two bilateral a mandibular implants. Eighty six patients were included in the study. Patient satisfaction was seen at two months and one year after implant placement. Lower component costs and treatment times with comparable costs and treatment times with comparables satisfaction and maintenance time over the first year indicated a mandibular overdenture with a single implant in the midline may be an alternative to customary two implant overdenture for maladaptive patients.

**Alsabeeha (2010)[2]** The aim of the study was to investigate the retentive force of six different attachment systems retentive force of six different attachments used for mandibular single-implant overdentures. Two prototype ball attachments of larger dimensions and four commercially available ball and stud attachments of different dimensions were evaluated. Five samples from each attachments were connected to three different implants. An Instron testing machine was used to deliver a vertical dislodging force at a cross- head speed of 50mm/min to each overdenture sample from the anterior direction. A total of

Three hundred tests were conducted. Maximum dislodgement force was measured. Results showed that the highest retentive force was achieved by 7.9mm prototype ball attachment, followed in decreased order by 5.9mm prototype ball attachment, 2.25mm ball attachment, locator white, locator pink and locator blue attachment. A statistically significant difference was found between all the three attachments. He concluded that attachments of larger dimensions provide higher retentive forces for mandibular single-implant overdentures.

**Liddelow et al (2010)**[23] The study aimed to ascertain whether simplifying mandibular overdenture treatment by using single-stage surgery and immediate prosthetic loading of a single implant will achieve acceptable implant success rates functional improvement and increased patient satisfaction. Thirty five patients with problematic mandibular dentures were treated. A single implant was placed in the mandibular midline. Patients were randomly fitted with a machined surface or oxidized groups. A ball attachment was placed and a retentive cap was incorporated into the existing denture. Reviews took place at 3, 12 and 36 months post treatment. Results showed that the 25 implants placed in oxidized-surface implants survived in a 36 month recall. Patient satisfaction was very high with a significant increase in all comfort and functional parameters.

**Fromentin et al (2010)**[15] the aim of this study was to validate an original portable device to measure attachment retention of implant overdentures both in the lab and in clinical settings. The device was built with a digital force measurement gauge (Imada) secured to a vertical wheel stand associated with a customized support to hold and position the denture in adjustable angulations.

Sixteen matrix and patrix cylindrical stud attachments (Locator) were randomly assigned as in vitro test specimens. Attachment abutments were secured in an implant analogue hung to the digital force gauge or to the load cell of a traction machine used as the gold standard (Instron Universal Testing Machine). Matrices were secured in a denture duplicate attached to the customized support, permitting reproducibility of their position on both pulling devices. Attachment retention in the axial direction was evaluated by measuring maximum dislodging force or peak load during five consecutive linear dislodgments of each attachment on both devices. After a wear simulation, retention was measured again at several time periods. The peak load measurements with the customized Imada device were similar to those obtained with the gold standard Instron machine. These findings suggest that the proposed portable device can provide accurate information on the retentive properties of attachment systems for removable dental prostheses.

**Bayer et al (2010)**[7] evaluated the retention force changes of an attachment system for overdentures. The influence of the lubricant and the alloy on wear constancy was examined. Cylindrical anchors of the Dalbo((R))-Z system were tested (Cendres+Métaux SA). Three groups of alloy-lubricant combinations were generated 1.Elitor ((R))/NaCl-solution (EN) 2.Elitor ((R))/Glandosane((R)) aquadest. (EG) and 3.Valor ((R))/Glandosane((R)) /aquadest. (VG). Ten samples of each group were subjected to 10,000 insertion-separation cycles. For the EN-group, this led to a large increase in retention force. The EG and VG group showed a constant decrease after an initial increase in retention force at the beginning of the wear simulation. The change of the alloy caused no statistically significant differences. The use of a more viscous lubricant reduced the retention force increase significantly. The use of a lubricant which simulates clinical conditions is an absolute need for wear simulation because the retention force changes are influenced enormously. The change of the alloy at the Dalbo ((R))-Z system did not influence the wear behavior. As a slight decrease in retention force was recorded, it is useful for an attachment system to allow compensation with an adjustable matrix.

**Van Kampen et al (2010)**[41] the study evaluated the influence of various attachment types in mandibular Implant retained overdentures on maximum bite force and EMG. Eighteen edentulous patients were fitted successively with the three attachments. Maximum bite force and electrical activity of masseter and temporalis muscle was measured. The maximum bite force doubled after treatment for each of the three attachments. The results showed that differenced in maximum bite force and muscle activity obtained with magnet, bar – clip and ball attachments were small. Thus all the three attachments greatly improve oral function.

# MATERIALS AND METHODS

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

The following materials were used in the study:

1. Type III dental stone (Asian chemicals, India)
2. Upper and lower edentulous model former (Ashoosons, Delhi, India) (Fig.4)
3. Separating medium (DPI cold mould seal, India) (Fig.5c)
4. Self cure acrylic resin (DPI Cold cure, India) (Fig.6)
5. Modelling wax (Cavex, Holland BV, The Netherlands) (Fig.7)
6. Type II dental plaster (Ramaraju surgicals, India)
7. Teeth set –Mold S1- Shade-24 (Premadent, India) (Fig.8)
8. Heat cure denture base acrylic resin (DPI Heat cure, India) (Fig.5a&b)
9. Carbide burs (Edenta, U.k)
10. Acrylic trimmers (Shofu, Japan)
11. Sand paper (Jawan brand, India)
12. Pumice (Delta, India)
13. Polishing cake (Rolex, India)

14. Implant replica (Tidel spiral, Israel) (Fig.9)
15. Impresssion coping for closed tray impression (Tidel spiral, Israel) (Fig.10)
16. Screwdriver, manual, unigrip (Tidel spiral, Israel)
17. Implant keeper (Preat Corporation, USA) (Fig.11b)
18. Shiner hex driver (Preat Corporation, USA) (Fig.11f)
19. Impression piece (Preat Corporation, USA) (Fig.11e)
20. Model Piece (Preat Corporation, USA) (Fig.11d)
21. Processing piece (Preat Corporation, USA) (Fig.11c)
22. Magnet tool (Preat Corporation, USA) (Fig.11g)
23. Shiner magnet (Preat Corporation, USA) (Fig.11a)
24. Impression tray-Size U4 (Jabbar & Co, India) (Fig.12)
25. Poly vinyl Siloxane impression material-Putty consistency (Aquasil, Dentsply) (Fig.13a)
26. Poly vinyl Siloxane impression material-Light bodied consistency (Aquasil ultra LV, Dentsply) (Fig.13b)
27. Fit checker (GC Corporation, Japan) (Fig.14)
28. B.P blade no.15
29. B.P blade handle no.3

30. Rubber bowl (Fig.15d)

31. Stainless steel spatula (Fig.15c)

32. Wax carver (Fig.15b)

33. Wax knife (Fig.15a)

34. Hot plate spatula

35. Wax spatula

36. Chip blower

37. Glass plate (Fig.18a)

38. Stainless steel wire (Konark , Everbright dental, India) (Fig.16a)

39. Universal orthodontic plier (Fig.16b)

40. Stainless steel chains (Fig.17)

41. Spirit columns (Fig.18b)

The following equipments were used for the study:

1. Automixing gun (Heraeus Kulzer,Germany) (Fig.13c)
2. Articulator (Classic,India) (Fig.19)
3. Dental flask and dental clamp (Jabbar,India)
4. Laboratory lathe (Suguna motors, India ) (Fig.20)
5. Dental surveyor (Saeshin Precision Ind.Co, Korea) (Fig.21)
6. Universal testing machine (Instron,U.S.A) (Fig.22)

**Description of the magnetic attachment (Preat Corporation, USA)**

The magnet used was a Neodymium Ferric Boron (Nd-Fe-B) type of magnet. It was a mono and closed–field system. It was manufactured by Preat Corporation, USA. The magnet had the following components.

1. Magnet-It has a diameter of 3.9mm and height of 2.4mm. It is covered by a white plastic capsule except in the surface contacting the keeper. The plastic capsule has threads to facilitate placement and removal of the magnet (Fig.11a).
2. Implant keeper-The keeper has a height of 3.5mm and diameter of 3.6mm.It is attached to the implant replica. It has a hex shaped slot on the superior surface to aid in its placement on to the implant (Fig.11b).
3. Black processing piece-used for creating the space for the magnet in the denture. It is made of plastic. Its outer surface has got threads similar to that of the plastic capsule with the magnet (Fig.11c).
4. Model piece -It is made up of plastic. It is used in the laboratory technique of fabrication of the denture. It simulates the keeper and is attached to the impression piece while duplication (Fig.11d).
5. Impression piece-It is made of plastic. It is used in the laboratory technique of fabrication of the denture. It is used for creation of a space for the keeper in the denture while processing (Fig.11e).
6. Shiner hex driver -It is made of steel. It is used for connecting the keeper to the implants (Fig.11f).

7. Magnet tool-It made of steel. It has two ends. One end is used for the removal of processing piece. The other end is used for insertion of magnet in the denture (Fig.11g).

**Description of the universal testing machine**

A universal testing machine (Instron Testing Machine, USA) (Fig no.22) was used for the present study. The machine consists of a lower chamber, upper chamber, a display board to display the amount of force exerted. The upper member has a hydraulic pressure unit and a loading cell. The forces for the testing are exerted by the upper member. The lower member has a bench vice to hold the test specimens. In this study, the loading cell of the upper member was connected to the specimen attached to the lower member through chains for the application of the pulling force. The whole unit is attached to computer for recording and converting data as required.

# METHODOLOGY

The following methodology was adopted for the study:

**1. Fabrication of a reference mandibular denture**

A. Fabrication of stone casts

B. Fabrication of record bases and occlusal rims

C. Mounting the occlusal rims on the articulator

D. Arrangement of artificial teeth

E. Processing of the reference denture

**2. Fabrication of test specimens**

A. Preparation of mandibular edentulous wax model

B. Incorporation of implant replicas into the wax model

C. Processing of the test models with implant replica

D. Duplication of the acrylic model with polyvinyl Siloxane impression material

E. Fabrication of stone casts

F. Fabrication of record base and occlusal rim

G. Mounting the occlusal rim on the articulator

H. Arrangement of artificial teeth

I. Processing of the test mandibular dentures

**3. Incorporation of magnetic attachment in the test models and the test dentures**

**4. Evaluation of retention and stability using universal testing machine**

A. Attachment of the hooks to the test denture

B. Tests for retention and stability

**5. Results and statistical evaluation**

**1. Fabrication of a reference mandibular denture.**

**A. Fabrication of the stone casts**

Maxillary and mandibular edentulous stone casts were formed by pouring typeIII dental stone (Asian chemicals, India) into an edentulous model former (Ashoosons, Delhi, India) (Fig.4) (Fig.23). Two mandibular casts and one maxillary cast were made. One mandibular and maxillary cast was used in the fabrication of the reference denture. The other mandibular cast was used to fabricate a record base with occlusal rim, which was later used in positioning the wax edentulous models on the surveyor during the placement of the implant replicas into the model.

**B. Fabrication of record bases and occlusal rims**

Record bases and occlusal rims were fabricated on the maxillary cast and the two mandibular casts. A layer of separating medium (DPI cold mould seal, India) (Fig.5c) was applied over the casts. Record bases were fabricated with autopolymerising acrylic resin (DPI Cold cure, India) (Fig.6) employing the sprinkle-on technique. Occlusal rims were constructed with modelling wax (Cavex, Holland BV, The Netherlands) (Fig.7). The maxillary occlusal rim was constructed to an anterior height of 22mm and a posterior height of 18 mm. The mandibular occlusal rim was made to an anterior height of 18 mm and a posterior height corresponding to the level of anterior 2/3 rd of the retromolar pad. The occlusal rims had a width of 5mm anteriorly and 8mm posteriorly (Fig.24).

**C. Mounting the occlusal rims on the articulator**

The occlusal rims with the casts were related in class I relation and mounted on a mean value articulator (Classic, India) (Fig.19) following the guidelines for mounting in an articulator (Fig.25). The casts were mounted using typeII dental plaster.

**D. Arrangement of artificial teeth**

Acrylic denture teeth (Premadent, India. Mold-S1 Shade 24) (Fig.8) was used. Teeth arrangement was done following the principles of tooth arrangement to achieve a class I canine relationship and a class I molar relationship. Wax-up and polishing was done (Fig.26).

**E. Processing of the reference denture**

Only the mandibular denture was processed. The maxillary trial denture was left undisturbed in the articulator and was later used for orienting the mandibular occlusal rim during the fabrication of test dentures. During dewaxing procedure, the teeth were removed from the flask so that the entire denture was fabricated with denture base resin. The processing of the denture was done in heat cure acrylic resin. (DPI Heat cure, India) (Fig.5 a&b). The processed acrylic model was trimmed with acrylic burs (Shofu, Japan) and carbide burs (Edenta, U.k). It was smoothened with sand paper (Jawan brand, India), wet polishing was done on a dental lathe (Fig. 20) with a cloth wheel and pumice (Delta, India), followed by dry polishing with a polishing cake (Rolex India) (Fig.27).

**2. Fabrication of test specimens**

**A. Preparation of the mandibular edentulous wax model**

Modelling wax was melted using a hot plate spatula and was allowed to flow into the mold space of a mandibular edentulous model former till the wax completely filled the mold. The wax was allowed to harden. Once the surface of the wax was hard, the model former with the wax was placed in a water bath at room temperature, to ensure complete solidification of wax. Later, the model was retrieved from the model former (Fig.28). Three such wax models were obtained.

**B. Incorporation of implant replicas into the wax model**

Implant replicas (Tidel spiral, Israel) (Fig.9) were placed in the three mandibular edentulous wax models by the following method.

The wax model was placed on a dental surveyor (Saeshin Precision Ind.Co, Korea) (Fig.21). The occlusal rim previously fabricated on the duplicated stone cast was positioned over the wax model. The wax model with the occlusal rim was positioned in such a way that the occlusal plane was perpendicular to the surveying arm. This was verified by placing two spirit columns (Fig.18b) in a horizontal direction over a glass plate (Fig.18a), one spirit column oriented in the x axis and the other in the y axis. The glass plate with the spirit columns was placed on the occlusal surface of the occlusal rim, and it was ensured that the liquid level in both the spirit columns was in the centre (Fig.29a). This in turn ensured that the implant replicas could be placed perpendicular to the occlusal plane. The model table was locked in this position. The occlusal rim was removed and the reference mandibular denture was placed on the wax model. The implant position corresponding to the test specimens was marked on the wax model (Fig.29b). For test specimen A, marks corresponding to the centres of the right and left canine was made, similarly for test specimen B, marks corresponding to the right and left first premolar, and for test specimen C, a mark corresponding to the midline was made over the wax model(Fig.3a-c). Implant replica attached to an impression coping (Tidel spiral, Israel) (Fig.10) (Fig.29c) was attached to the surveying arm of the surveyor. The surveying arm with the impression coping attached to the implant replica was lowered on to the wax model and made to contact the ridge area corresponding to the mark made using the reference denture. The contact point of the implant replica on the wax model was marked. Wax in the area marked was softened with a heated instrument so that the wax was pooled in that area. The surveying arm was further lowered and the implant replica was submerged into the wax model in such a way that the surface of implant replica was 2mm from the crest of ridge on the wax model (Fig.29d). This was done to mimic the presence of 2mm thick soft tissue over the implant placed at the level of the bone. Once wax was hard the impression coping with implant replica was detached from the surveyor. The impression coping was kept attached to the implant replica till the wax model was processed in acrylic. The impression copings attached to the implant replicas helped in maintaining the position of the implant replica during the processing of the acrylic model.

**C. Processing of the test models with the implant replicas**

The wax models thus obtained were processed in heat cure acrylic resin. Once the wax models were processed in acrylic the impression coping was removed from the processed acrylic models. The acrylic models were trimmed with acrylic burs and carbide burs and smoothened with sand paper. Wet polishing was done on a dental lathe with a cloth wheel and pumice, and dry polishing was done with a polishing cake (Fig.30).

**D. Duplication of acrylic models with polyvinyl siloxane impression material**

The implant keepers were attached to the implant replicas already incorporated into the three acrylic models (Fig 31a). The impression piece was then attached over the implant keeper in the test model (Fig.31b). Poly vinyl siloxane impression material-putty consistency (Fig.13a) and Light bodied consistency (Aquasil, Dentsply) (Fig.13b) was used for the duplication. During duplication the impression piece was picked up from the acrylic model and was incorporated in the impression (Fig.1) (Fig.31c). A model piece was attached to the impression piece which was incorporated in the impression (Fig.31d). The model piece represented the implant keeper.

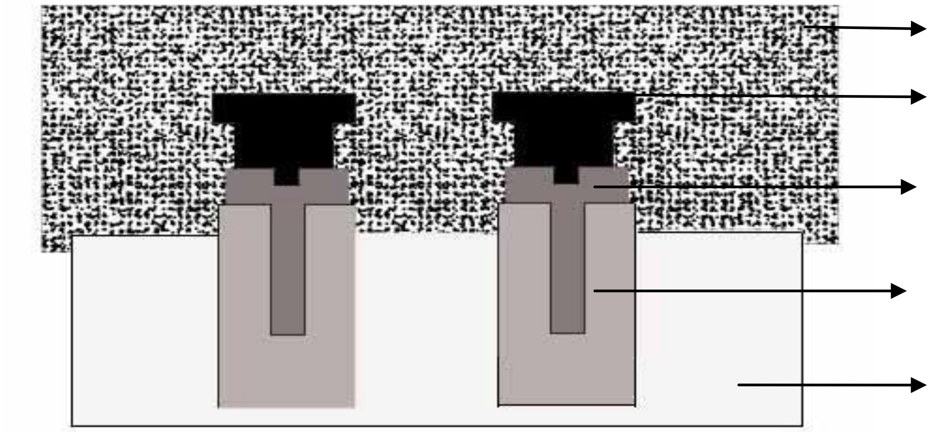



**Fig. 1 : Line diagram depicting the position of impression piece, implant keeper and implant replica in the acrylic model while making an impression**

**F. Fabrication of stone casts**

A stone cast was formed by pouring typeIII dental stone into each of the impression obtained from the three acrylic models (Fig.2a). On removal of the stone cast from the impression, the model piece got incorporated into the stone cast (Fig.32). The black processing piece was attached to the model piece which was already incorporated in the cast (Fig.33) (Fig.2b).

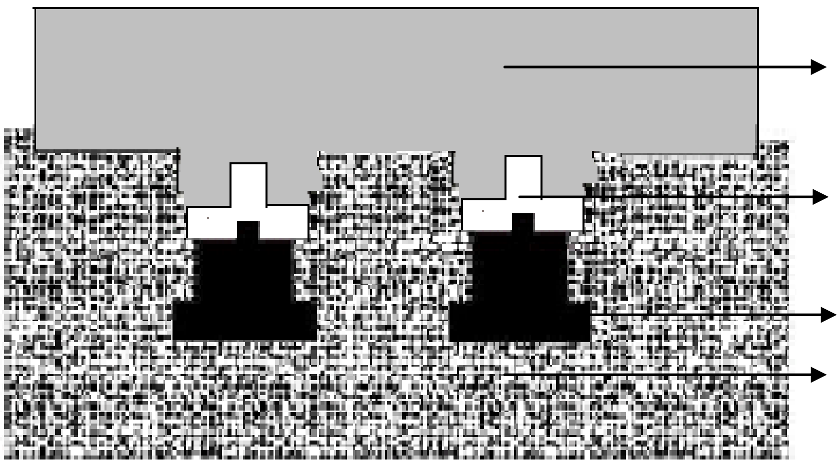



**Fig. 2a : Line diagram depicting the impression piece, model piece in the impression while pouring a cast**

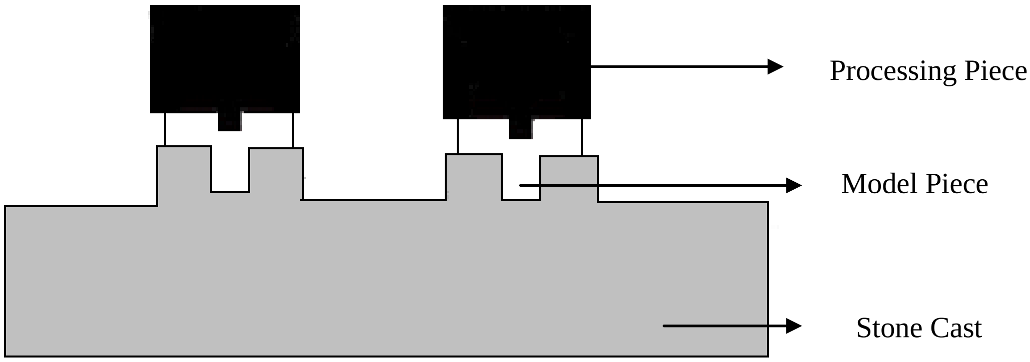



**Fig. 2b : Line diagram depicting the model piece and processing piece in a cast**

**F. Fabrication of record base and occlusal rim**

Record base and occlusal rim was constructed on the duplicated stone cast. Occlusal rim was constructed with modelling wax to an anterior height of 18 mm and a posterior height corresponding to the 2/3 of the retromolar pad. It had a width of 5mm anteriorly and 8mm posteriorly (Fig.34).

**G.Mounting the occlusal rim in the articulator**

The mandibular occlusal rim with the cast was related in a class I relation to the maxillary trial denture already mounted in the articulator (Fig.35).

**H. Arrangement of artificial teeth**

Teeth arrangement was done following the principles of tooth arrangement to achieve a class I canine relationship and a class I molar relationship. Wax-up and polishing was done (Fig.36).

**I. Processing of the test mandibular dentures**

The trial dentures were processed using heat cured denture base acrylic resin. The black processing piece got incorporated into the intaglio surface of the test denture during the processing (Fig.37).

**3. Incorporation of magnetic attachment in the test models and the test dentures**

The black processing piece was unthreaded from the prosthesis with the magnet tool (Fig.38). The magnet was threaded with its capsule into the space left by the processing piece in the prosthesis using the magnet tool (Fig. 39). The implant keeper was attached to the implant replica in the test model using a shiner hex driver (Fig.40). The denture with the magnet was seated over the model with the implant keeper. The magnet position was adjusted vertically to ensure complete contact between the magnets. This was done using a Fit Checker paste (GC, Japan) (Fig.14). Fit checker paste was applied over the contacting surface of the keeper and the denture with the magnet was seated over the respective model. Complete contact of the keeper and the magnet was verified by ensuring complete perforation of fit checker over the contacting surfaces (Fig.41). This was done for all the three test dentures.

In the above manner the three specimens required for the study were obtained and they were considered as specimens A, B and C (Fig.42).

Specimen A comprised of a mandibular test denture with the magnetic attachment system connected to the implant replicas placed in the B and D position in the mandibular edentulous acrylic model (Fig.42a).

Specimen B comprised of a mandibular test denture with the magnetic attachment system connected to the implant replicas placed in the A and E position in the mandibular edentulous acrylic model (Fig.42b).

Specimen C comprised of a mandibular test denture with the magnetic attachment system connected to the implant replica placed in the C position in the mandibular edentulous acrylic model (Fig.42c).

**4. Evaluation of retention and stability using universal testing machine.**

**A. Attachment of the hooks in the test denture**

The retention and stability was tested by subjecting the dentures to pulling forces in different directions. The pulling force was applied to the dentures by attaching chains to hooks attached to the denture on one side and the tensile load cell of the Instron testing machine on the other end. Three metal hooks with a radius of 3mm were made from 19 gauge stainless steel wire (Fig.16a) and were attached to the denture. One hook was attached in the anterior lingual surface corresponding to the midline. Two hooks were attached in the posterior retromolar region, one on each side. The hooks were attached in the denture using self cure acrylic resin (Fig.43). The hooks were attached in such a way that the surface of the hooks were all at the same level. This was verified by placing a glass plate (Fig.18a) with spirit columns (Fig.18b) over the hooks (Fig.44).

**B. Tests for retention and stability**

The test was done in a universal testing machine (Instron, U.S.A.).The test model with the test denture was placed in the cast holder of the surveyor. The model was positioned in the cast holder in such a way that the hooks were all in the same plane. This was also ensured by using a glass plate with spirit columns as done previously. The test specimen was also positioned in such a way that the load cell was equidistant from all the hooks. A Chain of 4cm length was attached to each of the hooks. The other end of the chain was attached to the load cell of the instron machine. A pulling force was applied on the denture with a cross head speed of 50mm/min. Each test denture was subjected to three tests. The load at which the dentures detached from the model was the considered as the dislodging force and it was recorded in Newtons (N).

**Test No.1- Effect of Vertical directed dislodging forces**

It was done to determine the retention of the magnets when subjected to a three point vertical pulling force. All the three chains were attached to the loading cell of the testing machine and the test was conducted (Fig.45). It was repeated ten times for each Specimen. Ten values were obtained for each test specimen.

**Test No.2-Effect of oblique rotational dislodging forces**

This test was conducted to evaluate the stability of the denture. It simulated the clinical condition when there is a displacement of the denture upon lateral excursion. For this test, only the chains attached to the posterior hook on the left side and the hook in the anterior midline was attached to the loading cell of the testing machine (Fig.46). The test was then conducted in a similar fashion to the retention test.

**Test No.3-Effect of posterior rotational dislodging forces**

This test was conducted to evaluate the stability of a denture when subjected to antero-posterior forces. It simulated the clinical condition when there is a displacement of the denture in protrusive movement, when the lower anteriors are thrust against the upper anteriors. For this test, only the chains attached to the two hooks on the posterior aspect of the denture was attached to the loading cell of the testing machine (Fig.47). The chain attached to the anterior hook was not connected. The test was then conducted in a similar fashion to the retention test.

The retention and stability values was recorded through a computer connected to a universal testing machine and the values were recorded in Newtons (N).

**5. Results and statistical Evaluation**

The results obtained were tabulated. The mean and the standard deviation for each specimen in the test was calculated and the results were subjected to statistical evaluation. The SPSS (SPSS for windows 8.0, SPSS software Corp., Munich, Germany) software package was used for statistical analysis.



**a** **b**


**c**

**Fig.3a: Edentulous mandible depicting the implant positions-B&D (canine position)**
**Fig.3b: Edentulous mandible depicting the implant positions-A&E (premolar position)**
**Fig.3c: Edentulous mandible depicting the implant position-C (Midline of the mandible)**

**Fig.4: Upper and lower edentulous model former**


**Fig. 5a: Heat cure polymer**
**5b: Heat cure monomer**
**5c: Cold mould seal**


**Fig.6: Self cure acrylic resin**


**Fig.7: Modelling wax**


**Fig.8: Teeth set**


**Fig.9: Implant replica**

**Fig.10: Impression coping**

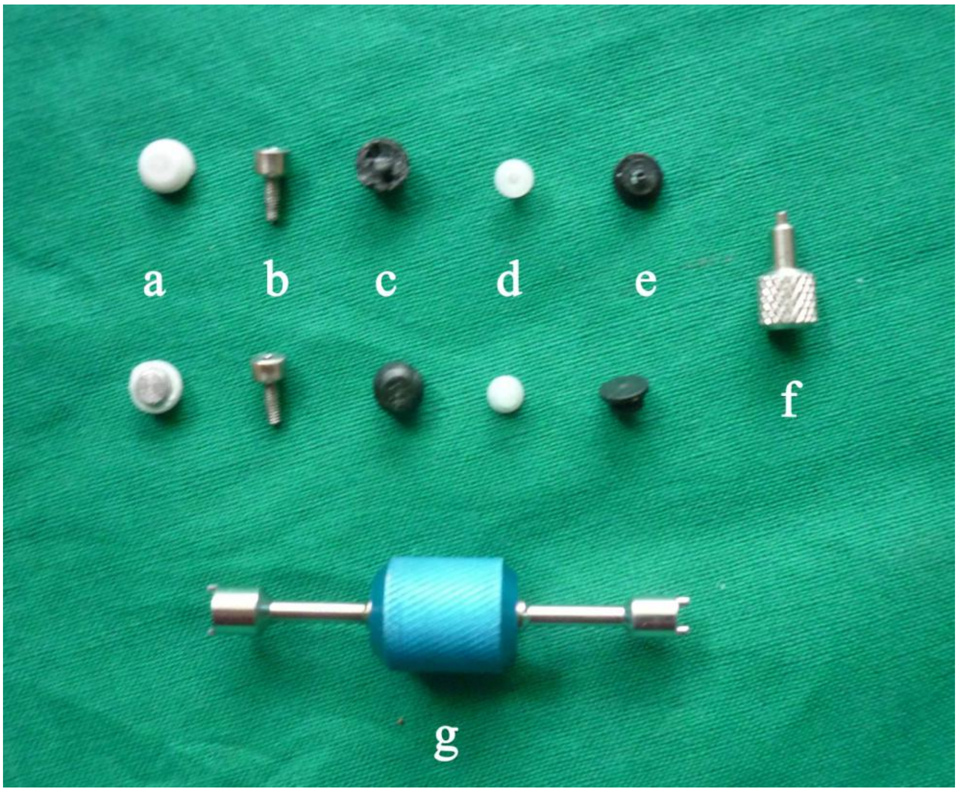



**Fig.11: Magnetic attachment set**
**11a: Magnet with capsule, 11b: Implant keeper,**
**11c: Processing piece, 11d: Model piece,**
**11e: Impression piece, 11f: Shiner hex driver,**
**11g: Magnet tool**

**Fig.12: Metal impression tray**


**Fig.13a: Poly vinyl siloxane impression material - Putty consistency**
**13b: Poly vinyl siloxane impression material- Light bodied consistency**
**13c: Auto mixing gun**


**Fig.14: Fit checker**

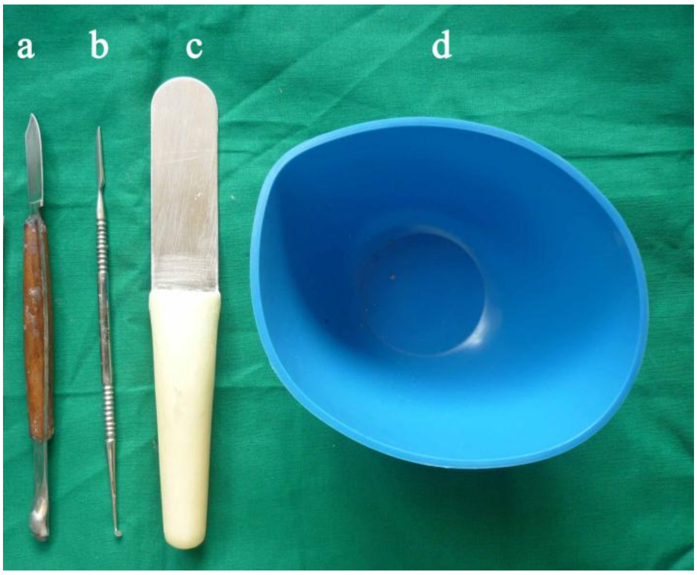
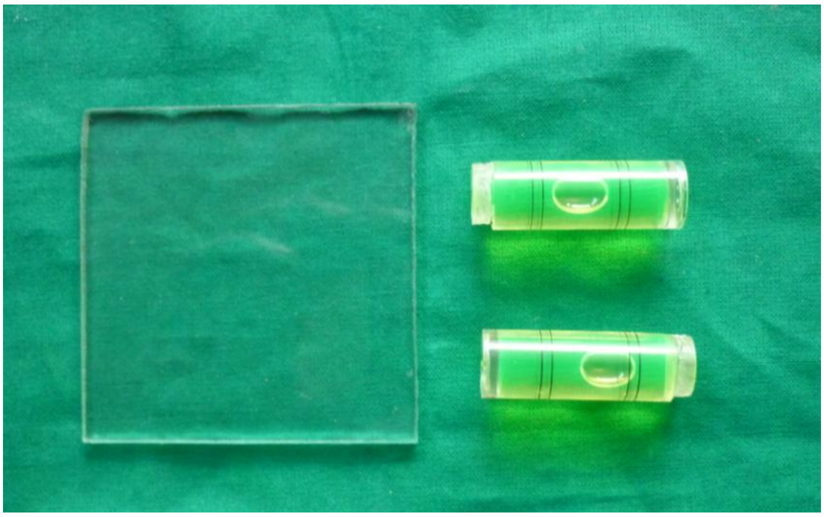



**Fig.15a: Wax knife, 15b: Wax carver,**
**15c: Stainless steel spatula, 15d: Rubber bowl**


**a b**

**Fig.16a: Stainless steel wire**
**16b: Universal orthodontic plier**

**Fig.17: Stainless steel chains**



**a** **b**

**Fig.18a: Glass plate**
**18b: Spirit columns**

**Fig.19: Articulator**

**Fig.20: Laboratory lathe**


**Fig.21: Dental surveyor**

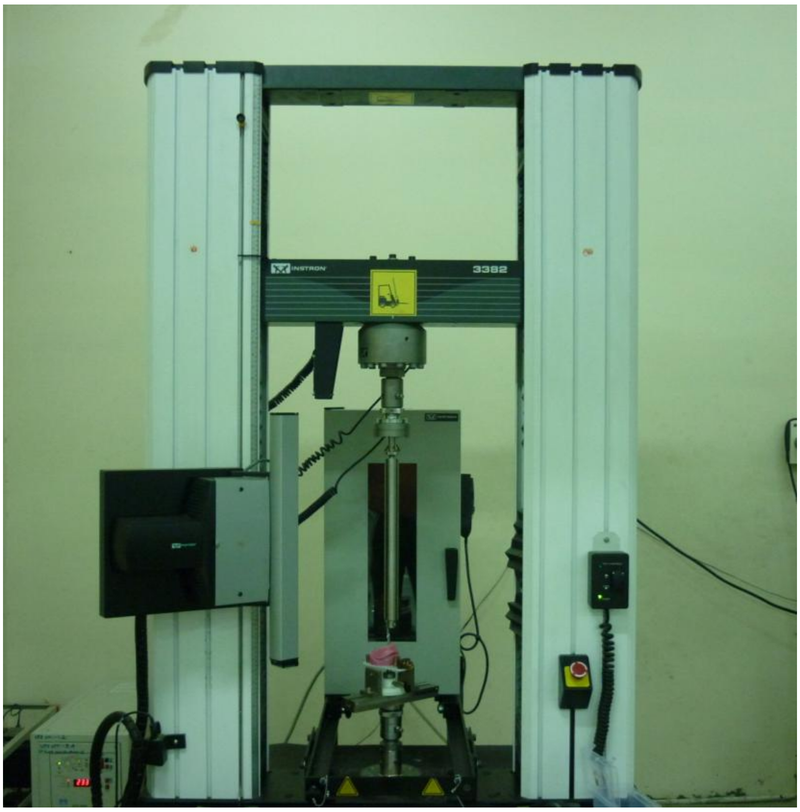



**Fig.22: Instron testing machine**

**Fig.23: Upper and lower stone casts**

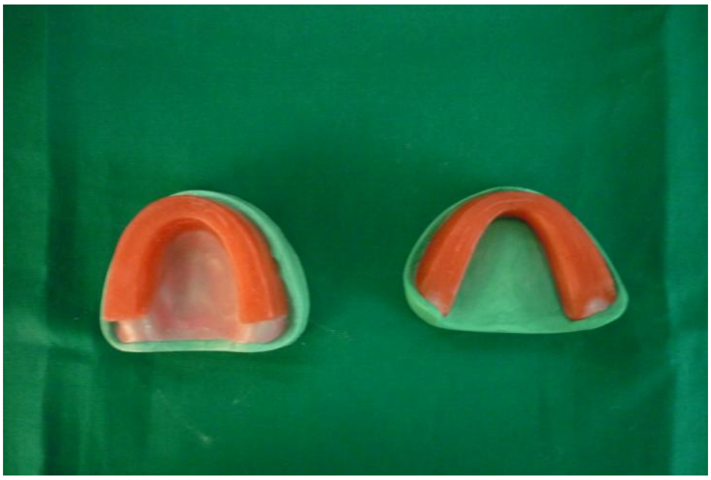


**Fig.24: Record bases and occlusal rims**

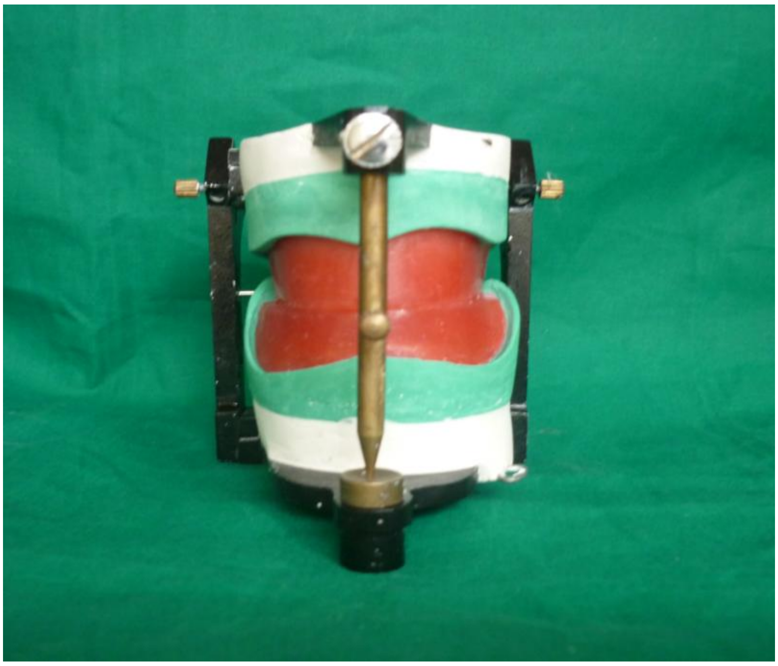


**Fig.25: Occlusal rims  mounted on the articulator**

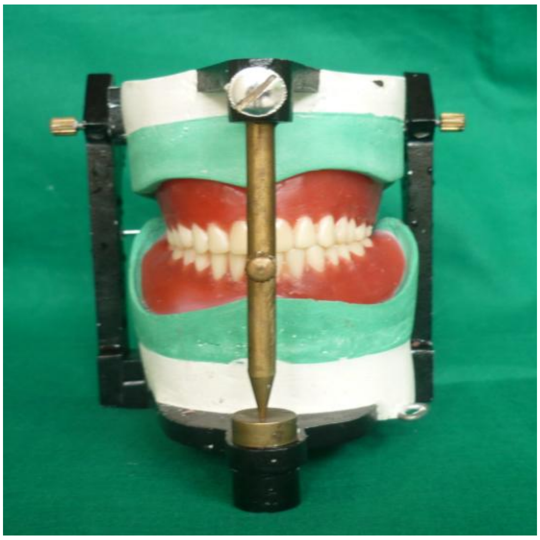
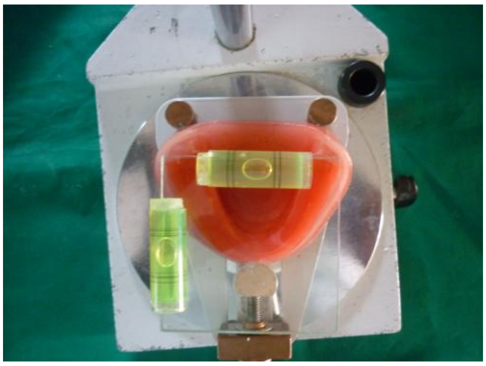
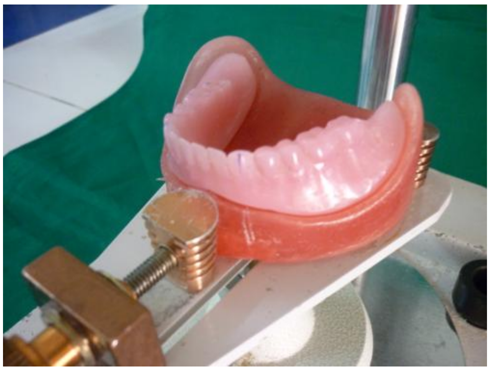


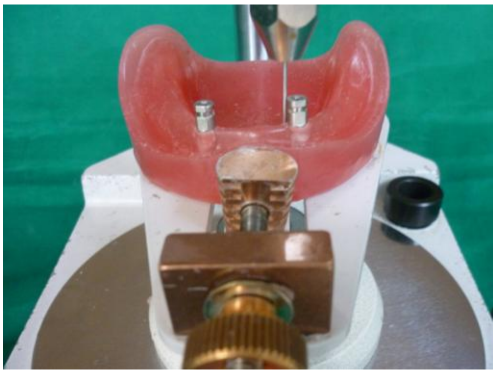
**Fig.26: Arrangement of artificial teeth**

**Fig.27: Processed reference denture**

**Fig.28: Mandibular edentulous wax model**

a b

c d

e

**Fig.29: Positioning implant replicas in the wax model**
**29a: Positioning the model with occlusal rim in the surveyor**
**29b: Reference denture placed on the wax model**
**29c: Implant replica attached to the impression coping**
**29d: The implant replicas positioned in the wax model**
**29e: Wax models for specimens A,B&C**

**Fig.30:Acrylic model with implant replicas**

**a** **b**

**c** **d**

**Fig.31: Duplication of acrylic test model**
**31a: Implant keeper attached to the implant replica in the acrylic model**
**31b: Impression piece attached to the implant keeper**
**31c: Duplication of acrylic model with polyvinyl siloxane impression material**
**31d: Model piece attached to the impression piece in the impression**

**Fig.32: Stone cast with model piece**

**Fig.33: Processing piece attached to the model piece on the stone cast**

**Fig.34: Record base with processing piece**

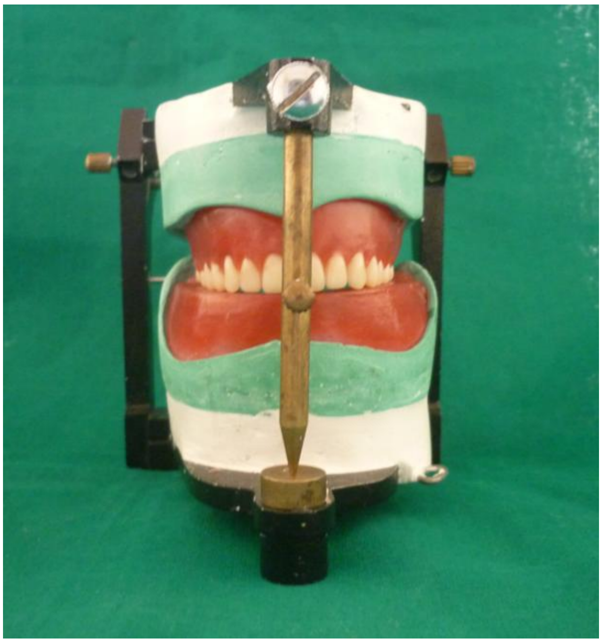


**Fig.35: Cast mounted on the articulator**

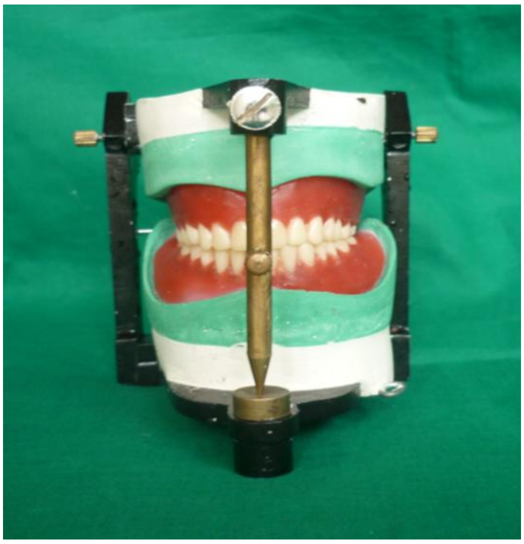


**Fig.36: Mandibular teeth arrangement**

**Fig.37: Mandibular test denture with the processing piece**

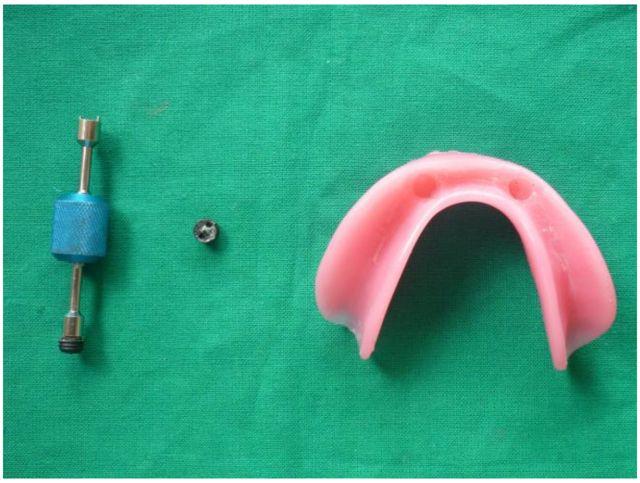


**Fig.38: Processing piece removed from the test denture**

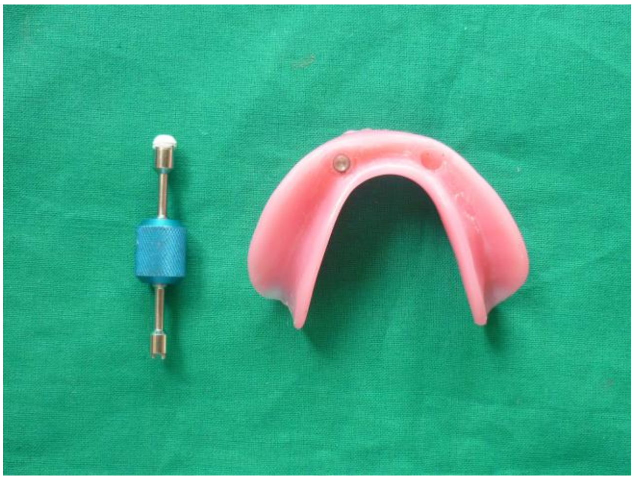


**Fig.39: Magnet placed in the test denture**

**Fig.40: Implant keeper attached to the implant replica in the test model**

**Fig.41: Complete contact of magnet and keeper verified with fit checker**

a b c

**Fig.42: Test specimens**
**42a: Specimen A**
**42b: Specimen B, 42c: Specimen C**

**Fig.43: Attachment of hooks to the test denture**

**Fig.44: Level of hooks verified with spirit columns**

**Fig.45: Test No.1**

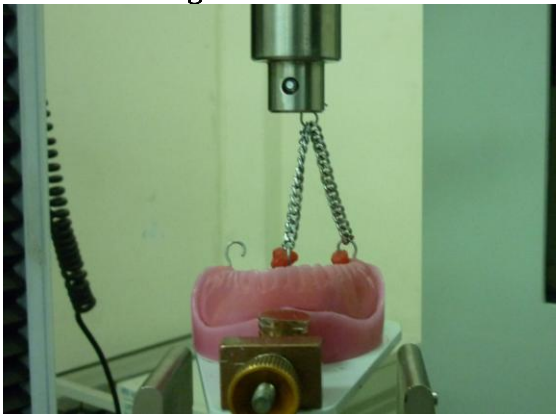


**Fig.46: Test No.2**

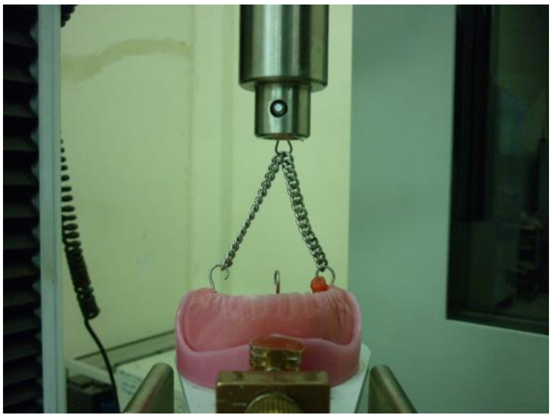
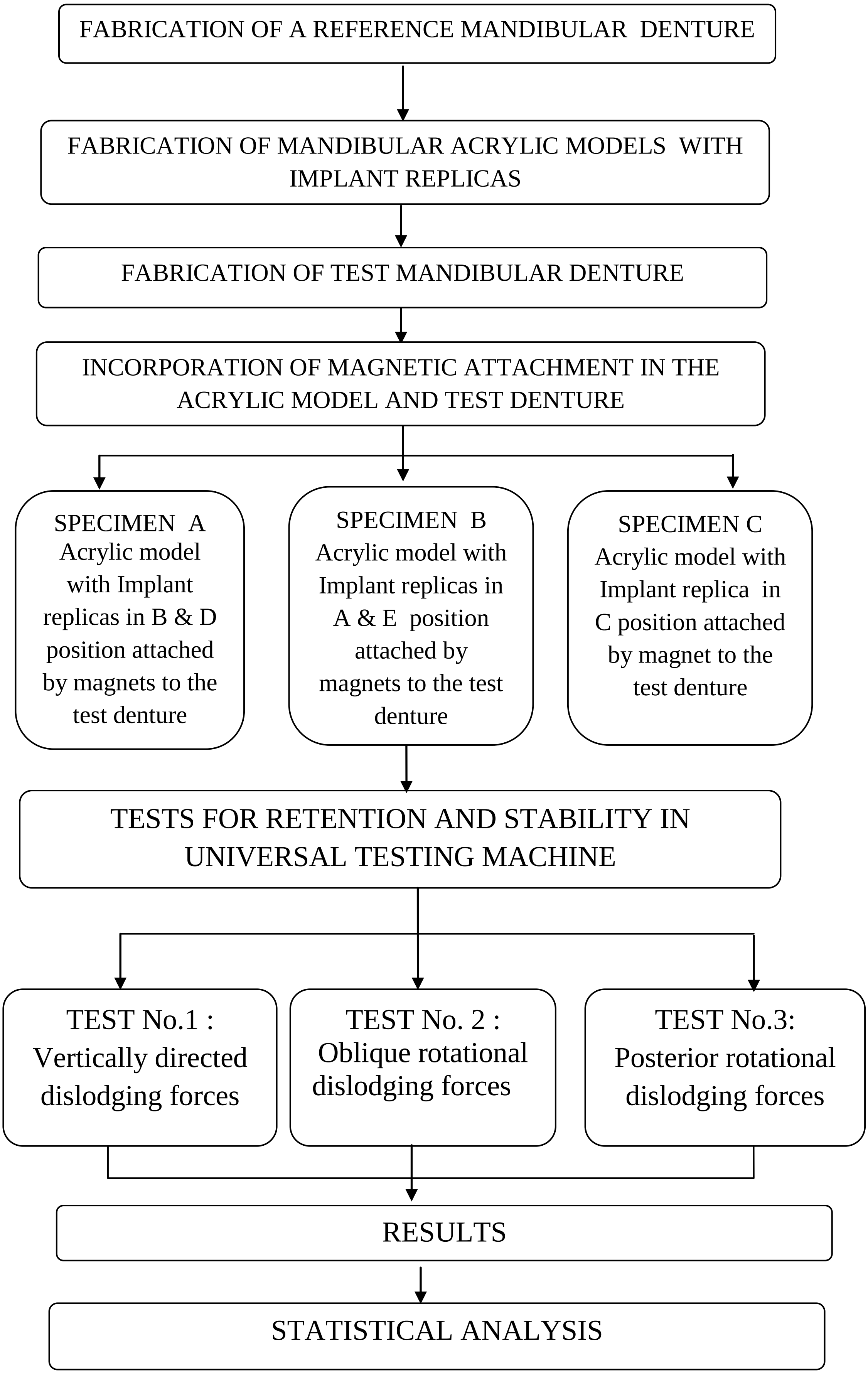


**Fig.47: Test No.3**

# METHODOLOGY



# RESULTS

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

Test models were prepared by placing implant replicas in a mandibular edentulous acrylic model. The test denture was fabricated on the test model. The components of the magnetic attachments were incorporated into the acrylic test models and the test dentures. Each acrylic model with the test denture represented one test specimen. Specimen A comprised of a mandibular test denture with the magnetic attachment system connected to the implant replicas placed in the B and D position in the mandibular edentulous acrylic model. Specimen B comprised of a mandibular test denture with the magnetic attachment system connected to the implant replicas placed in the A and E position in the mandibular edentulous acrylic model. Specimen C comprised of a mandibular test denture with the magnetic attachment system connected to the implant replica placed in the C position in the mandibular edentulous acrylic model.

Each model was subjected to three different tests on an Instron 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. Test No.3 was conducted to evaluate the Effect of posterior rotational dislodging forces. The force at which the denture detached from the model was recorded. Each test was repeated ten times for each test specimen and the mean was obtained.

Mean and standard deviation of all the values for each test specimen was obtained and was compared using one way ANOVA and Independent Samples Students T-Test. The spss software package was used for statistical analysis. In the present study $p<0.05$ was considered as the level of significance.

The following results were drawn from the study:

Table 1 shows the basic values and mean value (N) of the test specimen A for the three different tests.

Table 2 shows the basic values and mean value (N) of the test specimen B for the three different tests.

Table 3 shows the basic values and mean value (N) of the test specimen C for the three different tests.

Table 4 shows the mean value (N) and standard deviation of the test specimen for the three different tests.

Table 5 shows the test for significance between specimens for Test No.1 (One way Anova).

Table 6 shows the test for significance between specimens for Test No.1 (Independent Samples Students T-Test).

Table 7 shows the test for significance between specimens for Test No.2 (One way Anova).

Table 8 shows the test for significance between specimens for Test No.2 (Independent Samples Students T-Test).

Table 9 shows test for significance between specimens for Test No.3 (One way Anova).

Table 10 shows test for significance between specimens for Test No.3 (Independent Samples Students T-Test).

Table 11 shows test for significance within specimen A for the three tests (One way Anova).

Table 12 shows test for significance within specimen A for the three tests (Independent Samples Students T-Test).

Table 13 shows test for significance within specimen B for the three tests (One way Anova).

Table 14 shows test for significance within specimen B for the three tests (Independent Samples Students T-Test).

Table 15 shows test for significance within specimen C for the three tests (One way Anova).

Table 16 shows test for significance within specimen C for the three tests (Independent Samples Students T-Test).

Graph 1 shows the basic values (N) of the test specimen A for the three different tests.

Graph 2 shows the basic values (N) of the test specimen B for the three different tests.

Graph 3 shows the basic values (N) of the test specimen C for the three different tests.

Graph 4 shows the mean value (N) and standard deviation of the Test specimens for the three different tests.

Graph 5 shows the mean value (N) and standard deviation of the three different tests within the test specimens.

**Table 1 : Basic values and mean value (N) of the test specimen A for the three different tests**

| Pull No | Test No.1(N) | Test No.2 (N) | Test No.3(N) |
|---|---|---|---|
| 1 | 3.72 | 2.14 | 1.64 |
| 2 | 4.5 | 1.91 | 1.7 |
| 3 | 3.8 | 2.03 | 1.61 |
| 4 | 3.48 | 1.95 | 1.72 |
| 5 | 3.62 | 1.8 | 2.24 |
| 6 | 3.45 | 2 | 1.68 |
| 7 | 3.38 | 1.85 | 1.6 |
| 8 | 3.75 | 1.9 | 1.7 |
| 9 | 3.65 | 2.09 | 1.82 |
| 10 | 3.69 | 2.02 | 1.7 |
| **Mean** | **3.7** | **1.96** | **1.74** |

**Table 2 : Basic values and mean value (N) of the test specimen B for the three different tests**

| Pull No | Test No.1(N) | Test No.2(N) | Test No.3(N) |
|---|---|---|---|
| 1 | 4.1 | 1.96 | 1.9 |
| 2 | 4.3 | 1.67 | 2.15 |
| 3 | 3 | 1.19 | 1.41 |
| 4 | 3.5 | 2.13 | 1.4 |
| 5 | 3.72 | 1.68 | 1.65 |
| 6 | 3.55 | 2 | 2.02 |
| 7 | 4.04 | 1.7 | 1.85 |
| 8 | 3.9 | 1.82 | 1.95 |
| 9 | 3.79 | 1.65 | 1.8 |
| 10 | 4 | 1.6 | 2.8 |
| **Mean** | **3.79** | **1.74** | **1.89** |

**Table 3 : Basic values and mean value (N) of the test specimen C for the three different tests**

| Pull No | Test No.1(N) | Test No.2(N) | Test No.3(N) |
|---|---|---|---|
| 1 | 2.29 | 0.8 | 1 |
| 2 | 1.9 | 1.1 | 1.62 |
| 3 | 2.3 | 1.1 | 1.16 |
| 4 | 1.96 | 1.3 | 1.73 |
| 5 | 2.04 | 1.3 | 1.56 |
| 6 | 2.25 | 1.25 | 1.4 |
| 7 | 2.2 | 0.97 | 1.32 |
| 8 | 2.07 | 0.94 | 1.2 |
| 9 | 1.99 | 1.19 | 1.61 |
| 10 | 2.01 | 1.25 | 1.23 |
| **Mean** | **2.1** | **1.1** | **1.3** |

**Table 4: Mean value (N) and standard deviation of the test specimens for the three different tests**

| Groups | Test No.1 | | Test No.2 | | Test No.3 | |
|---|---|---|---|---|---|---|
| | **Mean** | **S.D** | **Mean** | **S.D.** | **Mean** | **S.D.** |
| Specimen A | 3.70 | 0.3118 | 1.96 | 0.1067 | 1.74 | 0.1861 |
| Specimen B | 3.79 | 0.3720 | 1.74 | 0.2614 | 1.89 | 0.4019 |
| Specimen C | 2.1 | 0.1464 | 1.12 | 0.4084 | 1.38 | 0.2397 |

**Table 5: Test for significance between specimens for Test No.1 (One way Anova)**

| | N | Mean | SD | P-Value |
|---|---|---|---|---|
| Specimen A | 10 | 3.704 | 0.3118 | <0.001** |
| Specimen B | 10 | 3.790 | 0.3720 | |
| Specimen C | 10 | 2.101 | 0.1464 | |
| Total | 30 | 3.198 | 0.8390 | |

INFERENCE: The mean value for Test No.1 of Specimen A was 3.7N, Specimen B was 3.79N and Specimen C was 2.1N. On comparison between Specimen A, Specimen B and Specimen C the results were found to be statistically highly significant (P-value <0.001).

**Table 6 : Test for significance between specimens for Test No.1 (Independent Samples Student T-Test)**

| | N | Mean | SD | P-Value |
|---|---|---|---|---|
| Specimen A | 10 | 3.704 | 0.3118 | 0.582 |
| Specimen B | 10 | 3.790 | 0.3720 | |
| Specimen A | 10 | 3.704 | 0.3118 | <0.001** |
| Specimen C | 10 | 2.101 | 0.1464 | |
| Specimen B | 10 | 3.790 | 0.3720 | <0.001** |
| Specimen C | 10 | 2.101 | 0.1464 | |

INFERENCE: The mean value for Test No.1 of Specimen A was 3.7N, Specimen B was 3.79N and Specimen C was 2.1N.On comparison between Specimen A and Specimen B the results were found to be statistically insignificant(P-value 0.582). On comparison between Specimen A and Specimen C the results were found to be statistically highly significant(P-value <0.001). On comparison between Specimen B and Specimen C the results were found to be statistically highly significant (P-value <0.001).

**Table 7: Test for significance between specimens for Test No.2 (One way Anova)**

| | N | Mean | SD | P-Value |
|---|---|---|---|---|
| Specimen A | 10 | 1.969 | 0.1067 | <0.001** |
| Specimen B | 10 | 1.740 | 0.2614 | |
| Specimen C | 10 | 1.120 | 0.1750 | |
| Total | 30 | 1.610 | 0.4084 | |

INFERENCE: The mean value for Test No.2 of Specimen A was 1.96N, Specimen B was 1.74N and Specimen C was 1.12N.On comparison between Specimen A, Specimen B and Specimen C the results were found to be statistically highly significant (P-value<0.001).

**Table 8: Test for significance between specimens for Test No.2 (Independent Samples Student T-Test)**

| | N | Mean | SD | P-Value |
|---|---|---|---|---|
| Specimen A | 10 | 1.969 | 0.1067 | 0.019* |
| Specimen B | 10 | 1.740 | 0.2614 | |
| Specimen A | 10 | 1.969 | 0.1067 | <0.001** |
| Specimen C | 10 | 1.120 | 0.1750 | |
| Specimen B | 10 | 1.740 | 0.2614 | <0.001** |
| Specimen C | 10 | 1.120 | 0.1750 | |

INFERENCE: The mean value for Test No.2 of Specimen A was 1.96N, Specimen B was 1.74N and Specimen C was 1.12N.On comparison between Specimen A and Specimen B the results were found to be statistically significant (P-value 0.019). On comparison between Specimen A and Specimen C the results were found to be statistically highly significant (P-value <0.001). On comparison between Specimen B and Specimen C the results were found to be statistically highly significant (P-value <0.001).

**Table 9: Test for significance between specimens for Test No.3 (One way Anova)**

| | N | Mean | SD | P-Value |
|---|---|---|---|---|
| Specimen A | 10 | 1.741 | 0.1861 | 0.002* |
| Specimen B | 10 | 1.893 | 0.4019 | |
| Specimen C | 10 | 1.383 | 0.2397 | |
| Total | 30 | 1.672 | 0.3550 | |

INFERENCE: The mean value for Test No.3 of Specimen A was 1.74N, Specimen B was 1.89N and Specimen C was 1.38N. On comparison between Specimen A, Specimen B and Specimen C the results were found to be statistically significant (P-value 0.002).

**Table 10: Test for significance between specimens for Test No.3 (Independent Samples Student T-Test)**

| | N | Mean | SD | P-Value |
|---|---|---|---|---|
| Specimen A | 10 | 1.741 | 0.1861 | 0.292 |
| Specimen B | 10 | 1.893 | 0.4019 | |
| Specimen A | 10 | 1.741 | 0.1861 | 0.002* |
| Specimen C | 10 | 1.383 | 0.2397 | |
| Specimen B | 10 | 1.893 | 0.4019 | 0.003* |
| Specimen C | 10 | 1.383 | 0.2397 | |

INFERENCE: The mean value for Test No.3 of Specimen A was 1.74N, Specimen B was 1.89N and Specimen C was 1.38N. On comparison between Specimen A and Specimen B the results were found to be statistically insignificant(P-value 0.292). On comparison between Specimen A and Specimen C the results were found to be statistically significant (P-value 0.002). On comparison between Specimen B and Specimen C the results were found to be statistically significant (P-value 0.003).

**Table 11: Test for significance within specimen A for the three tests (One way Anova)**

| | N | Mean | SD | P-Value |
|---|---|---|---|---|
| Test No.1 | 10 | 3.7040 | 0.31181 | <0.001** |
| Test No.2 | 10 | 1.9690 | 0.10671 | |
| Test No.3 | 10 | 1.7410 | 0.18610 | |
| Total | 30 | 2.4713 | 0.91616 | |

INFERENCE: On comparison between the mean values of Test No.1 Test No.2 and Test No.3 for Specimen A, the results were found to be statistically highly significant (P-value<0.001).

**Table 12: Test for significance within specimen A for the three tests (Independent Samples Student T-Test)**

| | N | Mean | SD | P-Value |
|---|---|---|---|---|
| Test No.1 | 10 | 3.7040 | 0.31181 | <0.001** |
| Test No.2 | 10 | 1.9690 | 0.10671 | |
| Test No.1 | 10 | 3.7040 | 0.31181 | <0.001** |
| Test No.3 | 10 | 1.7410 | 0.18610 | |
| Test No.2 | 10 | 1.9690 | 0.10671 | 0.003* |
| Test No.3 | 10 | 1.7410 | 0.18610 | |

INFERENCE: On comparison between the mean values of Test No.1 and Test No.2 for Specimen A, the results were found to be statistically highly significant (P-value<0.001). On comparison between the mean values of Test No.1and Test No.3 for Specimen A, the results were found to be statistically highly significant (P-value<0.001). On comparison between the mean values of Test No.2 and Test No.3 for Specimen A, the results were found to be statistically significant (P-value 0.003).

**Table 13: Test for significance within specimen B for the three tests (One way Anova)**

| | N | Mean | SD | P-Value |
|---|---|---|---|---|
| Test No.1 | 10 | 3.7900 | 0.37202 | <0.001** |
| Test No.2 | 10 | 1.7400 | 0.26136 | |
| Test No.3 | 10 | 1.8930 | 0.40194 | |
| Total | 30 | 2.4743 | 1.00681 | |

INFERENCE: On comparison between the mean values of Test No.1, Test No.2 and Test No.3 for Specimen B, the results were found to be statistically highly significant (P-value<0.001).

**Table 14: Test for significance within specimen B for the three tests (Independent Samples Student T-Test)**

| | N | Mean | SD | P-Value |
|---|---|---|---|---|
| Test No.1 | 10 | 3.7900 | 0.37202 | <0.001** |
| Test No.2 | 10 | 1.7400 | 0.26136 | |
| Test No.1 | 10 | 3.7900 | 0.37202 | <0.001** |
| Test No.3 | 10 | 1.8930 | 0.40194 | |
| Test No.2 | 10 | 1.7400 | 0.26136 | 0.326 |
| Test No.3 | 10 | 1.8930 | 0.40194 | |

INFERENCE: On comparison between the mean values of Test No.1 and Test No.2 for Specimen B, the results were found to be statistically highly significant (P-value<0.001). On comparison between the mean values of Test No.1and Test No.3 for Specimen B, the results were found to be statistically highly significant (P-value<0.001). On comparison between the mean values of Test No.2 and Test No.3for Specimen B, the results were found to be statistically insignificant (P-value 0.326).

**Table 15: Test for significance within specimen C for the three tests (One way Anova)**

| | N | Mean | SD | P-Value |
|---|---|---|---|---|
| Test No.1 | 10 | 2.1010 | 0.14640 | <0.001** |
| Test No.2 | 10 | 1.1200 | 0.17049 | |
| Test No.3 | 10 | 1.3830 | 0.23968 | |
| Total | 30 | 1.5347 | 0.45970 | |

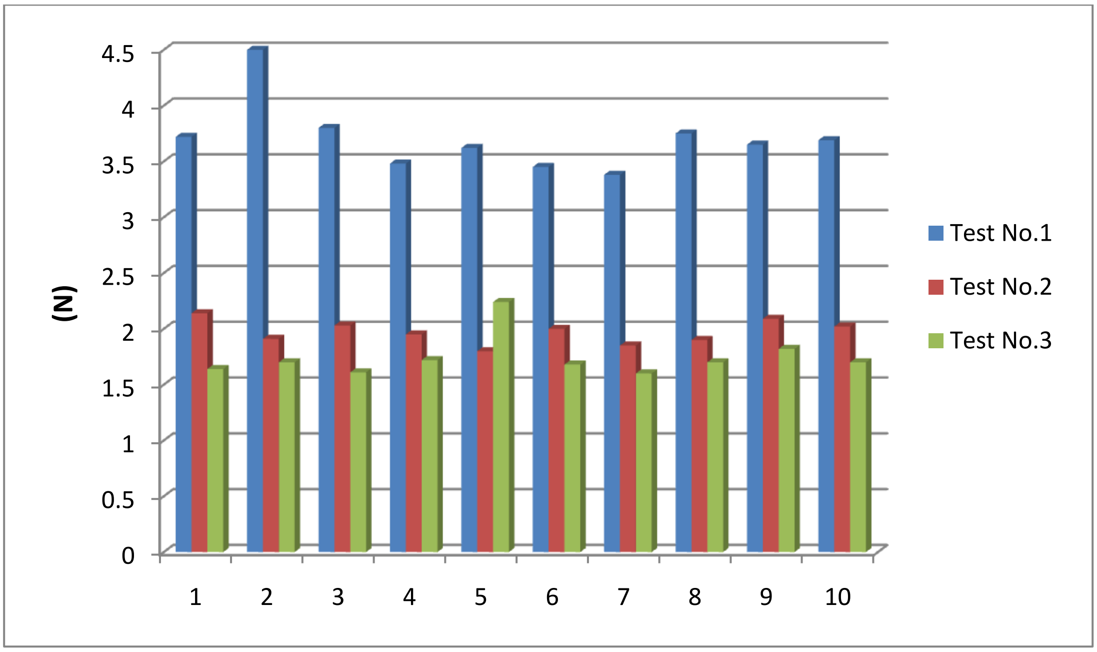
INFERENCE: On comparison between the mean values of Test No.1, Test No.2 and Test No.3 for Specimen C, the results were found to be statistically highly significant (P-value<0.001).

**Table 16: Test for significance within specimen C for the three tests (Independent Samples Student T-Test)**

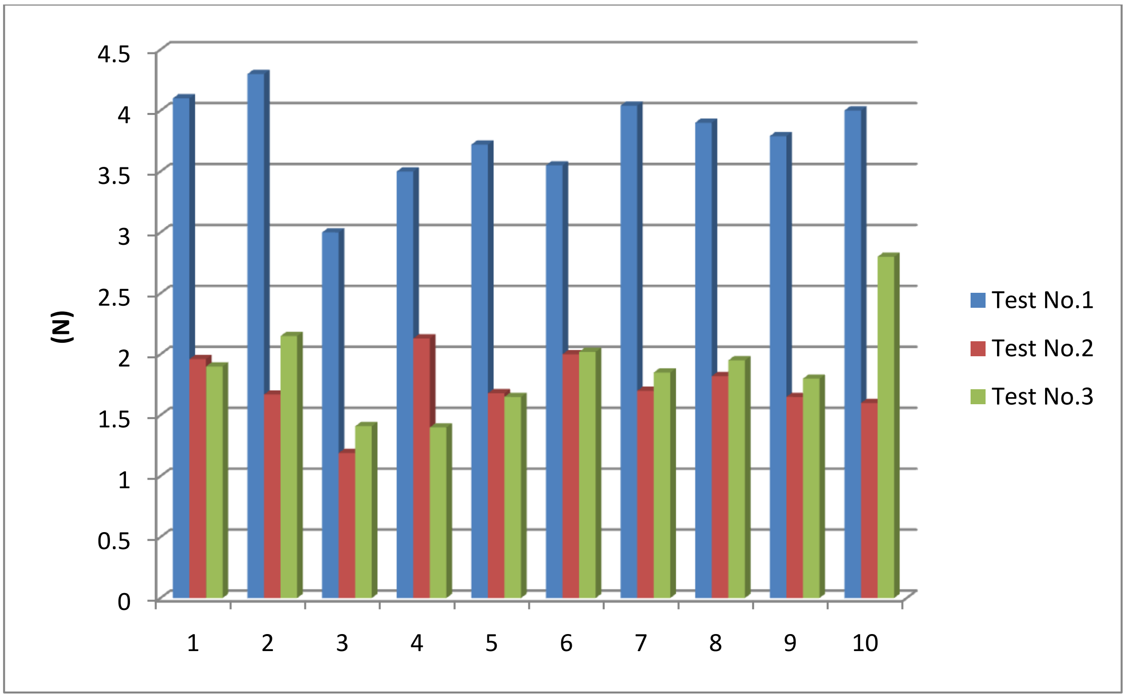
| | N | Mean | SD | P-Value |
|---|---|---|---|---|
| Test No.1 | 10 | 2.1010 | 0.14640 | <0.001** |
| Test No.2 | 10 | 1.1200 | 0.17049 | |
| Test No.1 | 10 | 2.1010 | 0.14640 | <0.001** |
| Test No.3 | 10 | 1.3830 | 0.23968 | |
| Test No.2 | 10 | 1.1200 | 0.17049 | 0.011* |
| Test No.3 | 10 | 1.3830 | 0.23968 | |

INFERENCE: On comparison between the mean values of Test No.1 and Test No.2 for Specimen C, the results were found to be statistically highly significant (P-value<0.001). On comparison between the mean values of Test No.1and Test No.3 for Specimen C, the results were found to be statistically highly significant (P-value<0.001). On comparison between the mean values of Test No.2 and Test No.3 for Specimen C, the results were found to be statistically significant (P-value 0.011).

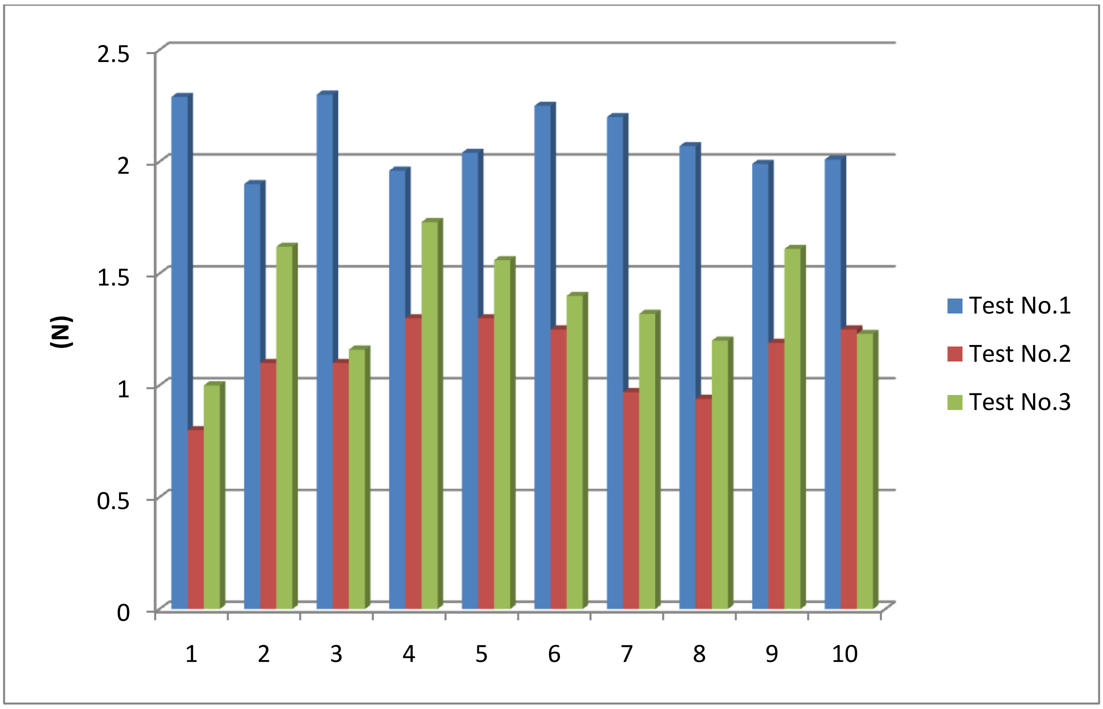
**Graph 1: Basic values (N) of the test specimen A for the three different tests**



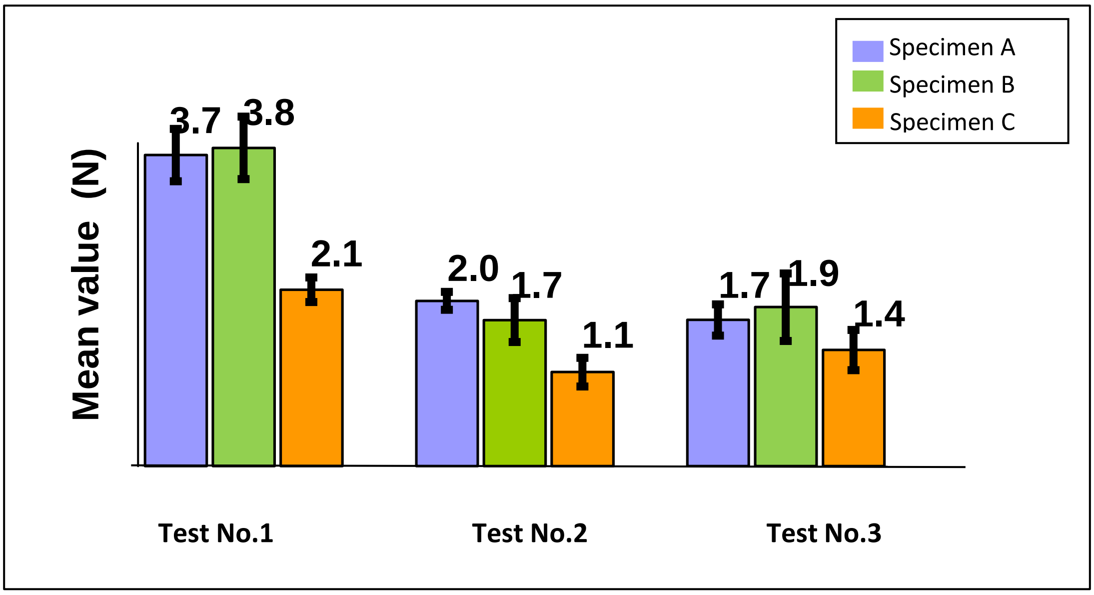

**Graph 2 : Basic values (N) of the test specimen B for the three different tests**



**Graph 3 : Basic values (N) of the test specimen C for the three different tests**

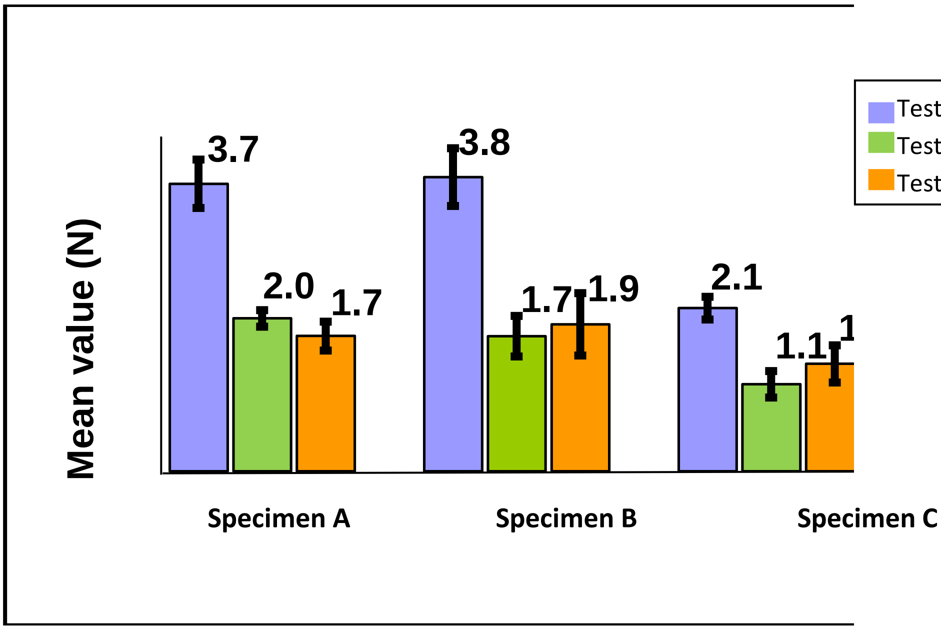


**Graph 4: Mean value (N) and Standard Deviation of the test specimens for the three different tests**




I Standard Deviation

**Graph 5: Mean value (N) and Standard Deviation of the three different tests within the test specimens**




I Standard Deviation

# DISCUSSION

Certain mechanical, biological and physical factors determine the retention, stability and support of the prosthesis, which inturn influence the success of the treatment. Both retention and stability are influenced by ridge height and surface area. In situations of long standing edentulousness there is usually a reduction in ridge height and surface area, which in turn affects the retention and stability. 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. This reduction in retention and stability is more commonly seen in mandibular denture than the maxillary denture. Numerous methods like magnets implanted in the jaw, incorporation of neutral zone concept in denture construction and denture adhesives have been reported in the dental literature to improve the retention and stability. Attachment systems have been historically employed as a means of improving the retention and stability of tooth supported overdentures in edentulous or nearly edentulous arches. Attachments like a ball or a bar connected to dental implants have also been used to improve the retention and stability of the denture in patients with atrophic mandible. Recent literature has also advocated the use of magnetic attachment to retain an overdenture.[3,12,27,28,35]

Magnetic attachments are becoming increasingly popular due to their small size and strong attractive forces and are being reported in the literature for retention of mandibular overdentures. The advantages of magnetic attachment include ease of cleansing, ease of placement, constant retention irrespective of the number of times the denture is removed and seated back, as well as self seating property. Despite their many advantages magnet have certain limitation. They have poor corrosion resistance therefore require encapsulation with inert alloys such as stainless steel or titanium. Studies have shown that magnets have less retention and stability values than ball or stud attachments. But according to Becker and Korber retention forces from 3.5 to 7 N should suffice to retain an overdenture by attachments. According to Botega the retention force of more than 3N has been shown to be adequate for denture retention. Although magnets have less retention and stability as compared to stud and bar attachments they have certain advantage over these attachments. When considering the horizontal component of oblique forces one can say that what is good for implant-retained overdenture prosthesis is not necessarily beneficial for the health of the implant, because implants well tolerate vertically directed forces but do not tolerate horizontally directed forces. Thus in situations where lateral forces are already present like in patients with para functional activity there is always a possibility of damage to the implant. In such situations studies have suggested an attachment like magnet with lesser retention. Such attachments detach from the implants easily whenever there is a lateral force exceeding the retentive ability of the implant and thereby deliver only less force to the implant. Hence a less retentive attachment such as a magnet may be preferred. The locator and ball attachment have high distortion of the retentive elements which would happen during dislodgement. Also this specimen of attachments systems may need adjustment of short service period. Similarly an attachment of lesser retention may be desirable in patients with dexterity problems who may have difficulty inserting and removing the overdenture. The self seating property of the magnets also helps in these circumstances. Therefore under specific circumstances matching the retentive characteristics of the attachment system to the physical conditions and needs of the patient may be an important treatment planning consideration and critical to restorative success. [8,41]

With regard to the number of implants required for retention of mandibular overdentures there is a consensus that two implants in the interforaminal region of the mandible is sufficient. These 2 implants are preferably placed in the B and D positions corresponding to the canine position due to the abundance of bone and the location which prevents the rocking of the restoration. On the other hand when it comes to placing two implants in the mandible, placing two implants in the mandible corresponding to the first premolar on either side ( A & E position) can also be a viable option. But placement of implants in these positions alone to retain a mandibular denture has never been advocated. Literature reveals that the magnitude of rocking and rotation of prosthesis is more when two implants are placed in the A & E position than when implants are placed in the B & D position. But as discussed previously the ability of the magnet to detach when excessive lateral forces are generated opens up the alternate option of using implants in A & E position with magnetic attachments, when placement of implants in B& D position is not feasible. So, in this present study magnetic attachment on implants placed in the A & E position was taken up as one of the study specimens.[3,26]

Studies which have compared the effect of inter-implant distance on the retention ability of attachments have concluded that an increase in inter-implant distance can provide better retentive values. The inter implant distance when implants are placed in B & D position is approximately 22mm. When implants are placed in A & E position, the distance can go upto 29mm. Hence, while using magnets as attachment for a mandibular overdenture placing implants in A & E position would be beneficial in terms of obtaining better retention because of an increase in interimplant distance and thereby helps in overcoming the disadvantage of less retention with magnetic attachments.[25]

While mandibular overdenture with two implants has been popularly advocated, the cost factor has been a major hindrance in reaching out this option to patients in developing countries. With the aim of reducing the treatment cost as well as the duration, mandibular overdenture supported by a single implant in the midline has been reported in recent literatures. These studies have reported adequate retention, stability and patient satisfaction with overdenture retained by one implant.[2,3,42]

Many studies have reported excellent retention while using a ball or a locator attachment with one implant placed in the midline of the mandible, but have failed to address the issue of increased lateral load on the implant which might be higher when only one implant is employed. As discussed previously, a magnetic attachment in such a situation can be highly beneficial. Hence in this present study a test specimen with mandibular overdenture retained by magnetic attachment on a single implant was included in this study.[2]

There are very few studies that have evaluated the retention and stability of a mandibular overdenture retained by magnet placed on one implant. Similarly, reports comparing the retention of magnetically retained mandibular overdenture placed on two implants in B & D position with two implants in A & E position and also with a single implant are very few. Considering the above factors the present in vitro study was taken up to comparatively evaluate the effect of number of implants and location of implants in retention and stability of magnetically retained overdenture.

The methodology carried was similar to the fabrication of a denture in a clinical practice. A reference denture was fabricated and this denture was used a guide to position implant replicas in the wax model obtained from a mandibular edentulous model former. The wax model was placed on a dental surveyor and it was ensured that the Implant replicas were placed perpendicular to the occlusal plane. The implant replicas were submerged such that the surface of implant replica was 2mm from the crest of ridge on the wax model. This was done to mimic the presence of 2mm thick soft tissue over the implant placed at the bone level. This wax model was processed in heat cure denture base resin and used as a test model for the procedure. The test model was then duplicated with poly vinyl siloxane impression material, in which a stone cast was prepared. This stone cast was used in the fabrication of a test denture. After the test denture was processed the magnetic attachment was incorporated into the denture and the test model as per the manufacturer’s instructions.

Three metal hooks were attached to the denture. One hook was attached in the anterior lingual surface corresponding to the midline. Two hooks were attached in the posterior retromolar region, one on each side. The model with the denture was positioned in a universal testing machine and testing was done. The in vitro study was performed in a isolated dry environment which permitted the evaluation of the magnetic attachment's efficacy irrespective of other retentive determinants. A pulling force was applied on the denture with a cross head speed of 50mm/min. This speed was used as it approximates with removal of denture from the mouth. The load at which the dentures detached from the model was the considered as the dislodging force and it was recorded in Newtons (N). Each test denture was subjected to three tests.[12]

Test No.1 was done to evaluate effect of Vertical directed dislodging forces. In this test all the three chains were attached to the Instron machine and the test was conducted. Test No.2 was conducted to evaluate the effect of oblique rotational dislodging forces. For this test, only the chains attached to the posterior hook on the left side and the hook in the anterior midline was attached to the loading cell of the testing machine. Test No.3 was conducted to evaluate the effect of posterior rotational dislodging forces. For this test, only the chains attached to the two hooks on the posterior aspect of the denture was attached to the loading cell of the testing machine. Test No.1 evaluated the retention by the retentive force of the attachment. Test No.2 and Test No.3 recorded the retentive force of the attachment under paraxial dislodging forces which was considered to be a measurement of the stability of the denture.

The mean value and standard deviation was calculated for the three specimens. One way Anova and Independent samples students T Test was employed for the comparison of the retention and stability values of the magnetic attachment under the three different tests and for comparison within specimens. Statistical significance was evaluated at a significance level 5% ($P<0.05$).

The results obtained from the specimen A showed a mean value of 3.7 N for Test No.1, 1.96N for Test No.2 and 1.74N for Test No.3. Similarly the results obtained from the specimen B samples showed a mean value of 3.79N for Test No.1, 1.74N for Test No.2 and 1.89 N for Test No.3. Similarly the results obtained from the specimen C showed a mean value of 2.1N for Test No.1, 1.12N for test No.2 and 1.38N for Test No.3.

On comparing the ability of the three specimens to resist vertically directed dislodging forces, it was evident that the specimen B sample had a higher mean value than the specimen A and specimen C. The difference between specimen A and specimen B was statistically insignificant whereas the difference between specimen A and specimen C and specimen B and specimen C was statistically significant.

A retentive force of 3N force has been recommended and reported as a minimum to be possessed by an attachment to be effective. The results of the present study shows that the specimen A and B samples have a retentive force more than this recommended value suggesting that placing implants in either of these position provides adequate retention. The marginally higher value obtained for the specimen B sample could be because of the increase in the interimplant distance which has been reported in a study by Michelinakis as a contributing factor in providing better retention. Chung et al in a study comparing the retentive characteristics of various attachments has reported similar retention values for magnets.[8,12, 25]

Comparison of the values of specimen A and specimen B has been found to be statistically insignificant, therefore the change in location of the implants from B & D and A & E does not affect the retention. On the other hand the comparing retentive value of the specimen C with specimen A and specimen C and specimen B has been found to be statistically highly significant which suggests that reducing the number of implants from two to one definitely affects the retention.

Wahab in a study evaluating the stability of implant retained mandibular overdenture retained by magnets on two implants, reported a value of 1.93N for oblique rotational dislodging forces. In a similar study Sadig reported a value of 1.82N for oblique rotational dislodging force. Rutkanas in a study evaluating the stability of implant retained mandibular overdenture retained by magnets on two implants and reported a value of 1.9N for oblique rotational dislodging forces. The values obtained in this present study for specimen A and specimen B fall in a similar range to those obtained in these previous studies. But the values of specimen C were lower than the values obtained from the previous study. Comparison of the values of specimen A and specimen B has been found to be statistically significant, therefore the change in location of the implants from B & D and A & E affect the resistance to oblique dislodging force of the prosthesis. On the other hand comparing the value of the specimen C with specimen A and specimen B, it has been found to be statistically highly significant which suggests that reducing the number of implants from two to one definitely affects the stability. The values obtained in this present study for specimen A and specimen B fall in a similar range to those obtained in these previous studies and the values of specimen C were lower than the values obtained from the previous study.[35,36,42]

On comparing the ability of the three specimens to resist posterior rotational dislodging forces, it was evident that the specimen B had a higher mean value than the specimen A and specimen C. The difference between specimen A and specimen B was statistically insignificant whereas the difference between specimen A and specimen C and specimen B and specimen C was statistically significant. Therefore the change in location of the implants from B & D and A & E does not affect the resistance to posterior rotational dislodging forces. But reducing the number of implants from two to one definitely affects the ability to resist posterior rotational dislodging forces and thereby the stability. The results obtained match those reported in literature.

Rutkanas in his study evaluating the retentive and stabilising quality of magnets retaining mandibular overdentures observed that the dislodging force values decreased in the following order Linear > Lateral > Posterior. In the present study on comparative evaluation of the results of Test No.1, Test No.2 and Test No.3 of the specimen A, it was seen that the resistance to vertically directed force was more, suggesting that implants in the B and D location resist vertically directed force better than the oblique rotational force and posterior rotational dislodging force. The results of specimen A of the present study are in line with that of Rutkanas study. On comparative evaluation of the results of Test No.1, Test No.2 and Test No.3 of the specimen B sample it was seen that the resistance to vertically directed force was more, followed by posterior rotational force and oblique rotational force. On comparative evaluation of the results of Test No.1, Test No.2 and Test No.3 of the specimen C sample, it was seen that the resistance to vertically directed force was more, followed by posterior rotational force and oblique rotational force. [34,35]

Even though mandibular overdenture retained by a single implant has lesser retention and stability, it can be still considered in patients with dexterity problems having difficulty in inserting and removing the overdenture. The reduced treatment cost is also a important factor in selecting this treatment option. It is well accepted that in vivo performance does differ from in vitro setting. This in vitro study did not consider the effects of variable fluid environments, multidirectional force application and effect of fatigue on the test specimen. The testing conducted was directed at limited, specific, and expected mechanical conditions and this in vitro protocol falls short of clinical reality. The above factors should be taken into account in the future studies. More studies to evaluate subjectively the outcome of such a treatment option by studying the masticatory efficiency and masticatory performance is necessary.

# CONCLUSION

The following conclusions were drawn from the results obtained in the present in vitro study conducted to comparatively evaluate the effect of location and number of implants on the retention and stability of magnetically retained implant supported mandibular overdenture.

1. The mean value of specimen A (two implant replicas in B and D position) under vertically directed dislodging forces was found to be 3.7N.
2. The mean value of specimen B (two implant replicas in A and E position) under vertically directed dislodging forces was found to be 3.79N.
3. The mean value of specimen C (one implant replica in C position) under vertically directed dislodging forces was found to be 2.1N.
4. On comparison of the results of vertically directed dislodging forces between the specimen A and specimen B, the specimen B had a higher retentive force but the difference was found to be statistically insignificant as suggested by the P-value 0.582. On comparison of the results of vertically directed dislodging forces between the specimen A and C, the specimen A had higher retentive force and the difference was found to be statistically highly significant as suggested by the P-value 0.001. On comparison of the results of vertically directed dislodging forces between the specimen B and C, the specimen B had higher retentive force and the difference was found to be statistically highly significant as suggested by the P-value 0.001.

5. The mean value of specimen A under obliquely rotational dislodging forces was found to be 1.96N.
6. The mean value of specimen B under obliquely rotational dislodging forces was found to be 1.74N.
7. The mean value of specimen C under obliquely rotational dislodging forces was found to be 1.61N.
8. On comparison of the results of obliquely rotational dislodging forces between the specimen A and B, the specimen A had a higher ability to resist oblique forces and the difference was found to be statistically significant as suggested by the P-value 0.019. On comparison of oblique rotational dislodging forces between the specimen A and C, the specimen A had a higher ability to resist oblique forces and the difference was found to be statistically highly significant as suggested by the P-value 0.001. On comparison of oblique rotational dislodging forces between the specimen B and C, the specimen B had a higher ability to resist oblique rotational dislodging forces and the difference was found to be statistically highly significant as suggested by the P-value 0.001.
9. The mean value of specimen A under posterior rotational dislodging forces was found to be 1.74N.
10. The mean value of specimen B under posterior rotational dislodging forces was found to be 1.89N.
11. The mean value of specimen C under posterior rotational dislodging forces was found to be 1.38N.

12. On comparison of the results of posterior rotational dislodging forces between the specimen A and B, the specimen B had a higher ability to resist posterior rotational forces and the difference was found to be statistically insignificant as suggested by the P-value 0.292. On comparison of posterior rotational dislodging forces between the specimen A and C, the specimen A had a higher ability to resist posterior rotational forces and the difference was found to be statistically significant as suggested by the P-value 0.002. On comparison of posterior rotational dislodging forces between the specimen B and C, the specimen B had a higher ability to resist posterior rotational forces and the difference was found to be statistically highly significant as suggested by the P-value 0.003.
13. On comparative evaluation of the results of Test No.1, Test No.2 and Test No.3 of the specimen A, the results were found to be highly statistically significant (P-value<0.001). On comparison between the mean values of Test No.1 and Test No.2, the results were found to be statistically highly significant (P-value<0.001). On comparison between the mean values of Test No.1and Test No.3, the results were found to be statistically highly significant (P-value<0.001). On comparison between the mean values of Test No.2 and Test No.3, the results were found to be statistically significant (P-value 0.003).
14. On comparative evaluation of the results of Test No.1, Test No.2 and Test No.3 of the specimen B, the results were found to be statistically highly

significant.(P-value<0.001). On comparison between the mean values of Test No.1 and Test No.2, the results were found to be statistically highly significant.(P-value<0.001). On comparison between the mean values of Test No.1and Test No.3, the results were found to be statistically highly significant (P-value<0.001). On comparison between the mean values of Test No.2 and Test No.3, the results were found to be statistically insignificant (P-value 0.326).

15. On comparative evaluation of the results of Test No.1, Test No.2 and Test No.3 of the specimen C, the results were found to be statistically highly significant (P-value<0.001). On comparison between the mean values of Test No.1 and Test No.2, the results were found to be statistically highly significant (P-value<0.001). On comparison between the mean values of Test No.1and Test No.3, the results were found to be statistically highly significant (P-value<0.001). On comparison between the mean values of Test No.2 and Test No.3, the results were found to be statistically significant (P-value 0.011).

# SUMMARY

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

A mandibular reference denture was fabricated on a mandibular edentulous model. It was used to position the implant replicas in the three wax models obtained from a lower edentulous model former. The wax models were processed to obtain three acrylic test models with the implant replicas incorporated in them. All the three acrylic models were duplicated to obtain stone casts on each of which a mandibular test denture was fabricated respectively. The components of the magnetic attachments were incorporated into the acrylic test models and the test dentures. Each acrylic model with the test denture represented one test specimen. Specimen A comprised of a mandibular test denture with the magnetic attachment system connected to the implant replicas placed in the B and D position in the mandibular edentulous acrylic model. Specimen B comprised of a mandibular test denture with the magnetic attachment system connected to the implant replicas placed in the A and E position in the mandibular edentulous acrylic model. Specimen C comprised of a mandibular test denture with the magnetic attachment system connected to the implant replica placed in the C position in the mandibular edentulous acrylic model.

The three test models with the test dentures were subjected to the tests for retention and stability in an universal testing machine by application of a pulling force with a cross head speed of 50mm/min. The load at which the denture

detached from the model was considered as the dislodging force and it was recorded in Newtons. 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 results of the study showed that for the Test No.1 the specimen B had the highest values followed by specimen A and specimen C. On comparison between the specimens it was shown that there was no statistically significant difference between specimen A and specimen B and a statistically significant difference between specimen B and specimen C and also between specimen A and specimen C. For Test No.2 the specimen A had the highest values followed by specimen B and specimen C. On comparison between the specimens it was shown that there was statistically significant difference between all the three specimens. For Test No.3 the specimen B had the highest values followed by specimen A and specimen C. On comparison between the specimens it was shown that there was no statistically significant difference between specimen A and specimen B and a statistically significant difference between specimen A and specimen C and also between specimen B and specimen C.

Specimen A samples had highest values for Test No.1 followed by Test No.2 and Test No.3. Specimen B samples had highest values for Test No.1 followed by Test No.3 and Test No.2. Specimen C samples had highest values for Test No.1 followed by Test No.3 and Test No.2. On comparison within Specimens it was seen that there was a statistical significance difference between the results of all three tests in all the three specimen except between Test No.2 and Test No.3 of Specimen B.

The present study concluded that the change of location of implants from B and D to A and E position did not significantly affect the retention and stability of the overdenture, with respect to the vertically directed dislodging forces and posterior rotational dislodging forces. Whereas the retention and stability significantly decreases with respect to oblique rotational forces. The mandibular overdenture with magnetic attachment over a single implant has the least retention and stability. Even though the retention and stability of the mandibular overdenture with a single implant in the midline was the least, it can still be considered as an amenable option for edentulous patients of lower socio-economic status. It can also be considered as an option in elderly patients with atrophic mandible in whom extensive surgery is not feasible. This option can also improve satisfaction with complete dentures in patients with adaptive disorders.

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