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Modified CAD/CAM Wax: The Dimension Accuracy of Wax/Metal Copy Patterns

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Abstract

Background: In dentistry, different researchers in various studies have tried various methods and techniques to reuse, recycle and manage the waste of dental materials. CAD/CAM wax could be recycled effectively without any degeneration of its original properties by refreshing with new materials using simple techniques. The objective of the current study is to evaluate the dimensional accuracy of the new modified machinable dental wax for CAD/CAM purposes.

Materials and Methods: In the present study three experimental blank discs were performed using the same technique for each type, but with different weight/compositions of dental and mineral waxes. A master die was scanned and designed for the crown copy patterns. Ten identical wax copings were milled for each experimental group (Type I, Type II, and Type III) to compare with the control (Dentify-Germany and Zotion™-China) discs. Wax patterns were cast into metal copies to assess the differences in accuracy values of the axial, proximal, and occlusal surfaces between the wax patterns and metal coping.

Result: Non- significant differences were noticed in the thickness accuracy between the wax pattern and the metal copy of the experimental discs of Type (I) and Type (II) that were manually produced compared to the commercial discs ($P>0.05$). While, Type III showed statistically significant differences were noticed between the wax and metal patterns, at different surfaces except in mesial surface ($P<0.05$).

Conclusion: Wax patterns fabricated using a new version of machinable wax produced by recycling some CAD/CAM wax with different fresh materials showed acceptable dimensional accuracy. Also, it seems to have few significant differences for CAD/CAM purposes in terms of patterns thickness than those obtained available and conventional wax™.

Keywords: Machinable wax; Dimensional accuracy; CAD/CAM wax; Recycling

Introduction

Traditionally, the wax pattern is important and time-consuming step for the production of the fused-metal crown of porcelain. The quality of the wax-up is dependent on the effort of the individual in this intensive task **(Sun and Zhang, 2012; Vojdani et al., 2013).** This may frequently result in errors due to materials or techniques used during fabrication steps such as waxing, investing and casting **(Abduo et al., 2010; Venkatesh and Nandini, 2013)**. Hence the development of an accurate wax pattern is an important factor that can influence the marginal fit during the casting process. Waxes, on the other hand, have several disadvantages, including softness, thermal sensitivity, elastic behavior, related to high coefficient of thermal expansion, which lead to dimensional change **(Mumford and Phillips, 1958; Morey, 1991; Abduo et al., 2010).** However, dental casting technique efficiency is highly dependent on the quality of the wax pattern material and variation of wax components and the bulk of material as its surface and dimensional characteristics are transferred to the ceramic veneer and thus to the final casting **(Bemblage and Karunakar, 2011; Byun, 2020)**

The dimensional accuracy of the castings technique is determined not only by the methods used but also by the different materials used in their construction **(Hunter and Hunter, 1990).** Also, the wax material and pattern geometry affect the accuracy of the wax pattern. Where the effect of pattern geometry is particularly difficult to obtain when forecasting dimensional changes induced by wax solidification. This leads to the selection of the type of wax for which is based on several properties such as durability, density, viscosity, and thermal expansion **(Faccenda, 2003).** Accordingly, a regulated manipulation and knowledge of the properties such as dimensional change of wax patterns could be used to make an acceptable final pattern **(Strub et al., 2006; Rajagopal et al., 2012).**

On the other hand historically dental technology focused on standardized lost-wax casting techniques that has been vastly developed with the advent of dental CAD/CAM systems **(Miyazaki and Hotta, 2011)**. CAD/CAM has changed dental laboratory manufacturing and led to many discoveries in the production methods of some restoration **(Bidra et al., 2013).** Generally, the fabrication of dental restorations from machined block-shaped materials by using a CAD/CAM machine makes the automatic margin detection and restoration design more simple compared to the traditional waxing technique **(Tan et al., 2008; Kim et al., 2014; Mansour, 2021).** In addition, the CAD/CAM wax pattern procedure intends to overcome mistakes in the casting process by decreasing production steps **(Xu et al., 2014; Fathi et al., 2016; Farjood et al., 2017).** Furthermore, CAD/CAM has some limitations, related to scanning systems, software design accuracy **(Davidowitz and Kotick, 2011; Park et al., 2015; Farjood et al., 2017).**

In this system, the use of CAD/CAM wax blocks provides accurate and dimensional stability in the machining of any design, and the patches could be recycled, cost-effective, highly machinable, and safe to work with. It should not only be considerable for time saved in the prove-out project **(Zaley, 2013),** but also the material type that may be an effect on the accuracy of CAD/CAM patterns **(Byun, 2020).**

As the CAD/CAM blocks are reusable materials can be managed the wax patches appropriately. Dental waste management is quite important in industrial manufacturing **(Fan and McGill, 1989)**. Where there are several studies have demonstrated about 80-90 percent of wax may be recycled without altering its characteristics**,** by eliminating impurities using a basic laboratory process **(Thopegowda et al., 2013; Arora et al., 2017).** Consequently, **Biernacki et al**, conclude that the wax pattern mixture collected from the recycling of hard waxes, instead of fresh mixtures, could be utilized to achieve accurate castings and decrease energy consumption in producing high-quality investment patterns for common engineering purposes and that the theory of more extensive recycling and handling of wax should be considered **(Biernacki et al., 2015).** This may also recommend by Ashby and Jones' who are previously appointed for recycling and re-using some materials which consider an efficient way to save energy **(Ashby and Jones, 1995).** However, Zaley reported that the recycling of CAD/CAM wax could change some of its mechanical properties **(Zaley, 2013).** As a result, more focus should be given on locally producing modified machinable dental wax utilizing commercially waste wax patches with the addition of fresh wax materials to produce a new type that may be competitive with the traditional wax in technique, properties, costs (**Witkowski, 2005; Strub et al., 2006; Çehreli et al., 2009; Thopegowda et al., 2013).** The modified wax patterns should provide better dimensional accuracy and surface finish as casting technique quality could be enhanced by improving one or more characteristics of the wax pattern **(Taşcıoğlu and Akar, 2003; Bemblage and Karunakar, 2011).**

Materials and method

1.Pilot study

Pilot study was conducted as a first step in this study via preparing the study silicon mould using the contour of the CAD/CAM wax block (Dentify GmbH, Germany) with a dimension of 14 (±0.1) mm× 98 (±0.1) mm in height and diameter respectively. A pilot wax blank was accomplished through mixing (40g China wax™, 30g Sticky wax™, 20g Inlay wax™, 10g Paraffin wax), with the same technique followed by (Ahmed and Muhsin, 2021). Then, pilot wax blank, securely locked in the blank holder inside the imes-icore dental milling machine to fabricate copy wax design of maxillary first molar as shown in Figure (1).

2. Modified Wax Preparations

CAD/CAM wax blank (Zotion™, China), inlay wax (Renfert, Germany), sticky wax (Renfert, Germany), paraffin wax (Middle Refineries Company/Dora Refinery/Iraq). According to the pilot study blank three study experimental blanks of Type (I), Type (II), and Type (III) were prepared with different ratios according to the table (1), and figure (2).

3. Study Sample Grouping

A fifty study sample of copings wax specimens were made and distributed into five groups by milling. The experimental (Type I, Type II, and Type III) and the control of (Dentify GmbH, Germany and Zotion™, China) wax blanks.

4. Sample Preparation

A standard maxillary right first molar was scanned by a model scanner (Shining 3D DS –EX Dental Scanner, China) and a crown copy was designed using CAD software (ExoCAD. GmbH). The structure thickness of the copy design was 0.7mm at overall(margin, occlusal, buccal, lingual, mesial, distal) with a cement space of 40 um, and the final output design was saved as (STL) file **(Kim et al., 2018)** as shown in figure (3). Then the virtual specimens were localized into virtual wax blank via iCAM V5 Smart software. After the STL file design is transferred to the CAD/CAM machine (imes-icore, Germany) the copy is milled using the (Type I, Type II, and Type III) modified wax and the control of(Dentify^{TM}) and (Zotion™) CAD-CAM wax blanks. For each study group specimen, one fine bur of (1 mm) diameter was used to ensure the accuracy and standardization during the machining process.

Finally, after the machining process is finished, the copy design specimens are separated from each blank as shown in Figure (4). In the present study each ten wax pattern specimen of each group were sprued and invested in metal casting ring. The phosphate bonded investment material (Bella vest Bego, Germany) was mixed according to the manufacture with the aid of a vacuum mixer (Whip Mix, UK) and poured into a casting ring under vibration, and left for one hour. Wax burn out was performed by heating each casting ring up to (900°C) for 1hr in electrical furnace. Afterwards, nickel-chromium alloy (Kera NH, Germany) was cast manually using a centrifugal casting machine. Subsequently, each casting ring was left for bench cooling. The metal specimens were divested, then separated from the main metal sprues, and all nodules and bubbles removed by stone burs. A sandblasting machine (Renfert, Germany) was used with sandblast powder of (250µm grit size) (Shera aluminum oxide, Germany) to eliminate investment residues and adherent oxide. Finally, all the metal coping specimens were cleaned ultrasonically for 5min as in figure (5).

5. Testing Procedure:

Generally, after separating the wax copy from the blank wax, the thickness accuracy was measured of each specimen using digital vernier at the middle third of axial and proximal surfaces to optimize 0.7mm as shown in Figure (6a). Whereas, the thickness structure of the occlusal surface was measured at the midpoint of the surface using metal caliper, figure (6b) **(Sharma et al., 2014).** Then the casting Ni-Cr copy specimens were sandblasted and measured at the same identified points and method.

Statistical Methods

The study data was analyzed via One-way ANOVA (post-hoc, Games Howell test) at a confidence level of 95% and a significant P-value of ($P \leq 0.05$).

Results

Generally, the thickness of the wax copy of modified type I, type II & type III wax blanks show non-significant differences ($P > 0.05$) that of their metal copy at all tested (buccal, lingual, mesial, distal, occlusal) surfaces except at that of the mesial surface of type III. Also, the modified wax/metal patterns present non-significant differences ($P > 0.05$) than that of commercially available wax (Germany and China).

Discussion

This study aims to investigate the new locally modified wax for CAD/CAM purposes. Many researchers approved the recycling of dental wax and reused them for different laboratory uses.
However, they also confirmed that the recycling of the dental wax results in a change of mechanical properties. So, it was necessary to add raw materials to

modify the recycled wax **(Zaley, 2013; Thopegowda et al., 2013; Arora et al., 2017).**

The use of CAD/CAM in dentistry has increasingly become more popular because CAD/CAM facilities offer more efficient, accurate, and consistent production of dental restorations than the conventional methods **(Davidowitz and Kotick, 2011).** Wax pattern fabricated via CAD/CAM milling process affected directly by the material type where it was found that the wax materials showed superior accuracy **(Byun, 2020).** Therefore, this study results showed that the new wax material has been within the acceptable range of a stabile accuracy during the milling and casting process including various steps **(Rajagopal et al., 2012).** Generally, after comparing the results of thickness accuracy values of wax patterns and their metal patterns of study groups. Type (I) and Type (II) experimental CAD/CAM wax showed a non-significant differences in thickness accuracy between the wax patterns and their metal patterns of the axial, proximal and occlusal surfaces in comparison to that of commercially available wax blanks TM. This assures that the new modified wax was prepared manually using simple techniques shows high dimensional stability during the milling process and the steps of the casting technique compared to conventionally CAD/CAM waxTM disc (Dentify GmbH, Germany and Zotion™, China). The results were in agreement with the findings of **(Thopegowda et al., 2013; Biernacki et al., 2015**) who confirmed that properties of recycled dental wax could be improved by the addition of fresh materials. Meanwhile, Type (III) modified wax also showed a non- significant differences in accuracy values at axial, proximal and occlusal surfaces between the wax patterns and their metal patterns, except that of the mesial surface with slight variations this may be due to the solidification process of the metal.

Conclusion

Within the present study limitation, the dimensional accuracy values of the wax patterns made of new modified wax that are cast into metal copy seem similar to that of patterns fabricated from the commercially available blank discs. This indicates that the local production of milling wax manually from recycled waste patches of commercial CAD/CAM dental wax and the inclusion of various dental and mineral waxes provides a new resource of wax that can be competitive with the more common and more commercially used discs for CAD/CAM application. Therefore, new modified CAD/CAM waxes using simple lab techniques may show high expectations for future uses.

Conflicts of Interest

The authors reported that they have no conflicts of interest.

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Table (1): Study Wax Ratio for Modified Wax Preparation

Study Groups		CAD-CAM Wax Wt. % (g)	Sticky wax Wt. % (g) (Renfert, Germany)	Hard Inlay wax Wt. % (g) (Renfert, Germany)	Paraffin wax Wt. % (g) Dora Refinery/ Iraq
Control groups	Germany Wax ™ Dentify GmbH Germany	100	0	0	0
	China Wax ™ (China)	100	0	0	0
Exprimental groups	Type I	60 (China)	30	5	5
	Type II	55 (China)	30	10	5
	Type III	50 (China)	35	10	5

Table (2): ANOVA-Test (Post hoc-Games Howell) showing the thickness accuracy of the commercially CAD/CAM wax (Germany)

Groups		Mean Difference	Std. Error	P-Value	Sig.	95% Confidence Interval	
Wax Copy	Metal Copy					Lower Bound	Upper Bound
Buccal Surface	Buccal Surface	.0040	.01290	.757	NS	-.0216	.0296
Lingual Surface	Lingual Surface	.0090	.01290	.487	NS	-.0166	.0346
Mesial Surface	Mesial Surface	.0000	.01290	1.000	NS	-.0256	.0256
Distal Surface	Distal Surface	.0250	.01290	.056	NS	-.0006	.0506
Occlusal Surface	Occlusal Surface	.0050	.01290	.699	NS	-.0206	.0306

Table (3): ANOVA-Test (Post hoc-Games Howell) showing the thickness accuracy of the commercially CAD/CAM wax (Zotion™, China)

Groups		Mean Difference	Std. Error	P-Value	Sig.	95% Confidence Interval	
Wax Copy	Metal Copy					Lower Bound	Upper Bound
Buccal Surface	Buccal Surface	.0050	.01052	.636	NS	-.0159	.0259
Lingual Surface	Lingual Surface	-.0010	.01052	.925	NS	-.0219	.0199
Mesial Surface	Mesial Surface	.0160	.01052	.132	NS	-.0049	.0369
Distal Surface	Distal Surface	.0050	.01052	.636	NS	-.0159	.0259
Occlusal Surface	Occlusal Surface	.0100	.01052	.345	NS	-.0109	.0309

Table (4): ANOVA-Test (Post hoc-Games Howell) showing the thickness accuracy of modified wax (Type I)

Groups		Mean Difference	Std. Error	P-Value	Sig.	95% Confidence Interval	
Wax Copy	Metal Copy					Lower Bound	Upper Bound
Buccal Surface	Buccal Surface	.0100	.01047	.342	NS	-.0108	.0308
Lingual Surface	Lingual Surface	.0050	.01047	.634	NS	-.0158	.0258
Mesial Surface	Mesial Surface	.0010	.01047	.924	NS	-.0198	.0218
Distal Surface	Distal Surface	.0120	.01047	.255	NS	-.0088	.0328
Occlusal Surface	Occlusal Surface	.0100	.01047	.342	NS	-.0108	.0308

Table (5): ANOVA-Test (Post hoc-Games Howell) showing the thickness accuracy of the modified wax (Type II)

Groups		Mean Difference	Std. Error	P-Value	Sig.	95% Confidence Interval	
Wax Copy	Metal Copy					Lower Bound	Upper Bound
Buccal Surface	Buccal Surface	-.0010	.00862	.908	NS	-.0181	.0161
Lingual Surface	Lingual Surface	.0010	.00862	.908	NS	-.0161	.0181
Mesial Surface	Mesial Surface	.0040	.00862	.644	NS	-.0131	.0211
Distal Surface	Distal Surface	.0060	.00862	.488	NS	-.0111	.0231
Occlusal Surface	Occlusal Surface	.0050	.00862	.564	NS	-.0121	.0221

Table (6): ANOVA-Test (Post hoc-Games Howell) showing the thickness accuracy of modified wax (Type III)

Groups		Mean Difference	Std. Error	P-Value	Sig.	95% Confidence Interval	
Wax Copy	Metal Copy					Lower Bound	Upper Bound
Buccal Surface	Buccal Surface	-.0060	.01156	.605	NS	-.0290	.0170
Lingual Surface	Lingual Surface	.0180	.01156	.123	NS	-.0050	.0410
Mesial Surface	Mesial Surface	.0260*	.01156	.027	S	.0030	.0490
Distal Surface	Distal Surface	.0210	.01156	.073	NS	-.0020	.0440
Occlusal Surface	Occlusal Surface	.0050	.01156	.666	NS	-.0180	.0280

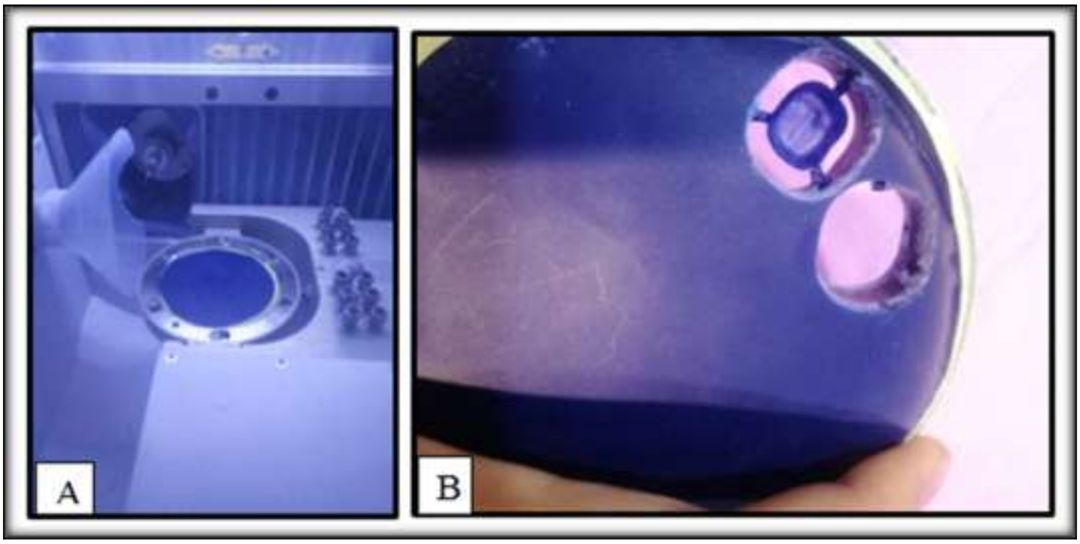
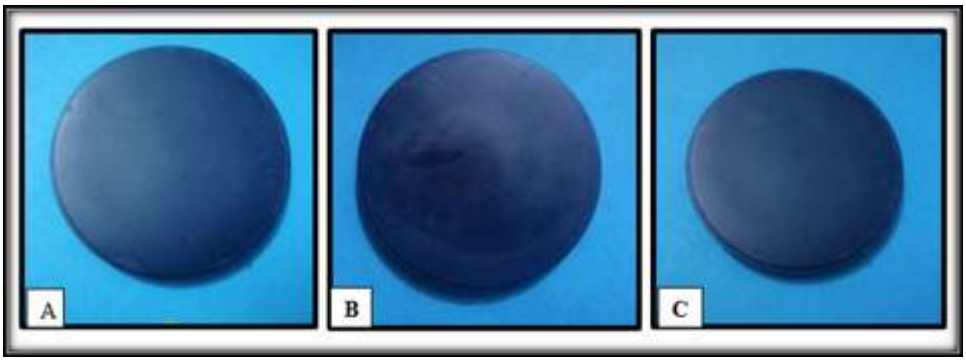


Figure (1): (A) Pilot experimental modified wax blank was fixed in the blank holder; (B) Copy of crown after milling process



Figure(2) : Experimental wax blanks: (A) Type I; (B) Type II; and (C) Type III

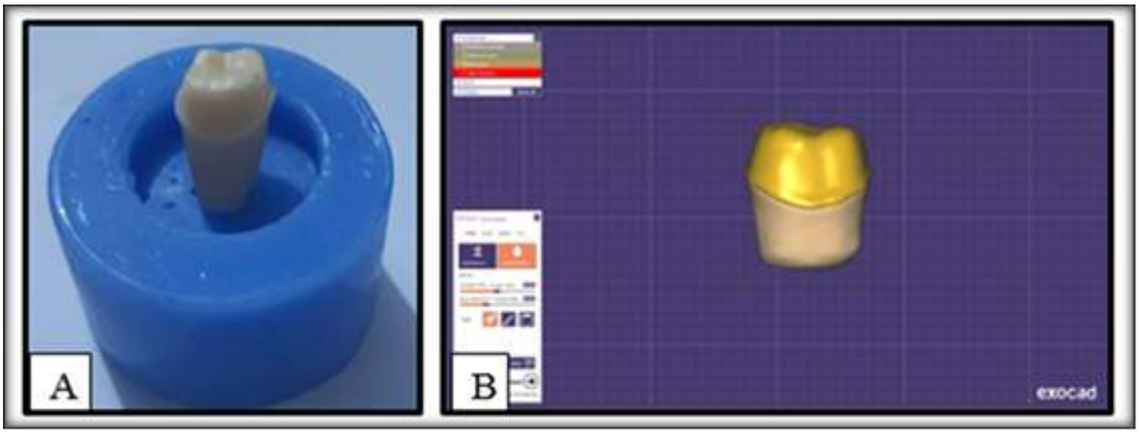


Figure (3) : (A) Master die of maxillary right molar after preparation; (B) Specimens designing with I CAM V5 program

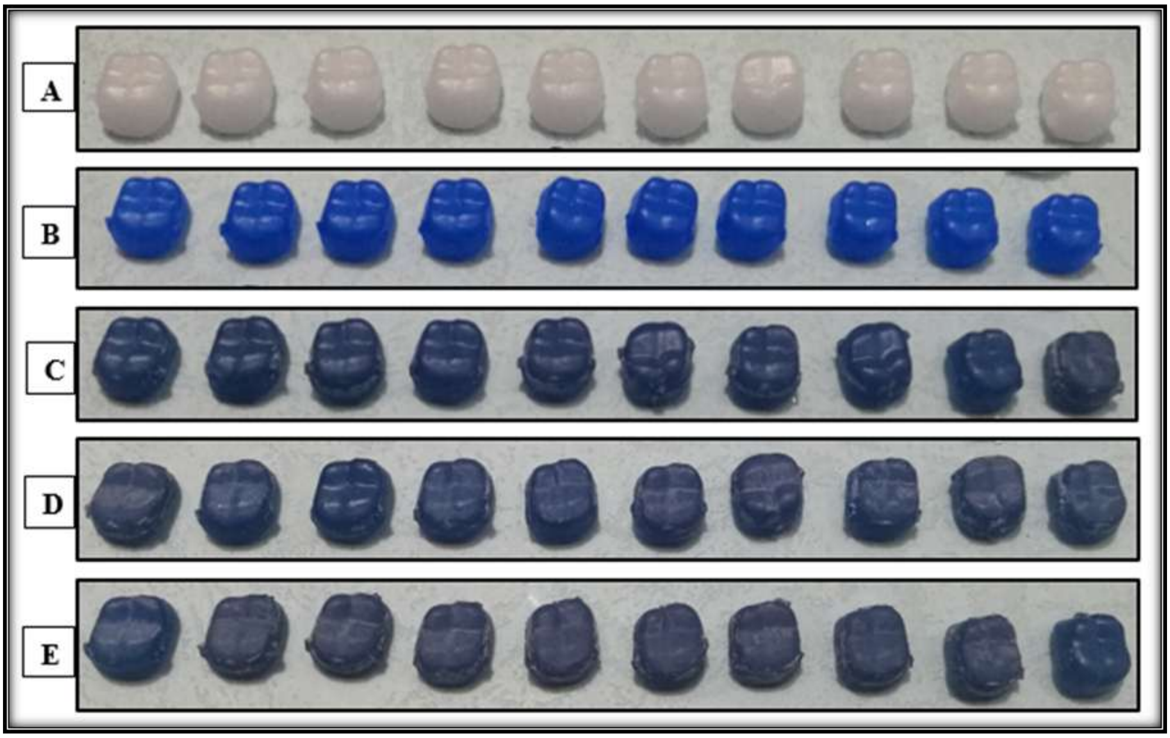


Figure (4): Wax copy from CAD/CAM wax, (A) Germany wax TM ; (B) China wax TM; (C) Type I; (D) Type II; and (E) Type III

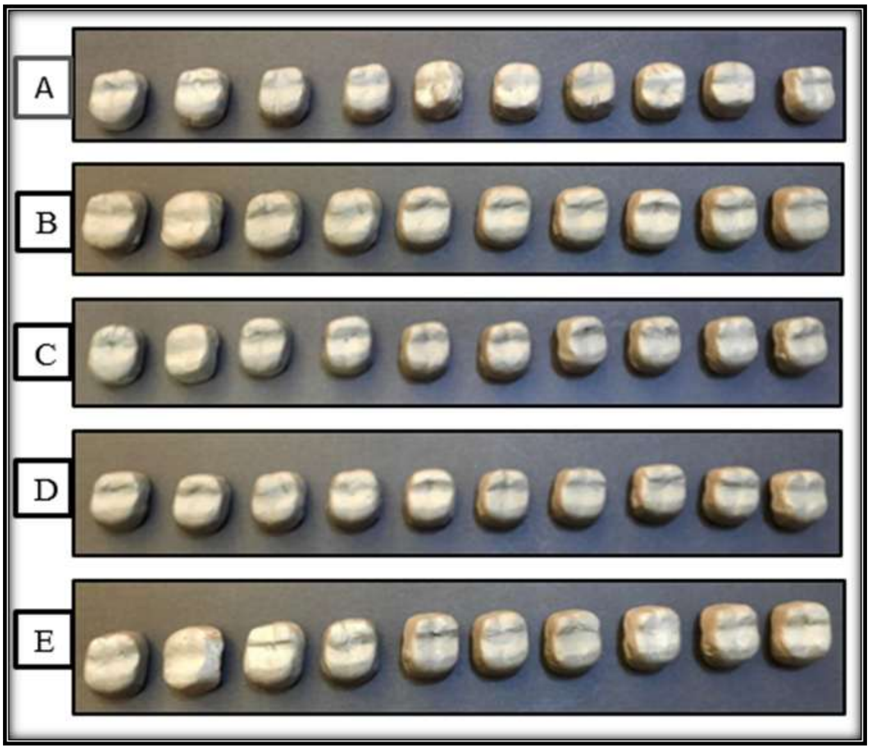


Figure (5): Metal copings from CAD/CAM wax, (A) Germany wax TM ; (B) China wax TM; (C) Type I; (D) Type II; and (E) Type III

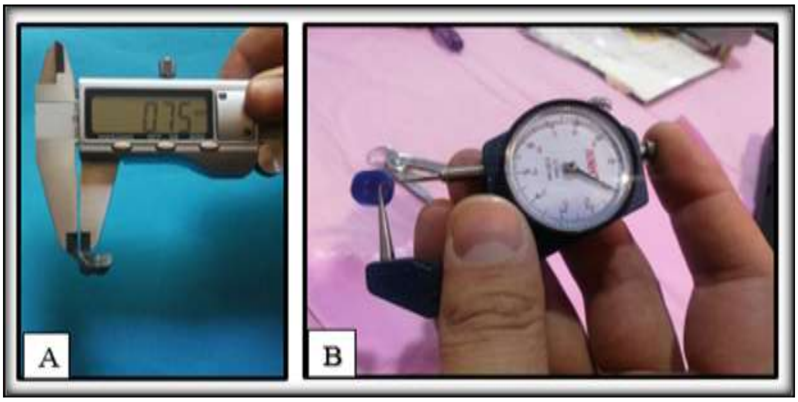


Figure (6) :(A) Digital vernier during measure the axial and proximal surfaces; and (B) Metal gauge during measure occlusal surface

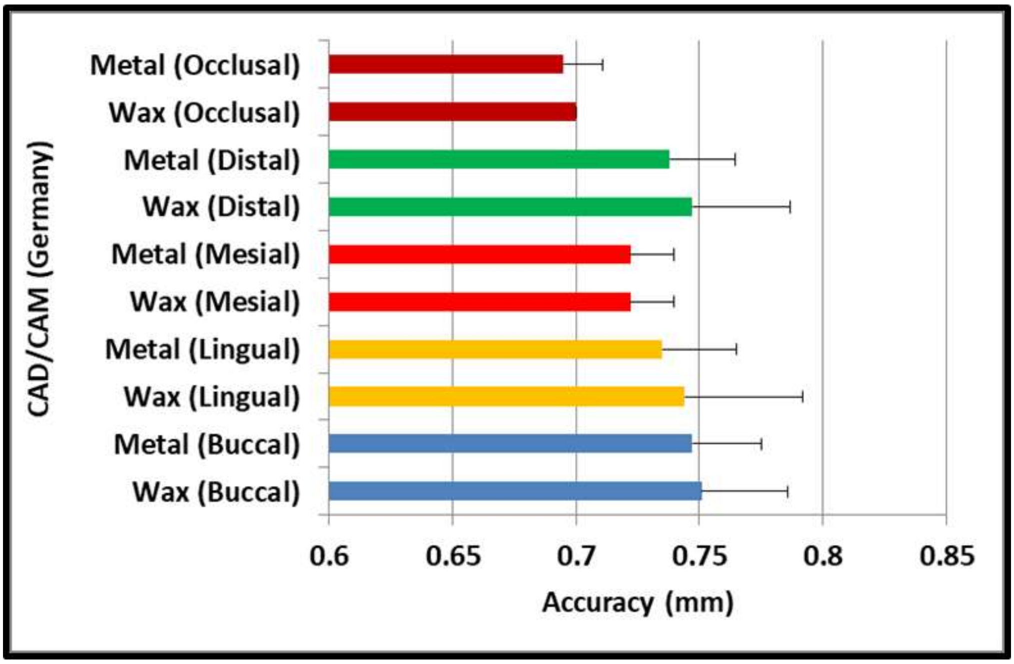


Figure (7) :Bar chart showing the thickness accuracy means distribution of the CAD/CAM wax (Germany)

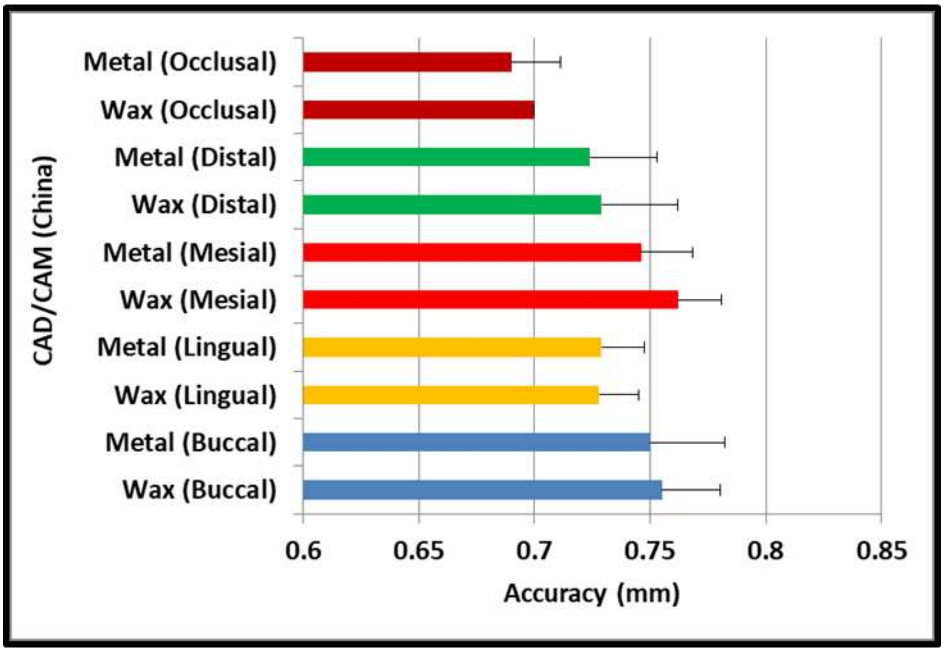


Figure (8) : Bar-chart showing the thickness accuracy means distribution of the CAD/CAM wax (China)

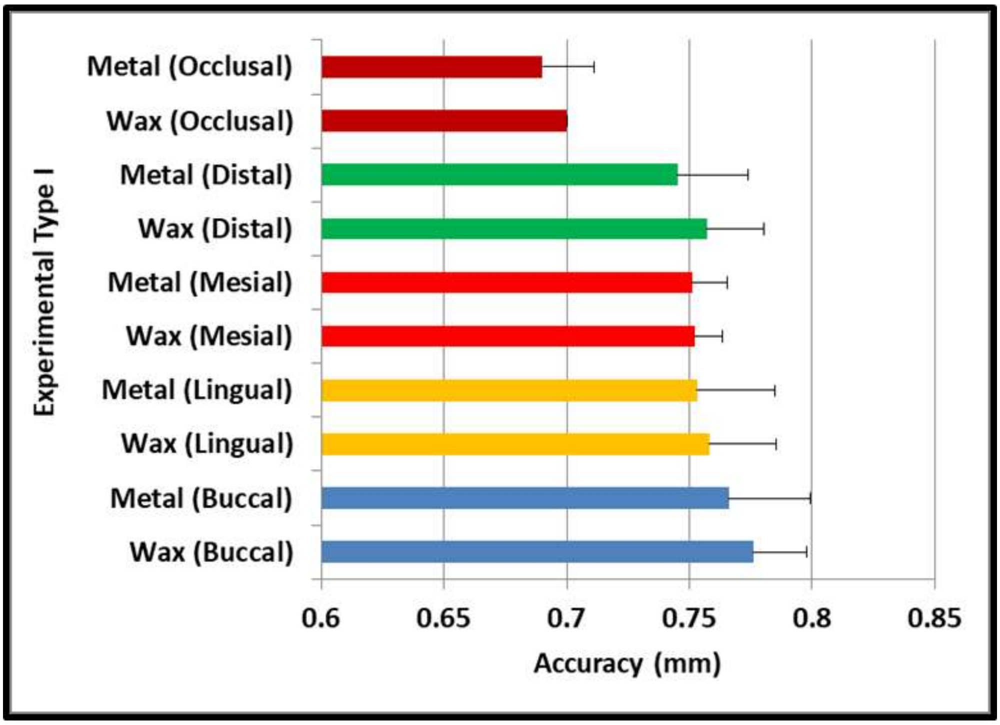


Figure (9) : Bar-chart showing the thickness accuracy means distribution of the modified CAD/CAM wax (Type I)

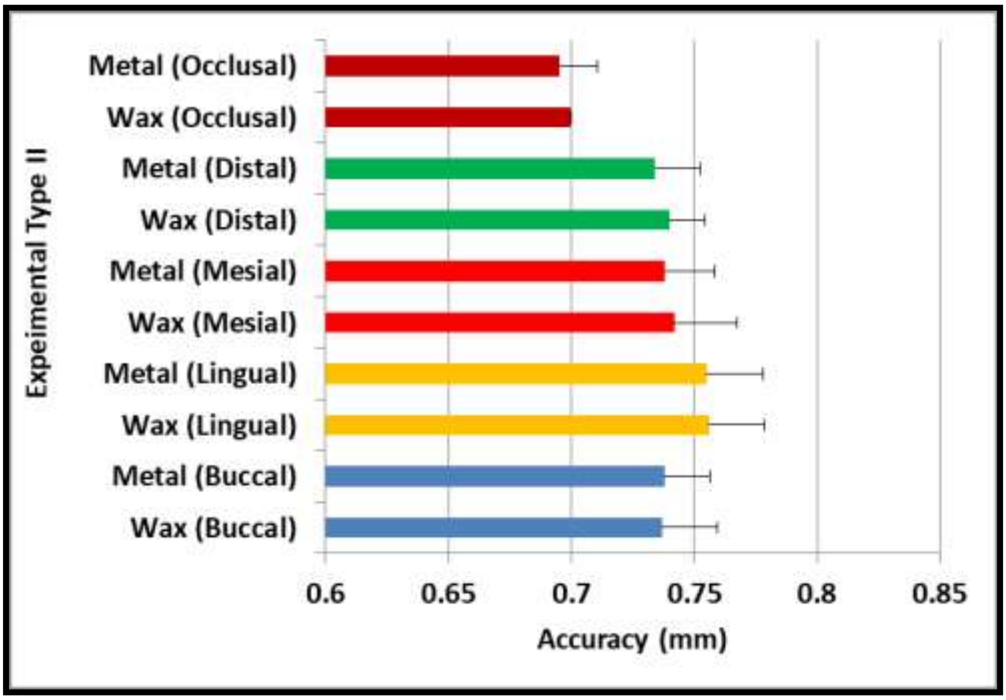


Figure (10) : Bar-chart showing the thickness accuracy means distribution of the modified CAD/CAM wax (Type II)

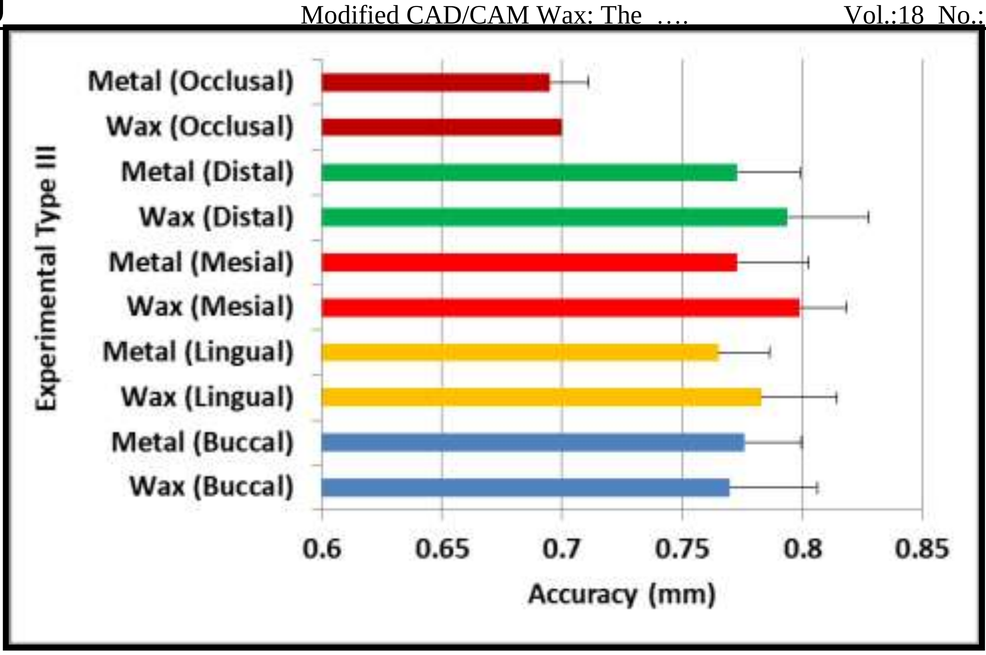


Figure (11): Bar-chart showing the thickness accuracy means distribution of the modified CAD/CAM wax (Type II)