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Comparative Evaluation of Wettability of Conventional Vs Cad/Cam Denture Base Resins

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Abstract:

Introduction:

In edentulous patients, the replacement of lost teeth and tissues with a complete denture to obtain an acceptable esthetic and function seems to be a challenge for the dentist.The success of a complete denture is based on the degree of retention and stability of the prosthesis.

Aim:

The aim of the study was to compare the wetting properties of conventional and CAD/CAM bases denture base resins by artificial saliva substitute by using contact angle measurements.

Method:

Three denture base materials were selected: CAD/CAM denture base material (Group A - Milled resin, Group B - 3D printed resin) and BPS (Group C) denture material. A total of 30 samples were used for each group in the study. The advancing and receding contact angles with artificial saliva (experiment group) and distilled water (control group) were measured with a goniometer. The contact angle hysteresis was also calculated from the advancing and receding contact angles values.

Result:

The comparison of means of each type of angle showed statistically significant difference across the groups ($p<0.05$) using one-way ANOVA. The advancing angle of Group A (80.311 ± 3.004) is higher followed by Group C (76.583 ± 3.376) and Group B (74.464 ± 3.265). Similarly, the receding angle was found to be higher in Group A (64.747 ± 3.1113), followed by Group C (58.978 ± 2.270) and Group B (52.569 ± 1.709). The advancing angle with distilled water was high in Group A (81.222 ± 4.571), then Group C (77.651 ± 3.334) and Group B (75.755 ± 3.157). Group A had the highest receding angle (61.275 ± 2.605) with distilled water followed by Group C (55.948 ± 2.656) and Group B (50.231 ± 1.719).

Tukey's post hoc test revealed that the multiple comparisons of advancing angles and receding angle of artificial saliva and distilled water between the groups to be statistically significant expect in milled vs BPS (Biofunctional Prosthetic System)

Conclusion:

The contact angle of hysteresis of 3D printed denture base resins was higher, followed by the BPS heat cure resins and the milled resin. The wettability was found to be higher in distilled water than the artificial saliva. When compared between the groups, all the groups showed significant results except milled and printed.

Keywords: Denture,contact angle,resin,CAD CAM

Introduction:

In edentulous patients, the replacement of lost teeth and tissues with a complete denture to obtain an acceptable esthetic and function seems to be a challenge for the dentist.[1] The success of a complete denture is based on the degree of retention

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and stability of the prosthesis.[2] Retention is defined as "that quality inherent in the dental prosthesis acting to resist the forces of dislodgement along the path of placement" (GPT-8). In simple terms, it is the resistance to removal. Retention is influenced by a number of factors such as physical, physiological, surgical and mechanical in nature.[3–5] The physical forces include adhesion, cohesion, surface tension, capillarity viscosity and atmospheric pressure.[6][7]The wetting capacity of a liquid is determined by its tendency to spread on the surface of a solid and it can be studied by measuring the contact angles formed between them. The extent to which an adhesive will wet a surface is based on the shape of the irregularities on the surface of adherend, viscosity of the adhesive and the contact angle at which the adhesive meets the adherend surface.[8] The lower the contact angle, the better is the wettability on the surface. When the contact angle is zero, complete wetting occurs.[9] The angle that a liquid drop forms on a dry solid surface is the advancing contact angle. When the liquid recedes on the previously wet surface, receding contact angle is formed.[10] The basic requirement for retention is the contact angle hysteresis, which is the difference between the advancing liquid–solid contact angle and the receding contact angle.

The wetting properties of denture base materials to saliva, therefore, plays an important role in the retention of dentures. However in conditions like xerostomia which is characterized by significantly decreased salivary flow, can affect retention and cause discomfort while wearing the denture. Xerostomia is common in systemic conditions like Parkinson's disease, salivary gland hypofunction, Sjogren's syndrome, or side effects of drug therapies that use antihistamines, diuretics, antihypertensives, etc.[11][12] Altered salivary flow rates usually cause difficulty in eating and swallowing, angular cheilitis and dry or burning tongue. Dry mouth is associated with alteration of taste, fissuring of the tongue, epithelial atrophy, irritation to the oral mucosa and ulceration. Salivary substitutes have been advocated as a replacement therapy in such conditions and should possess adequate wetting on the denture base.

Since its introduction in 1937, conventional heat polymerized poly methyl methacrylate denture base resin has been the material of choice for denture fabrication and then came the BPS (Biofunctional Prosthetic System) were dentures were fabricated using injection moulding technique. But, over the years CAD/CAM technology has a wide range of applications in dentistry due to its advanced acquisition and production capability.[13][14] Milled and 3D printed dentures have become an alternative to conventional methods in the fabrication of complete dentures. There are various studies that compare the wettability of different types of conventional denture base materials. However, scientific data regarding the wettability of digital denture base resins with artificial salivary substitutes are sparse. With the previous experiment of research [15–21]The purpose of this in vitro study was to compare the wetting properties of conventional and CAD/CAM bases denture base resins by artificial saliva substitute by using contact angle measurements.

Materials And Methodology:

In the present study, the wettability of CAD/CAM denture base material (Group A - Milled resin, Group B - 3D printed resin) were compared with BPS (Group C) denture base material (Table 1).

Denture base sample preparation:

A total of 30 samples were used for each group in the study. All the samples were designed at a dimension of 25mm x 10mm x 3mm through a Computer Aided Design (CAD) program, (Meshmixer: Autodesk REsearch). A Standard Tessellation Language (STL) file was created and exported to the milling machine (imes-icore CORiTEC 150i Series) to mill the sample in the denture base blank (Ivotion Upper Monolithic Digital Denture Disc) (Group A) (Figure 1). For Group B, the same STL file was exported to a print preparation software, PreForm (Formlabs). Supports were added to the bars and oriented in such a way that the samples are on top of the bar parallel to the platform of the 3D printer. The STL file was then exported to the 3D printer to print the samples (Figure 2). The 3D printed samples went through the manufacturers recommended post curing processing; washed for 5 minutes in 96% isopropyl alcohol followed by photo curing for 30 minutes at 80 C in 100% pure vegetable glycerin (Form Cure; Formlabs). All the supports were then cut from the sample. To fabricate Group C samples, the same STL file was used to mill wax patterns, which acted as a template to fabricate the heat cure samples. The wax patterns were invested in the flask and were fabricated by injection moulding technique using the manufacturer's instructions. Figure 3 shows all the samples used for the study.

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Goniometer and Contact angle measurement:

The surface wettability of the prepared samples were evaluated using the Telescopic Goniometer, Kernco Model No:G II (Kerno Instrument Co, Texas ,USA) by determining the contact angle. The instrument is equipped with a special photo micrographic camera attachment, which helps to record the observed data. To measure the wettability of denture base materials, the prepared and properly cleaned sample was placed on the mechanical stage of the contact angle goniometer (Ossila) (Figure 4). A small drop of a CMC-based artificial saliva substitute (Aqwet; Cipla) was placed on the surface of the sample using microburette and the contact angle measured initially is the Advancing Contact Angle (ϴA). A standardised jig was fabricated and used to check the receding angle. Once the drop reaches its equilibrium, it starts receding i.e., Receding Contact Angle (ϴR) (Figure 5). Both the contact angles were measured directly. Contact Angle Hysteresis was determined by calculating the difference between the Advancing Contact Angle (ϴA), and the Receding Contact Angle (ϴR)[22][23]

Contact Angle Hysteresis = (ϴA) - (ϴR)

The same procedure was repeated with distilled water (control group).

Statistical analysis:

Descriptive statistics for the advancing contact angle, receding angle, and contact angle hysteresis were determined for control (distilled water) and experimental (Aqwet) groups with a statistical software program (IBM SPSS Statistics, v20.0; IBM Corp). One-way ANOVA was used to determine the statistical significance of difference in the mean values of parameters across the 3 groups and to verify the significant difference in a pair of groups, "Tukey's post hoc multiple comparison test" was used.

Results:

The comparison of means of each type of angle showed statistically significant difference across the groups ($p<0.05$) using one-way ANOVA (Table 2). It is inferred from this study that the advancing angle of Group A (80.311 ± 3.004) is higher followed by Group C (76.583 ± 3.376) and Group B (74.464 ± 3.265). Similarly, the receding angle was found to be higher in Group A (64.747 ± 3.1113), followed by Group C (58.978 ± 2.270) and Group B (52.569 ± 1.709). The advancing angle with distilled water was high in Group A (81.222 ± 4.571), then Group C (77.651 ± 3.334) and Group B (75.755 ± 3.157). Group A had the highest receding angle (61.275 ± 2.605) with distilled water followed by Group C (55.948 ± 2.656) and Group B (50.231 ± 1.719).

Tukey's post hoc test revealed the multiple comparisons of advancing angles and receding angle of artificial saliva and distilled water between the groups (Table 3).

Discussion:

The current study investigated the wettability of conventional and CAD/CAM denture base material by measuring the contact angle. It was found that the receding contact angles were lesser than the corresponding advancing angles which is similar to the results obtained by Craig et al.[24] They suggested that it resulted from the difference in adhesion between the solid and liquid drop; and the liquid drop and the liquid film, on a previously wetted surface. On the contrary, Monsenego et al reported that the contact angle hysteresis, which is the difference between advancing liquid-solid contact angle and the receding contact angle, is the most important requirement for retention of denture.[10] Zissis et al, suggested that an increased contact angle hysteresis of a fluid indicates increased wettability of the surface of the specimen.[25] Hence, in the present study, the contact angle hysteresis was also calculated to reach more precise inferences and the values were higher for printed denture base material with distilled water followed by artificial saliva. This might be because the pores or crevices on the adherent surface traps the fluid as it flows over the solid surfaces, resulting in a difference between each denture material.[26]

Meirowitz et al in their study reported that the milled resin showed better wettability, followed by conventional heat cured resin and 3D printed resins.[27] It is understood that the resin quality and quality of CAD/CAM milling burrs, or in case of conventional dentures, the quality of the master cast and manufacturing protocol also plays an important role. Each CAD/CAM system has a different milling machine, different milling burrs with a defined cutting geometry and a limited radius of movement. The different performances of the varying burr types and burr types and burr action become apparent only on irregular surfaces, such as denture bases. Steinmassl et al proposed that although most CAD/CAM dentures have smoother and more hydrophilic surfaces than conventional dentures, there is no difference in their free surface energy, exempt for coated dentures.[28] One of the major concerns regarding the milled denture base is the milling groove configuration that increases the risk of biofilm retention and cleanability. Since wettability is associated with microbial adhesion, use of CAD/CAM denture base material will reduce the chances for attracting Candida colonisation.[29]

Conclusion:

The contact angle of hysteresis of 3D printed denture base resins was higher, followed by the BPS heat cure resins and the milled resin. The wettability was found to be higher in distilled water than the artificial saliva. When compared between the groups, all the groups showed significant results except milled and printed. The limitation of the study includes an in vitro set-up. Patient-based study dentures may be the most appropriate specimens for determining the clinical denture base contact angle. The results of this study provide knowledge to the practitioners about the material of choice for patients with reduced salivary flow.

Reference:

1. Battersby BJ, Gehl DH, O'Brien WJ. Effect of an elastic lining on the retention of dentures. J Prosthet Dent. 1968 Dec;20(6):498–500.
2. Kumar MS, Thombare RU. A Comparative Analysis of the Effect of Various Denture Adhesives Available in Market on the Retentive Ability of the Maxillary Denture: An In Vivo Study [Internet]. Vol. 11, The Journal of Indian Prosthodontic Society. 2011. p. 82–8. Available from: http://dx.doi.org/10.1007/s13191-011-0067-8
3. Hardy IR, Kapur KK. Posterior border seal—Its rationale and importance [Internet]. Vol. 8, The Journal of Prosthetic Dentistry. 1958. p. 386–97. Available from: http://dx.doi.org/10.1016/0022-3913(58)90064-7
4. Indhulekha V, Ganapathy D, Jain AR. Knowledge and awareness on biomedical waste management among students of four dental colleges in Chennai, India. Drug Invention Today. 2018;10(12):32–41.
5. Jain AR, Dhanraj M. A clinical review of spacer design for conventional complete denture. Biology and Medicine. 2016;8(5):1.
6. Barbenel JC. Physical retention of complete dentures [Internet]. Vol. 26, The Journal of Prosthetic Dentistry. 1971. p. 592–600. Available from: http://dx.doi.org/10.1016/0022-3913(71)90083-7
7. Monsénégo P, Proust J. Complete denture retention. Part I: Physical analysis of the mechanism. Hysteresis of the solid-liquid contact angle [Internet]. Vol. 62, The Journal of Prosthetic Dentistry. 1989. p. 189–96. Available from: http://dx.doi.org/10.1016/0022-3913(89)90312-0
8. Zisman WA. INFLUENCE OF CONSTITUTION ON ADHESION [Internet]. Vol. 55, Industrial & Engineering Chemistry. 1963. p. 18–38. Available from: http://dx.doi.org/10.1021/ie50646a003
9. Website [Internet]. [cited 2021 Jun 4]. Available from: Sakaguchi RL, Powers JM. Acknowledgments [Internet]. Craig's Restorative Dental Materials. 2012. p. xi. Available from: http://dx.doi.org/10.1016/b978-0-323-08108-5.10022-2
10. Monse´ne´go P, Baszkin A, de Lourdes Costa M, Lejoyeux J. Complete denture retention. Part II: Wettability studies on various acrylic resin denture base materials [Internet]. Vol. 62, The Journal of Prosthetic Dentistry. 1989. p. 308–12. Available from: http://dx.doi.org/10.1016/0022-3913(89)90338-7
11. Duxbury AJ, Thakker NS, Wastell DG. A double-blind cross-over trial of a mucin-containing artificial saliva. Br Dent J. 1989 Feb 25;166(4):115–20.
12. Mendoza AR, Tomlinson MJ. The split denture: a new technique for artificial saliva reservoirs in mandibular dentures. Aust Dent J. 2003 Sep;48(3):190–4.
13. Susic I, Travar M, Susic M. The application of CAD / CAM technology in Dentistry [Internet]. Vol. 200, IOP

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Conference Series: Materials Science and Engineering. 2017. p. 012020. Available from: http://dx.doi.org/10.1088/1757-899x/200/1/012020
14. Baba NZ, Goodacre BJ, Goodacre CJ, Müller F, Wagner S. CAD/CAM Complete Denture Systems and Physical Properties: A Review of the Literature. J Prosthodont. 2021 May;30(S2):113–24.
15. Kushali R, Maiti S, Girija SAS, Jessy P. Evaluation of Microbial Leakage at Implant Abutment Interface for Different Implant Systems: An In Vitro Study. J Long Term Eff Med Implants. 2022;32(2):87–93.
16. Aparna J, Maiti S, Jessy P. Polyether ether ketone - As an alternative biomaterial for Metal Richmond crown-3-dimensional finite element analysis. J Conserv Dent. 2021 Nov;24(6):553–7.
17. Kasabwala H, Maiti S, Ashok V, Sashank K. Data on dental bite materials with stability and displacement under load. Bioinformation. 2020 Dec 31;16(12):1145–51.
18. Agarwal S, Maiti S, Ashok V. Correlation of soft tissue biotype with pink aesthetic score in single full veneer crown. Bioinformation. 2020 Dec 31;16(12):1139–44.
19. Merchant A, Maiti S, Ashok V, Ganapathy DM. Comparative analysis of different impression techniques in relation to single tooth impression. Bioinformation. 2020 Dec 31;16(12):1105–10.
20. Agarwal S, Ashok V, Maiti S. Open- or Closed-Tray Impression Technique in Implant Prosthesis: A Dentist's Perspective. J Long Term Eff Med Implants. 2020;30(3):193–8.
21. Rupawat D, Maiti S, Nallaswamy D, Sivaswamy V. Aesthetic Outcome of Implants in the Anterior Zone after Socket Preservation and Conventional Implant Placement: A Retrospective Study. J Long Term Eff Med Implants. 2020;30(4):233–9.
22. Zissis AJ, Polyzois GL, Jagger RG, Waters MG. Wettability of visible light-curing denture lining materials. Int J Prosthodont. 2001 May;14(3):250–4.
23. Murray MD. Investigation into the wettability of poly(methylmethacrylate) in vivo. J Dent. 1986 Feb;14(1):29–33.
24. Craig RG, Berry GC, Peyton FA. Physical factors related to denture retention [Internet]. Vol. 10, The Journal of Prosthetic Dentistry. 1960. p. 459–67. Available from: http://dx.doi.org/10.1016/0022-3913(60)90009-3
25. Zissis AJ, Polyzois GL, Yannikakis SA, Harrison A. Roughness of denture materials: a comparative study. Int J Prosthodont. 2000 Mar;13(2):136–40.
26. Kilani BHZ, Retief DH, Guldag MV, Castleberry DJ, Fischer TE. Wettability of selected denture base materials [Internet]. Vol. 52, The Journal of Prosthetic Dentistry. 1984. p. 288–91. Available from: http://dx.doi.org/10.1016/0022-3913(84)90114-8
27. Meirowitz A, Rahmanov A, Shlomo E, Zelikman H, Dolev E, Sterer N. Effect of Denture Base Fabrication Technique on Candida albicans Adhesion In Vitro [Internet]. Vol. 14, Materials. 2021. p. 221. Available from: http://dx.doi.org/10.3390/ma14010221
28. Steinmassl O, Dumfahrt H, Grunert I, Steinmassl PA. Influence of CAD/CAM fabrication on denture surface properties. J Oral Rehabil. 2018 May;45(5):406–13.
29. de Oliveira E, de Figueiredo EZ, Spohr AM, Grossi ML. Properties of Acrylic Resin For CAD/CAM: A Systematic Review and Meta-Analysis of In Vitro Studies. J Prosthodont [Internet]. 2021 May 25; Available from: http://dx.doi.org/10.1111/jopr.13394

Table 1: Groups included in the study.

GROUPS	MATERIALS	TYPE OF PROCESSING	MANUFACTURE
A	Pre Polymerized Methyl Methacrylate (PMMA)	Dry milling	Ivoclar Vivadent
B	Methacrylate-based photopolymerized resin	3D printing	Dentca 3D printing denture resin
C	BPS	Heat cured Injection moulding	Ivoclar Vivadent

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Table 2: Descriptive statistics for contact angle values for 3 denture base materials using artificial saliva and distilled water (ANOVA)

ARTIFICIAL SALIVA SUBSTITUTE	CONTACT ANGLE PARAMETER	GROUPS			p VALUE
		A	B	C	
ARTIFICIAL SALIVA	**Advancing angle**	80.311 ± 3.004	74.464 ± 3.265	76.583 ± 3.376	0.001
	Receding angle	64.747 ± 3.1113	52.569 ± 1.709	58.978 ± 2.270	0.00
	Contact angle of hysteresis	15.563 ± 3.878	21.895 ± 3.632	17.605 ± 4.740	0.03
DISTILLED WATER	**Advancing angle**	81.222 ± 4.571	75.755 ± 3.157	77.651 ± 3.334	0.01
	Receding angle	61.275 ± 2.605	50.231 ± 1.719	55.948 ± 2.656	0.00
	Contact angle of hysteresis	19.948 ± 4.311	25.494 ± 3.993	21.703 ± 4.419	0.04

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Table 3: Multiple comparison of advancing and receding contact angle among groups using Tukey's post hoc test

CONTACT ANGLE PARAMETER	COMPARISON BETWEEN GROUPS	MEAN DIFFERENCE	SIGNIFICANCE
ARTIFICIAL SALIVA:			
ADVANCING ANGLE	MILLED VS PRINTED	5.84	0.001*
	MILLED VS BPS	3.72	0.039*
	PRINTED VS BPS	2.11	0.320
RECEDING ANGLE	MILLED VS PRINTED	12.17	0.000*
	MILLED VS BPS	5.76	0.000*
	PRINTED VS BPS	6.40	0.000*
DISTILLED WATER:			
ADVANCING ANGLE	MILLED VS PRINTED	5.46	0.008*
	MILLED VS BPS	3.57	0.502
	PRINTED VS BPS	1.89	0.000*
RECEDING ANGLE	MILLED VS PRINTED	11.04	0.000*
	MILLED VS BPS	5.32	0.000*
	MILLED VS PRINTED	5.71	0.000*

* shows statistically significant results between the groups.

FIGURE 1: (A) Nesting of samples in the milling software. (B) Milled samples in the PMMA blank.

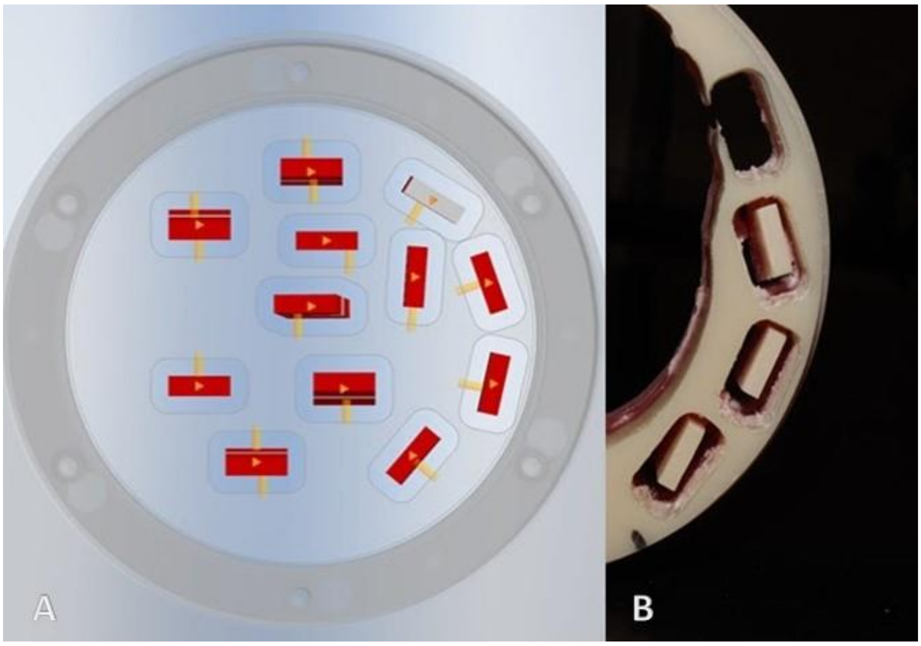

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FIGURE 2: (A) Nesting of samples in the 3D printing software (B) 3D printed sample with sprue-like support.

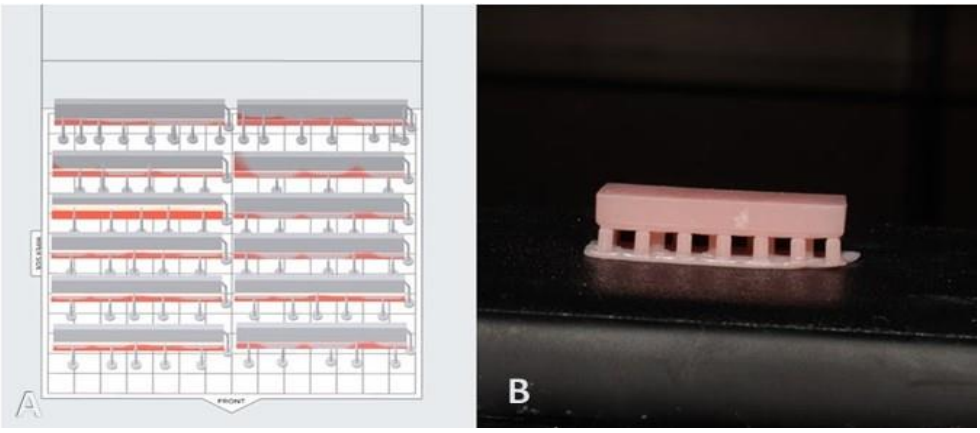

Figure 3 shows (A) Milled denture base material; (B) 3D Printed denture base material; (C) BPS injection molded heat cure denture material.

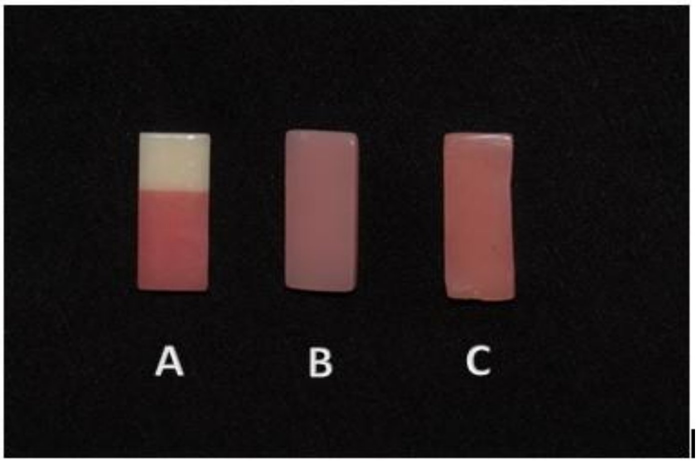

Figure 4: Goniometer used in the present study to measure the contact angle

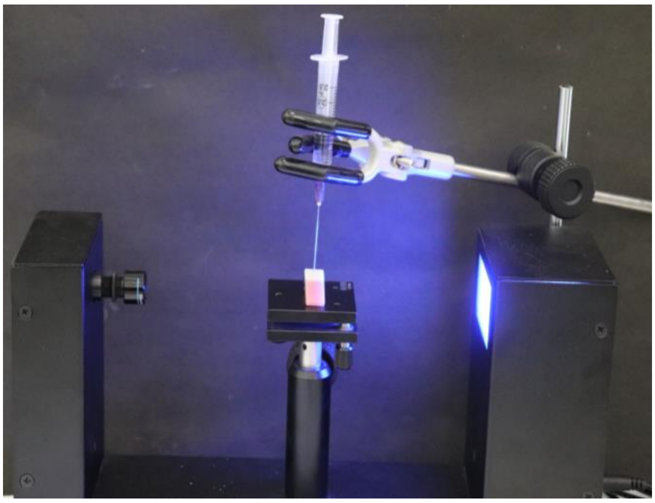

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Figure 5 shows the digital images of goniometer measurements. (A) Advancing contact angle (ϴA); (B) Receding contact angle (ϴR).