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Manufacture of Anatomical Synthetic Demonstrating Models

Mohamed A.M. Abdel- Rahman[1*] --- Hanan E.L. Mokhtar[2]

[1,2]Department of Anatomy, Faculty of Medicine, Zagazig University, Egypt

Abstract

The practical demonstration session is usually conducted using wet dissected cadaver specimens, plastinated specimens and sometimes plastic anatomical models. Computer-aided teaching means are added nowadays. Due to high formalin toxicity, high cost of plastinated specimens, high cost of computer-aided teaching programs, the synthetic specimens or plastic models are still good substitutes for practical teaching and learning, especially in developing countries like Egypt. Since imported synthetic models are relatively expensive, especially the magnified or those of high quality, the present trial aims at finding a simplified designing idea for manufacture of anatomical models. This simplified methodology helps in changing the two dimensional (2D) pictures to 3D synthetic anatomical local models. These models can be of great help in illustrations and teaching purposes especially for minute parts like natural ear ossicles, which can never be displayed in practical lessons except as pictures. In the present study, different human middle ear ossicles were obtained by repeated dissections of multiple wet cadavers to make an average dimensions for each ossicle. Two dimensional photographs for the ossicles on 1 mm-squared background sheet were taken to confirm measurements and the desired magnification was determined according to the reasonable demonstration distance. The third dimension is deduced by repeated reading of different sources and by reviewing their pictures in different aspects. Three-dimensional primitive magnified models made of sculpting clay were made. Permanent models were manufactured by using synthetic liquid polyester. All models contain wire core skeleton. These manufactured demonstrating anatomical models were found to be durable and easily portable in addition to their relatively simplified manufacturing methodology. They can also offer the basis for manufacturing of implants and prosthesis needed for rehabilitation purposes.

Keywords: Synthetic, Polyester, Modeling, Casting, Anatomical, Models, Demonstration, Teaching, Learning.

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Contents

* *Corresponding Author*

1. Introduction

Sun, et al. [1] tried to produce an improved finite element (FE) model of the human middle ear and to compare the model with human data. They began with a systematic and accurate geometric modeling technique for reconstructing the middle ear from serial sections of a freshly frozen temporal bone. A geometric model of a human middle ear was constructed in a computer-aided design (CAD) environment with particular attention to geometry and microanatomy. Using the geometric model, a working FE model of the human middle ear was created using previously published material properties of middle ear components. This working FE model was finalized by a cross-calibration technique, comparing its predicted stapes footplate displacements with laser Doppler interferometer measurements from fresh temporal bones. The final FE model was shown to be reasonable in predicting the ossicular mechanics of the human middle ear.

Transparent stereo-lithographic rapid prototyping (RP) technology was known to be a practical model construction tool for optical flow measurements such as digital particle image velocimetry (DPIV), laser doppler velocimetry (LDV), and flow visualization [2]. The same authors employed recently available transparent RP resins. Stereo-lithographic model printing with this procedure is considered a direct single-step process, enabling faster geometric replication of complex computational fluid dynamics (CFD) models for exact experimental validation studies.

Rapid Prototyping techniques (RP) in the medical field for designing and manufacturing complex anatomical parts (scaffolds for tissue engineering, three dimensions solid replicas of different bone structures like skull, knee, vertebra, etc.), implants, prostheses, was a very actual research subject with recognized importance and impact over a large number of people [3-7].

In a research, micro-scale X-ray computed tomography (μCT) recordings have been used as geometric input data for models of the middle ear (ME) ossicles. This μCT technique delivers high resolution data on the three dimensional shape of ossicles and other ME bony structures. In another research, the same authors obtain data from high resolution orthogonal plane fluorescence optical sectioning (OPFOS) microscopy, which generates data of unprecedented quality both on bone and soft tissue (ME) structures. Each of these techniques delivers sets of automatically aligned virtual sections. The datasets coming from different techniques need to be registered with respect to each other [8, 9].

Abdul Manan, et al. [10] postulated that the model castings in plaster of Paris (POP) have been used by art and craft industries; however it is largely unexplored in anatomy education. In the western countries, the use of POP in learning begins since kindergarten as a fun way for kids to learn creatively. The properties of POP which can be made conform and manipulated to any contour has attributed for its use in model casting.

Teaching anatomy in most of Egyptian medical schools is entirely based on lectures and demonstration sessions, which are usually conducted using formalin-preserved dissected cadavers & wet specimens, (insufficient & toxic) and plastinated specimens (expensive). The plastic anatomical models are still considered of great help and reasonable substitutes to natural specimens for demonstration in practical lessons. So this study is a trial to assess the possibility of manufacturing more or less accurate, cheaper and not-imported anatomical models from synthetic liquid polyester.

2. Material, Methods and Results

A-Making an Average for Natural Specimens

1- The middle ear ossicles were chosen as an example.
2- Different human ossicles specimens were obtained by multiple dissections to make an average for each ossicle.

B-Photographing

3- Two dimensional photographs for the ossicles were made on a dark background sheet to identify their features (figure 1).
4- Two dimensional photographs for the ossicles on 1 mm- squared background sheet were taken to confirm measurements (figure 2).
5- The desired magnification was determined according to demonstration distance (27:30 folds).

C-Primitive Model Manufacture

6- Magnified ossicles with wiry core (for each specimen) were designed on 3-dimensional base.
7- Three-dimensional primitive models made of sculpting clay were manufactured. The third dimension was deduced by repeated reading of different sources and by reviewing their pictures in different aspects.
8- Accurate feature of the specimens were sculpted, adjusted and photographed (figures 3 "on dark background", 4 "on 1 cm-squared background").

D-Permanent Model Manufacture

9- An accurate wire cores for the permanent specimens were prepared.
10- Casting: A rubber casting socket was prepared which is formed of 2 halves (superficial and deep).
11- Synthetic liquid polyester was poured into the deep socket and superficial socket (separately), and then the 2 haves of the cast specimen were approximated and fused together.
12- Liquid cobalt and liquid peroxide were added (30 gm from each for each 1 kg of liquid polyester) to make it dry.
13- The surface of the specimen was smoothed and then polished.

E- Putting the Specimens in the Demonstration Form

As for the ossicles, one set was left as separate bones (figures 5 "on dark background" & 6 "on 1 cm-squared background"). Another set were held articulated together (by incudo-malleolar and incudo-stapedial joints) and fixed on a stand made by wires and a wooden base. The demonstrating models were labeled (figures 7-10).

Figure-1. Left sided human ossicular chain on a black background to demonstrate features. (1-malleus 2- Incus 3-stapes).

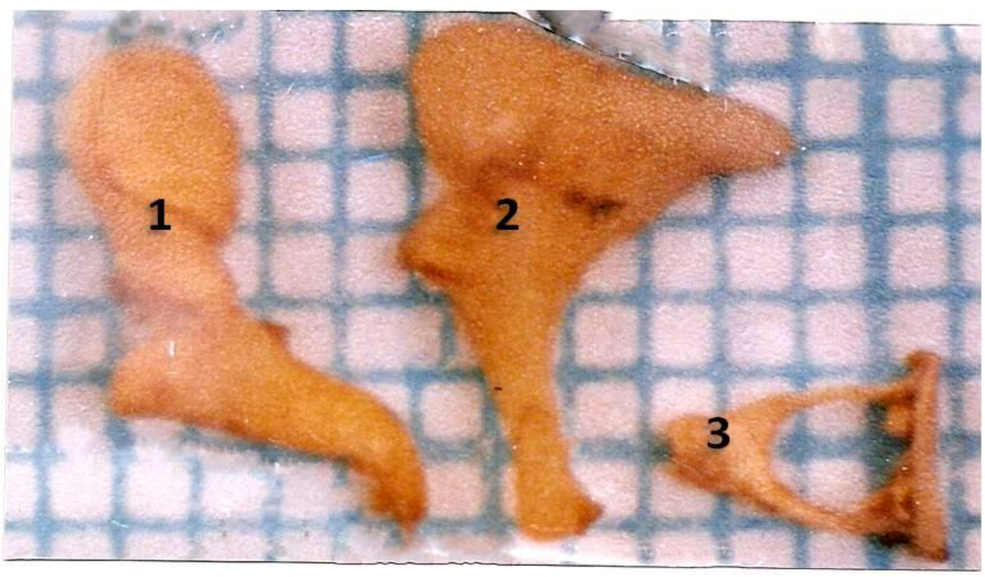

Figure-2. Left sided human ossicular chain on 1mm-squared background sheet to determine measurements. (1-malleus 2- Incus 3-stapes)

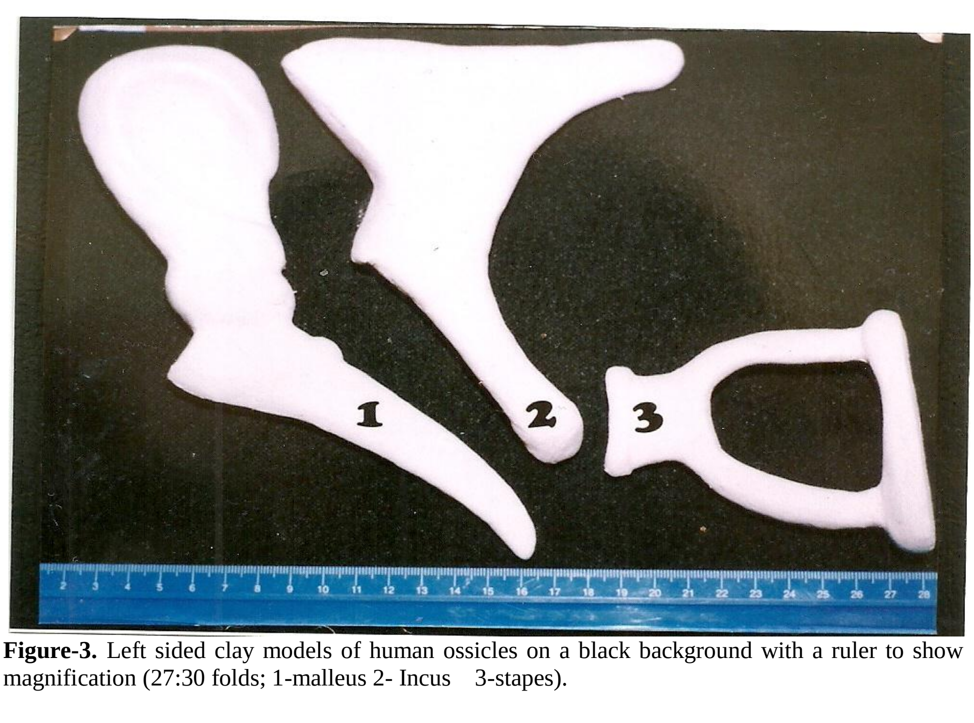

Figure-3. Left sided clay models of human ossicles on a black background with a ruler to show magnification (27:30 folds; 1-malleus 2- Incus 3-stapes).

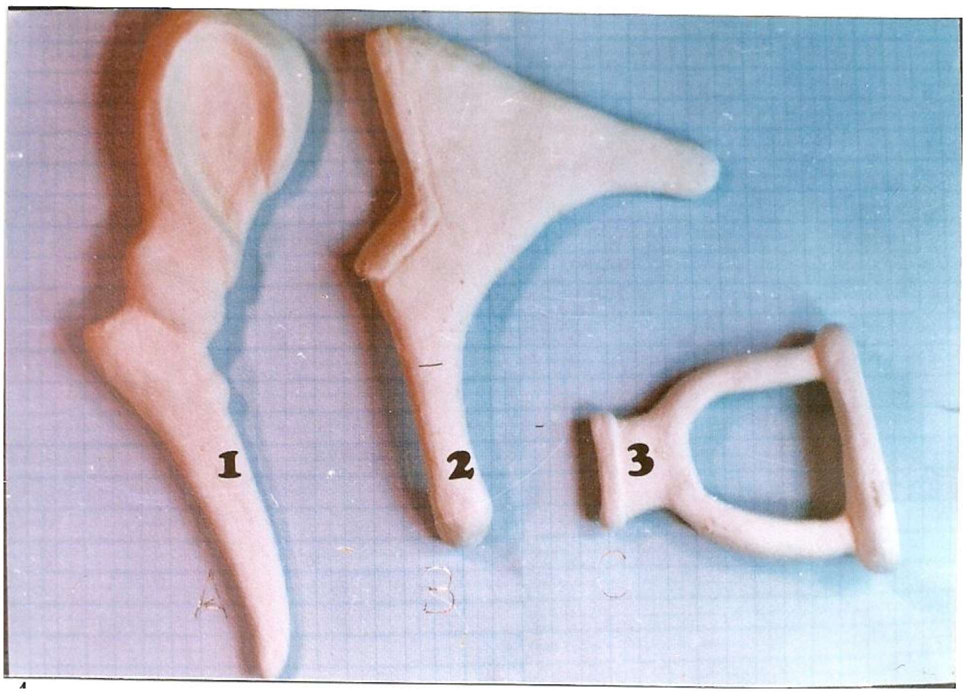

Figure-4. The same previous models placed on 1cm-squared background sheet to show magnitude of magnification**.** (1-malleus 2- Incus 3-stapes)

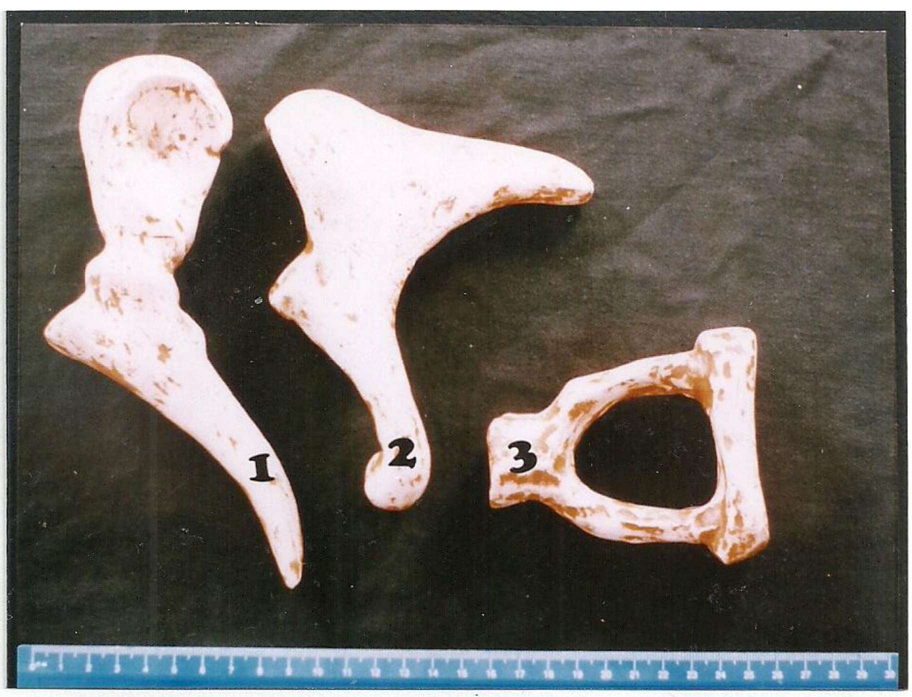

Figure-5. Left sided polyester models of non articulated human ossicles chain on a black background with a ruler to show magnification and relative proportions. (1-malleus 2- Incus 3-stapes)

Figure-6. The same previous models are placed on 1cm-squared background sheet to confirm magnification and relative proportions**.** (1-malleus 2- Incus 3-stapes)

Figure-7. Final picture of synthetic magnified articulated human ossicles put in a demonstration construction (left sided, anterior view) (1-malleus 2- Incus 3-stapes)

Figure-8. The same previous articulated models (posterior view, from lateral to medial) (1-malleus 2- Incus 3-stapes)

Figure-9. The same previous articulated models (medial view, 1-malleus 2- Incus 3-stapes)

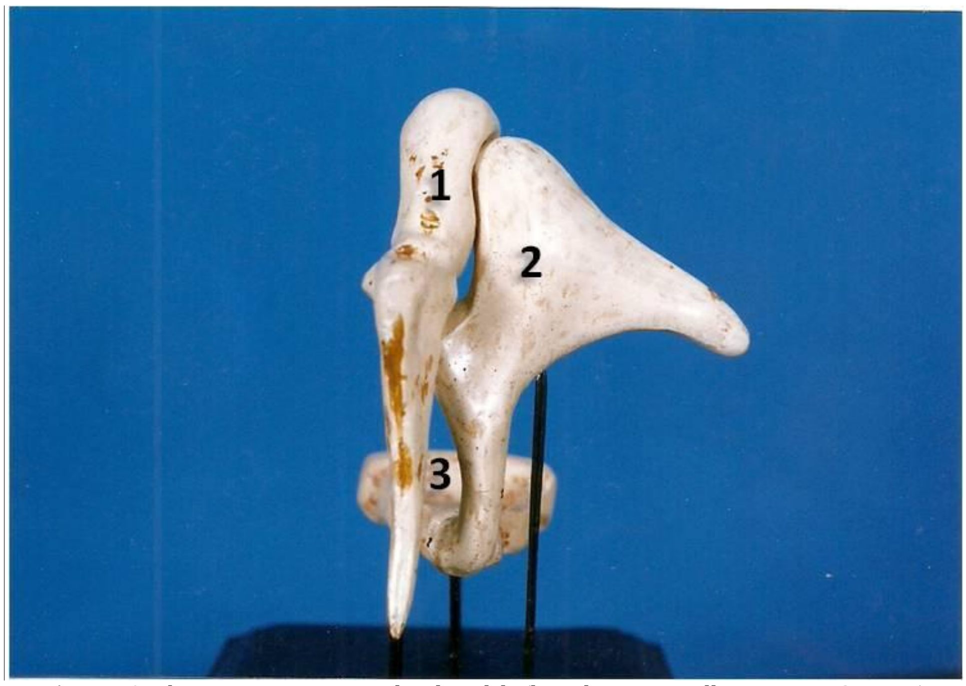

Figure-10. The same previous articulated models (lateral view, 1-malleus 2- Incus 3-stapes)

3. Discussion

The main objective of this study was to find a simplified idea for demonstrating anatomical models and to assess the possibility of manufacturing more or less accurate and cheap models from available local materials. These anatomical models can be used for illustration and teaching purposes. The technique described here was for generating externally almost accurate solid durable anatomical models by use of liquid material (polyester). The methodology was suitable for manufacture of plastic models for small bones of minute dimensions (on the order of millimeters "like middle ear ossicles"). The magnified models for the middle ear ossicles provided a good educational demonstrating tool and added a good experience with the complicated 3D anatomy. It also gave a chance for students to see some body parts, which could never be demonstrated in reality in a practical lesson. This agrees with Satoda, et al. [11], who stated that in dissection practice, it is very difficult to demonstrate to students the structure of the middle ear ossicles because of their minute sizes but the magnified synthetic models are useful in explaining these points**.** As for models of large dimensions (like long bones), they can be possibly carried out by using simple geometric parameters based on morphometric measurements using natural specimens as described in the literature [12].

According to the relatively simplified manufacturing methodology in this study, the medical students can design these models sculpting their detailed parts by themselves as a fun way of learning where they could understand and remember the anatomical structure better. This was previously proved in an outcome-based study, where the students could show and perform better by using their skills [10, 13].

Since the appearance and development of Rapid Manufacturing (RM) processes, accurate medical models, implants or prostheses were produced using the technology of advanced computer-aided design (CAD), computer-aided manufacturing (CAM) or Rapid Prototyping (RP) techniques [3-5]. The advantages of such an approach are detailed in the literature [14, 15] a special importance being given to its commercial potential in producing customized biocompatible implants [16, 17]. However, in the present work, RM processes were not used as they were considered more suitable for making of implants or prosthesis made for patients in rehabilitation fields but were considered an expensive and complicated methodology if the models are produced just for visualization, demonstration or educational purposes.

In the current research, the ear ossicles models were made of polyester with wire cores in it. Polyester being strong, an available product, quick drying, very durable, resistant to stretching, shrinking, wrinkling, abrasion and mildew, it was used in this work as a casting material in agreement with Raghavendra, et al. [18] and Jezek [19] who used the same materials.

Moreover, the current study provides a simplified detailed non-computer-based method for manufacture of irregular bones or introduces a futuristic idea to design different format of models to represent all body regions. Synthetic models of complex bony structures or more soft and rubbery structure can be used for surgical skill training and education in skill labs as proved by Unger, et al. [20].

Additionally, mass production of manufactured models may further reduce the cost of production. The permanent bone models were considered highly realistic making the educational value of the models strongly appreciated. In future further work, three-dimensional models of the human middle ear ossicles accompanied with their ligaments, tendons, joints and their attached muscles, could be made to explain clearly the mechanisms of sound conduction system as previously described by previous literatures [11, 21].

In the current almost solid models, there was no need to study internal structure. Illustrating internal structure of hollow organs may be performed in further work. Therefore, a lot of trials in future need to be performed to produce more accurate ("hard and soft"; "solid and hollow") models with more accurate magnification and details. Manufacturing of prosthesis or implants may also be tried after adding of some updated computer-aided software like 3ds max program. More accurate with more facilities work was made before by Decraemer, et al. [22], who proved that**,** the quantitative measurement of the three-dimensional (3-D) anatomy of the ear is of great importance in the manufacture of teaching models and the design of mathematical models of parts of the ear, and also for the interpretation and presentation of experimental results.

4. Conclusion

In developing Muslim countries like Egypt, there is a problem in providing cadavers for practical anatomical sessions. Moreover, formalin toxicity needs no more proofs. Therefore, cadaver-free teaching is more and more becoming a must in medical colleges all over the world. Meanwhile, expensive alternatives (like plastinated specimens or computer-aided teaching methods) increase difficulty of the problem. Therefore, synthetic models still represent a good substitute. All of the preceding reasons motivate the present team for this work. The methodology was tried to be as simple as possible avoiding expensive and sophisticated or complicated computerized methodologies, which are of more help in designing and manufacturing of synthetic implants and prosthesis. This methodology for manufacturing of demonstrating local cheaper synthetic anatomical models tried to cope with limited facilities and resources in Egyptian medical schools. The produced models are fairly-cheaper, sufficiently-durable and easily-portable. Therefore, these models and those hoped to be produced in future, might be of great help in demonstration in practical lessons to face the previously-mentioned limitations.

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الـ بولـ يـسـ تر من إيـ ضاحـ يةـ تـ شريـ حـ يةـ نماذج تـ صـ نـ يع: مخـ تار لـط في الـ سـ يد حـ نان .ود الـ رحمن عـ بد محمود الـمـ نـعم عـ بد محمد .د.أ
مـ صر -الـزقـ ازيـ ق جامعة -الـ بـ شري الـطب كـ لـ يةـ - والأجـ نةـ الـ تـ شريـ ح قـ سم

بـ لا سـ تـ يكـ يةـ تـ شريـ حـ يةـ نماذج أو بـ الـ لدائـ ن محـ قونـ ة أوعـ يـ نات مـ شرحة، جـ ثث بـ ا سـ تخدام الـ عمـ لـ يةـ الـ تو ضـ يحـ يةـ تـ دار الـ دورات ما عادة :مـ قدمة
وارتـ فاع لـ لـ فورمالـ ين، الـ عالـ يةـ لـ لـ سمـ يةـ ونـ ظرا .الأيـ ام هذه فـ ي الـ حا سوب بـ تـ قـ نـ يةـ تـ دريـ س و سائـ ل حديـ ثا أ ضـ يف وقـ د .الأحـ يان بـ عض فـ ي
زالـ ت ما الـ بلا سـ تـ يكـ يةـ الـ نماذج أو فـ الـ عـ يـ نات ,الـ حا سوب بـ مـ ساعدة الـ تعـ لـ يم و سائـ ل أ سعار وارتـ فاع بـ الـ لدائـ ن الـمحـ قونـ ة الـ عـ يـ نات تـ كـ لـ فة
.مـ صر مـ ثل الـ نامـ يةـ الـ بـ لدان فـ ي وخا صة الـ عمـ لي والـ تدريـ س لـ لـ تعـ لـ يم جـ يدة بـ دائـ ل تـ عـ تـ بر

فـ كان ,الـ عالـ يةـ الـ جودة ذات تـ لك أو الـ مكـ بر الـ حجم ذات خا صة نـ سـ بـ يا، مكـ لـ فة الـ مـ ستوردة الـ بلا سـ تـ يكـ يةـ الـ عـ يـ نات إن وبـ ما :الـ بحث هدف
فـ ي تـ ساعد الـ مـ بـ سطة الـ منهجـ يةـ هذه .الـ تـ شريـ حـ يةـ الـ نماذج لـ تـ صـ نـ يع مـ بـ سطـ تـ صمـ يم فـ كرة تـ قديـ م هو الـ درا سة هذه من الـ رئـ يـ سي الـ هدف
فـ ي كـ بـ يرا عونـ ا تـ كون أن الـ نماذج لـ هذه يـ مكن كما .الأبـ عاد ثـ لاثـ يةـ محـ لـ يةـ مـ صـ نـ عةـ تـ شريـ حـ يةـ نماذج الـ ى الأبـ عاد ثـ نائـ يةـ الـ صور تـ غـ يـ ير
عر ضها يـ سـ تحـ يل والـ تي الـ طـ بـ يعـ ية، الأذن عظـ يمات مـ ثل الـ دقـ يقة لـ لأجزاء بـ الـ نـ سـ بة وخا صة الـ تدريـ س وأغراض الـ تو ضـ يحـ يةـ الـ و سائـ ل
.كـ صور إلا الـ عمـ لـ يةـ الـ دروس فـ ي

الـ تـ شريـ ح خلال من لـ لإنـ سان الـ و سطى الأذن عظـ يمات مخـ تـ لف عـ لى الـ حصول تـ م الـ درا سة هذه فـ ي :والـ نـ تائـ ج الـ مـ سـ تخدمة والـ طرق الـ مواد
مربـ ع مـ لم1 بـ تـ قـ سـ يم ورقـ يةـ خـ لـ فـ يةـ عـ لى لـ عظـ يمات الأبـ عاد صورثـ نائـ يةـ أخذت .عظـ يمةـ لـ كل الأبـ عاد مـ تو سط لـ معرفـ ة لـ لجـ ثث الـ مـ تكرر
من الـ ثالـ ث الـ بعد ا سـ تـ نـ تاج وتـ م أمـ تار عدة من لـ لرؤيـ ة الـ ممكـ نة لـ لمـ سافـ ة وفـ قا الـ مطـ لوب الـ تكـ بـ ير تـ حديـ د وتـ م والـ عرض الـ طول لـ قـ ياس
تـ م كما مخـ تـ لـ فة جوانـ ب من الـ عظـ يمات صور ا سـ تعراض خلال ومن مخـ تـ لـ فة مـ صادر من الـ مـ تكررة الـ قراءة بـ وا سطة الـ طـ بـ يعـ يةـ الـ عظـ يمات
فـ ارق لـ بـ يان مربـ ع سم1 بـ تـ قـ سـ يم ورقـ يةـ خـ لـ فـ يةـ عـ لى لـ ها الأبـ عاد صورثـ نائـ يةـ أخذت الـ نحتـ طـ ين من مـ صـ نوعة أولـ يةـ مجـ سمات تـ صـ نـ يع
عـ لى يـ حـ تويـ ان والـ نهائـ ى الـ مـ بدئـ ي الـ نموذجـ ين من كـ ل وكان .الـ سائـ ل الـ بولـ يـ سـ تر من الـ صـ نع دائـ مة نماذج تـ صـ نـ يع تـ م ثـ م .الـ تكـ بـ ير
قـ اعدة عـ لى بـ أ سلاك تـ ثـ بـ يـ تها وتـ م مـ تمـ فـ صـ لة"و "مـ تـ فـ صـ لة غـ ير") الـ نهائـ يةـ الـ مجـ سمات من مجموعـ تـ ين عمل تـ م) الأ سلاك من داخـ لى هـ يكـ ل
.("مخـ تـ لـ فة زوايـ ا من تـ صويـ رها وتـ م لـ لعرض جاهزة لـ تـ صـ بح خـ شـ بـ ية

الـ خلا صة:

.الـ نـ سـ بـ يةـ الـ تـ صـ نـ يع منهجـ يةـ بـ ساطة إلـ ى بـ الإ ضافـ ة بـ سهولـ ة وتـ حمل دائـ مة لـ تكون مـ صـ نـ عةـ تـ و ضـ يحـ يةـ تـ شريـ حـ يةـ نماذج تـ صـ نـ يع تـ م
.الـ تأهـ يل إعادة لأغراض الـ لازمة الـ تعويـ ضـ يةـ الأجهزة لـ تـ صـ نـ يع الأ ساس تـ وفـ ر أن يـ مكن أنـ ها كما

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