Von Berg, George Botha

ACCURACY OF POLYETHER VS PLASTER IMPRESSIONS FOR LONG-SPAN IMPLANT SUPPORTED PROSTHESES

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ACCURACY OF POLYETHER VS PLASTER IMPRESSIONS FOR LONG-SPAN IMPLANT SUPPORTED PROSTHESES

George Botha von Berg

A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of MSc (Dent)

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DECLARATION

I, George Botha von Berg, hereby declare that this dissertation is my own work. It is being submitted for the degree of MSc (Dent) at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other University.

Signed by:

……………………………………..

George Botha von Berg

On this……………… day of……………………… 2007

To my father, Dudley Albert von Berg, who completed his BSc at the University of the Witwatersrand during the difficult post-war years, and an MSc at the same institution during the 1960s.

ABSTRACT

Two different implant impression materials viz. a polyether (Impregum ®) and a plaster (Plastogum ®) impression material were used and compared with respect to the accuracy with which abutment positions were reproduced from a stainless steel master model containing five implant analogues. Ten polyether impressions and ten plaster impressions were taken and cast in stone. The positions of the precision impression copings on the twenty impressions were measured using a Reflex Microscope. The positions of the implant analogues on the twenty casts were also measured and compared to the positions on the stainless steel master model. Statistical analysis indicated significant differences between the polyether impression and the plaster impression for full arch implant supported prostheses. The use of plaster resulted in smaller interabutment error but with less predictable variance in dimensions.

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1. INTRODUCTION

Osseointegrated implants are a successful way of replacing missing teeth with long-term reliable restorations, whether for single teeth, partial or full arch prostheses. During the trial fitting of a long span prosthesis, the framework often does not fit passively. This may transfer detrimental or even harmful forces onto the implant-bone interface, resulting in complications, including loss of marginal bone and integration, framework fracture and gold screw loosening. It is thus imperative to find the most accurate way of transferring the information from a patient's mouth to a master model on which the prosthesis will be manufactured. Techniques for perfecting the precision of fit of the prosthesis have not been fully mastered in dentistry and therefore various impression and manufacturing techniques have been employed by various authors. The passive fit of the implant-borne metal framework is a prerequisite to minimise the above-mentioned complications.

Authors have made use of various impression techniques to accomplish a passive-fit.[20- 22] Some studies find no difference between various impression techniques while other studies indicate a significant difference.[21-28, 30, 31] The use of plaster as an impression material has been recommended in some studies in order to eliminate the potential for error in contrast to using elastomeric impression materials.

2. LITERATURE REVIEW

It has been shown that dental implants have a very good prognosis over a long period of time, with predictable results especially for full arch prostheses in edentulous jaws. [1-14] The first edentulous patients were treated in 1965. [1] Since then, a number of clinical complications have been described. [2] Gold screw fracturing and screw loosening were more frequent in prostheses which were supported by only two implants in partially edentulous restored cases. Even though implants can be used in short-span bridges, [3] fewer complications occurred with the use of more implants supporting a prosthesis .[4]

Iglesia and Moreno[15] describe passive fit as the "circumferential and simultaneous contact of all the abutments on their respective implants, and of all the gold cylinders of the prosthesis on their respective abutments. " The authors made a plaster key that splinted the abutments, and when tightened in the absence of passive fit, the plaster fractured. Factors affecting the accuracy of fit begin with the impression techniques and materials. Comparing the accuracy of polyether impression material with plaster for long span implant supported prostheses is one of many factors that have been considered to make the metal framework of such prostheses more passive fitting in order to eliminate stress on the components.[28, 38] Elastomeric materials have been used traditionally, while plaster is a stable and accurate material, and therefore a possible choice for accurate reproduction of implant position.

1. Importance of a passive fit:

i) Mechanical response

It is important to achieve a passive fit between components in order to eliminate mechanical failures which may include screw and abutment loosening or fracture, or fracturing of either the prosthesis or implants.[12, 16] There may be reasons for failure other than the non-passive fit of components. Lekholm et al. [9] found that most failing implants were related to implant length and poor maxillary bone quality. Zarb and Schmitt [10] suggest that clinical stress loading, for example parafunction, may lead to loosening or fracturing of screws. Screw fracture normally follows screw loosening, the cause of which was difficult to establish. [13]

During the try-in stage of the metal framework it was found that the level of static stresses caused by fit discrepancies is dependent on the shape and location of the gap(s), interabutment distance, and the shape, dimensions, and the rigidity of the metal of the superstructure. [17] There is a positive relationship between the size of the fit discrepancy and the magnitude of stress on the superstructure. The preload (tension due to tightening) in the gold screw is used to bring the mating surfaces closer together, which makes the screw vulnerable to fatigue fractures and loosening. Kan et al. [18] described various clinical methods to evaluate implant framework fit.

ii) Biological response

Bone response may lead to non-integration or crestal bone loss around the implant. A study by Jemt and Book [5] shows that none of the prostheses presented had a completely passive fit to the implant, with a maximum three-dimensional distortion of 275 µm, and a mean marginal bone loss of 0.5 and 0.2 mm for the 1-year and 5-year groups respectively. They concluded that there had to be a certain biological tolerance for misfit. Another finding was that no orthodontic bone remodelling took place around the implants due to these forces induced by the misfit, although Jemt and Lekholm [8] found bone deformation resulted between implants that were subjected to an ill-fitting framework. Therefore stress introduced into the implant system may still be present years after prosthesis placement. Strain gauges attached to an abutment indicated that a significant force was introduced on the implant when a fixed prosthesis was connected.[6] The authors found that a greater tension/compression load on the implant was introduced by a fixed prosthesis compared to that of an overdenture. A poor fit could hence introduce tremendous stresses in the system which may lead to implant failure or metal fatigue fractures. Generally, more problems were found in maxillae compared to mandibles. [7]

Jemt and Lekholm [8] refer to dynamic and static loading: dynamic forces arise due to chewing, and static loading is the result of tension in the tightened gold screws of an ill-fitting framework.

2. Factors influencing passive fit:

a). General

Regardless of some problems like improper implant placement [11] and bending overload, [12] the predictability of Brånemark implants has been confirmed.[13]

Jemt and Lie [19] suggest that distortion is significantly higher in the maxillary arches due to the curvature of the implant arch and larger number of implants usually placed in the maxilla. It may also be related to increased alloy content in the castings and poor alignment of implants.

b). Impressions

i) Impression technique

The next factor that contributes towards the precision of the prosthesis is the impression procedure. The procedure may be affected by the technique (open tray or closed tray) to be used. The impression technique comprises using square direct or tapered indirect transfer copings.[20] Numerous studies were done where the square impression copings were either splinted or left unsplinted. [20-31] Some square transfer copings were splinted with Duralay or another acrylic resin, with [21] or without reinforcement with dental floss, or reinforced with carbon steel pins, [22] steel burs [23] or orthodontic wire. [24] Vigolo at al. [25,26] used square impression copings sandblasted and coated with the adhesive recommended by the manufacturer of the impression material. They found this technique highly successful, providing greater accuracy. Goll [23] used gold cylinders as transfer copings, splinted with Duralay, reinforced with steel burs and covered with impression plaster. He recommends machined componentry because they are more accurately manufactured. Assif, Marshak and Schmidt [27] splinted the transfer copings directly to an acrylic resin custom tray. Copings splinted to each other with resin proved to be more accurate than the custom tray method. Assif et al. [28] also found that using autopolymerizing acrylic resin proved to be significantly more accurate than dual-cure acrylic resin as a splinting material. It was found by Philips et al. [29] that tapered copings may distort the impression material upon removal. Carr [20] also found the direct transfer method to be the most accurate due to the deformation of impression material with the indirect method. The results of the above-mentioned studies were not conclusive on whether the impression copings should be splinted [22, 23, 25 - 28] or not [21, 24, 30, 31].

ii) Impression materials.

The selection of the most accurate impression material is the objective of this study. Traditionally there are six different types of impression materials in dentistry: agar hydrocolloid (reversible), alginate hydrocolloid (irreversible), polysulphide rubber, condensation-cured silicone rubber, addition-cured silicone rubber, and polyether rubber. [32] This study, will however, concentrate on a seventh material, i.e. impression plaster. A study done by Linke, Nicholls and Faucher [32] shows that all materials tested produced casts with an arch perimeter larger than the standard reference model. The reversible hydrocolloid showed the least interabutment distortion and the irreversible hydrocolloid the most distortion. It appears logical that reversible hydrocolloids should be used, but they are seldom used today due to the technique's sensitivity and equipment requirements.

It has been proved by Finger and Ohsawa [33] that different impression materials have different setting contraction values. A study was done by Wee [34] to determine the amount of torque required to rotate a square impression coping in an impression. He also compared dimensional accuracy among various groups of impression materials with a travelling microscope. Polyether was found to produce the highest overall torque values and was significantly more accurate. This was followed by addition cured silicone and polysulphide materials. The casts made from polyethers and addition cured silicones were significantly more accurate than casts made from polysulphide impression material. The use of either polyether or addition cured silicone impression material is therefore recommended for direct implant impressions. The high dimensional stability and coping torque of polyether has made it the impression material of choice for taking impressions for full arch implant supported prostheses. [34]

Comparing addition cured silicone (AS), condensation cured silicone (CS), polysulphide (PS), and polyether (PE), Johnson and Craig [35] found that AS showed the smallest change in vertical dimension, AS and CS had the best recovery from undercuts, and AS and PE were the least affected by delays in pouring time. Akça and Çehreli [36] found no difference between the results of Impregum, (a polyether), and Panasil, (a polyvinylsiloxane). A combination of silicone impression material and impression plaster was described by Eid [37], and a combination of polyether and plaster was described by Inturregui et al. [38], where the polyether alone resulted in the closest duplication of the master cast. Impression plaster and irreversible hydrocolloid were also combined by Nissen et al. [39] in partially edentulous patients. Plaster was used to splint the transfer copings. Assif et al. [28] also found plaster to be the impression material of choice in completely edentulous patients, since, in their opinion, it is less time-consuming and cheaper.

iii) Impression Trays

Tautin [40] used a rigid thermoplastic impression tray which was manufactured in the patient's mouth from softened modelling compound. According to Johnson and Craig [41] a custom tray is the impression tray of choice. Moseley and co-workers [42] predicted the maximum stress that the impression tray encountered during removal of a complete impression from the oral cavity. For autopolymerizing polymethyl methacrylate resin trays the yield strength is sufficiently high to safely assume that the tray will not distort under removal forces. In their study, Eames and co-workers [43] constructed trays with 2, 4, and 6 mm space for impression material and found that the 2 mm spacing provided greater overall accuracy for polyether.

iv) Casting of impressions.

Casting of the impressions may be influenced by humidity and temperature, water/powder ratio, amount of vibration and spatulation used. [44]

v) Component tolerances.

Machining tolerances between implant components should also be considered. Ma et al. [45] conclude that machining tolerance determines the degree of movement that is

possible between paired components. Tolerances exist between abutment, impression coping, stainless steel abutment replicas, and gold cylinder. To ensure an intimate fit, there is always an inherent machining tolerance between the connecting surfaces. The two factors that contribute to machining tolerances are dimensional variation and surface roughness. The tolerances measured between the abutment and gold cylinder were 23.1 µm, and those between the stainless steel abutment replica and gold cylinder were 37.1 µm. These values were found to be significantly different ($P<0.05$) which indicates that a passive fit obtained in the laboratory may not guarantee a passive fit in-vivo, as the passive fit in the laboratory may be outside the tolerance range of the in-vivo components. Hecker and Eckert [46] found that the machining tolerance of the stainless steel analogue and gold cylinder was significantly larger compared with that of the abutment and gold cylinder. This may cause a prosthesis that appears to fit in the laboratory to have a misfit of greater proportion in the clinical setting.
Southern Implants, which were used in this study, have a component tolerance of 0.01 mm for critical implant components like the hex of an implant. The 2.7 mm wide hex could be 2.69 to 2.71 mm. It has a tolerance of 0.05 for non critical components like the length of an impression coping for instance.

c). Framework manufacturing

As far as manufacturing of the metal framework is concerned, the computer assisted design/computer assisted manufacturing (CAD/CAM) procedure uses machined and laser-welded titanium frameworks which are manufactured by copy milling sections of an acrylic resin framework pattern in grade 2 titanium and then laser welding the sections together.[47] Jemt et al. [48, 49] found that the welded titanium frameworks are as accurate as gold alloy castings in a fixed prosthesis. Takahashi and Gunne [50] found the fit of the Procera system, produced by the CAD/ CAM technique, to be significantly better than that of frameworks made with a cast gold alloy. After studying six implant systems, Lang and co-workers [51] found that the CAD/CAM produced Procera abutment should be considered for universal application.

When frameworks don't fit passively they need to be sectioned and indexed with self-curing acrylic. Of the index materials available, Cho and Chee [53] found that G.C. Pattern resin has a comparable accuracy to Duralay acrylic resin, but has a setting time of only three minutes compared to Duralay's seven minutes, which saves operating time. Mojon et al. [54] also compared two index materials: Duralay resin had a volumetric shrinkage of 7.9% and Palavit G. resin 6.5%, compared to the 21 % shrinkage of pure methylmethacrylate. The authors also analyzed the influence of powder-to-liquid ratio on dimensional change of the index material and found that adding more liquid to the mix increased shrinkage.

d). Mandibular flexure

Hobkirk and Schwab [52] found that mandibular deformation of up to 420 μm can be encountered upon jaw opening, which should be considered both when taking an impression and during placement of a mandibular fixed prosthesis.

3. PURPOSE OF THE STUDY

The purpose of this study was to compare the dimensional accuracy of polyether and plaster impressions, and their resultant casts when compared to a stainless steel master model. The null hypothesis is that there is no difference between polyether and plaster impression materials relative to the master model.

4. MATERIALS AND METHODS

Testing Device

A stainless steel plate containing 5 stainless steel implant analogues (LS12, 3.75 mm, Southern Implants, Irene, South Africa) was used as a master model for impression taking (Fig. 4.2). The model represented an occlusal arch with five implants for a full arch implant supported prosthesis. The analogues were fixed by machine pressing into the baseplate and retained in the model by small locknuts preventing any rotation. The analogues were numbered 1 through 5 from left to right (Fig. 4.3). Implant analogues numbers 2 and 4 were placed at an 8° lingual inclination to represent the clinical situation. Precision impression copings (CB12P, Southern Implants) were used which were torqued down onto the model to 10 Ncm (Fig. 4.4) before impression taking.

Impression taking

Standard acrylic impression trays (Fig. 4.5, 4.6) were manufactured (Excel Special Tray Material, Wright Health Group Ltd) on a template over the baseplate to ensure standardization of size and shape and a 2 mm spacing under the trays. [40-43] Windows were cut into each tray to expose the transfer copings and guide pins. The windows were covered by a single layer of pink baseplate wax. (Kemdent no 4, Associated Dental Products, Swindon, UK)

The trays were left to cure for 24 hours before impression taking. Ten polyether impressions (Impregum ®, Pentamix Lot 202589, exp 2007-03, 3M ESPE, AG Seefeld, Germany) and ten plaster impressions (Plastogum ®, Harry J. Bosworth, Lot 0309-492, exp 2006-09, Skokie, Illinois) were taken of the master model complying with the manufacturers' instructions for use. ESPE polyether adhesive (Lot 126976, exp2005-02) was used for the Impregum impressions. Two coats were put on the trays, separated by 15 minute's drying time.

The ten polyether impressions were first taken with the 50 available precision impression copings (Fig. 4.7). Measurements of the polyether impressions (Fig. 4.14) were done on the Reflex Microscope before their stone casts were poured and measured. Once the casts had been made, the same 50 impression copings were used to take the ten plaster impressions (Fig. 4.16). First the plaster impressions were measured under the Reflex Microscope, and then their respective stone casts were poured and measured.

Impressions were taken in a controlled environment with temperature ranging from 19.5 °C to 20.3 ° C for the polyether impressions, measured with a Supco THC 200 hygrometer. The values during plaster impression taking were 20.5°C to 22.2°C. The temperature ranges differed between the two impression materials as polyether and plaster impressions were taken on different dates. The reason for this was that the stone casts of the polyether impressions had to be made first. Only then could the same 50 impression copings be used for the plaster impressions. It is unknown to what degree the measurements were affected by this small difference in temperature.

The impression materials were mixed according to the manufacturers' recommendations and left for at least 15 minutes before removal from the master model. After removal of the impressions, stainless steel implant analogues (LS12, Southern Implants) were attached to the precision impression copings. This was done without disturbing the impression copings in the impression by holding the analogue in a clamping device (Fig. 4.8), and torquing the two components to 10 Ncm with a Southern Implant torque wrench (Figs. 4.9, 4.10 and 4.11). Casts were poured in stone, namely Pemaco-CD Peach (Pemaco Incorporated, St Louis, MO, USA) according to manufacturer specifications under normal laboratory conditions (Figs. 4.15 and 4.17).

Measurements

Measurements of the polyether and plaster impressions, and the respective casts were taken on the Reflex Microscope (Reflex Measurement Ltd., Greenways, Ditcheat, Somerset, UK) (Fig. 4.12). The Reflex Microscope is an optical plotter which measures to an accuracy of 1 µm. It is linked directly to a microcomputer and allows direct three-dimensional measurement (x, y, and z-plane) of irregularly shaped objects up to 100 mm maximum dimensions. A small diameter light spot which can be set at 20 µm, 10 µm or 5 µm size appears in the field of view (Fig. 4.13). It is mainly used to calculate linear dimensions between two points. It gives an operator measurement error of less than 0.2 mm for linear distances, and a mean undermeasurement of 0.28%, which compares favourably with other measuring devices (Speculand, Butcher, Stephens [55]).

The x and y planes are determined by moving the object table to the left and right, or forwards and backwards. The z-plane is determined by moving the ocular piece up or down, which brings the object into focus in the same plane as the light spot. During measurement temperature ranged from 21.8 ° C to 26.2°C. The temperature range has no significant effect on the master model as the thermal expansion coefficient of stainless steel is equal to $10^{-5}/^{o}C$.

Measurements of the master and stone models were made on the top corners of the hex of the analogues. The 10 µm light spot was placed at a tangent to the outermost edge. (See Fig. 4.19). Similarly, when measuring the impressions, the light spot was placed at a tangent to the innermost corner of the precision impression coping which coincides with the position of the analogue's outermost corner (Fig. 4.18). Each impression and each cast was measured three times, from which a mean value was calculated. The stainless-steel master model was measured 30 times to ensure consistency during the experiment. Distances were compared between the polyether impression, plaster impression and the master model for specific positions, and also between the different casts and the master model.

These are the 10 measurements of the inter-implant distances (taken 3 times each) that have been taken for polyether and plaster for both impressions and casts:

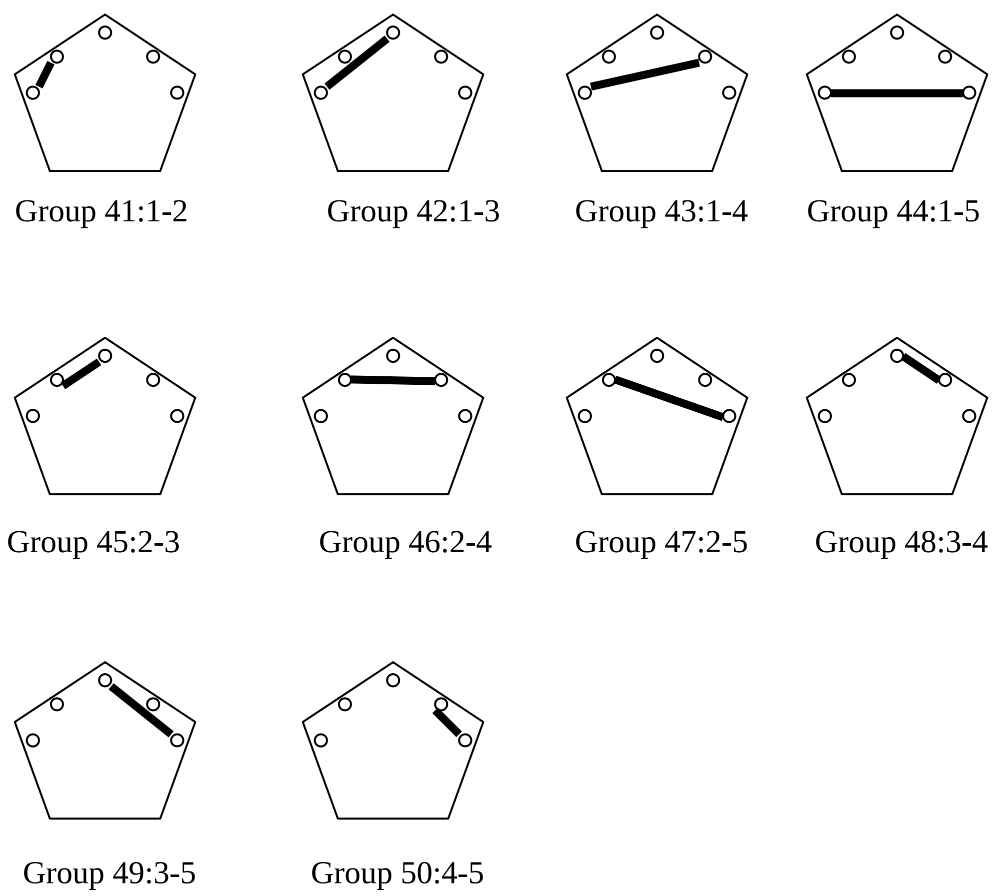

Fig. 4.1 Ten Measuring Positions

PHOTOGRAPHS

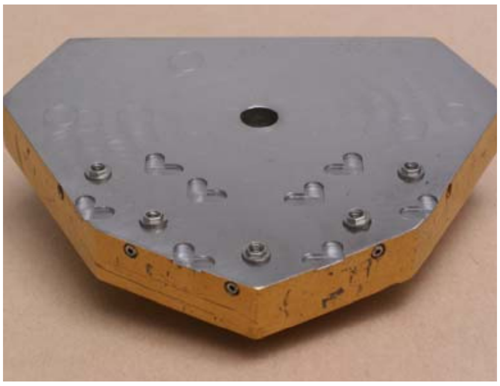

Figure 4.2 Stainless Steel Master Model

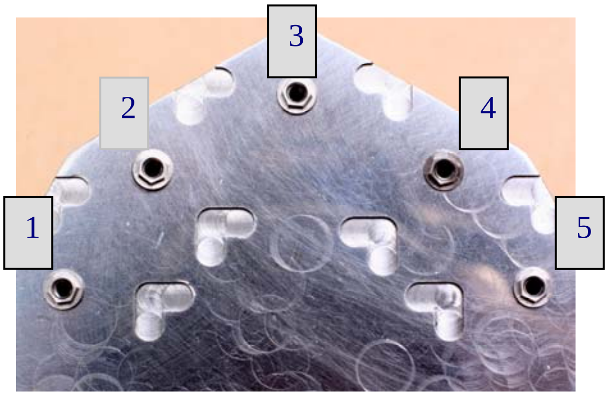

Figure 4.3 View of Stainless Steel Model with Implant Analogues Numbered

Figure 4.4 Stainless Steel Model with Precision Impression Copings in Place

Figure 4.5 Acrylic Impression Tray

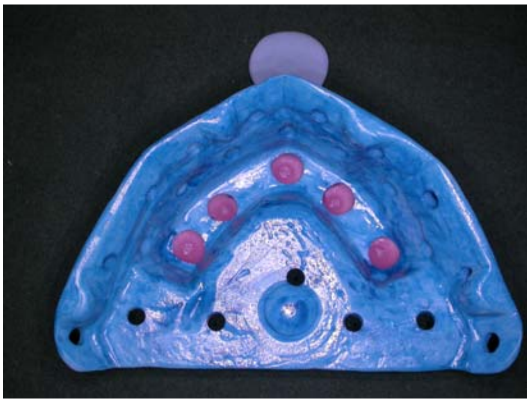

Figure 4.6 Inside of Impression Tray

Figure 4.7 Polyether Impression

Figure 4.8 Analogue Clamping Device

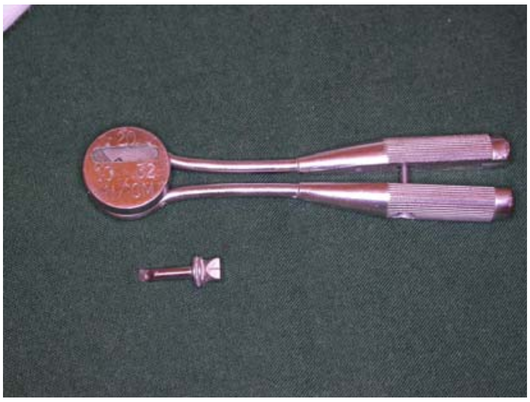

Figure 4.9 Southern Torque Wrench

Figure 4.10 Torquing Impression Coping onto Implant Analogue

Figure 4.11 Polyether Impression with Implant analogue in Place

Figure 4.12 The Reflex Microscope

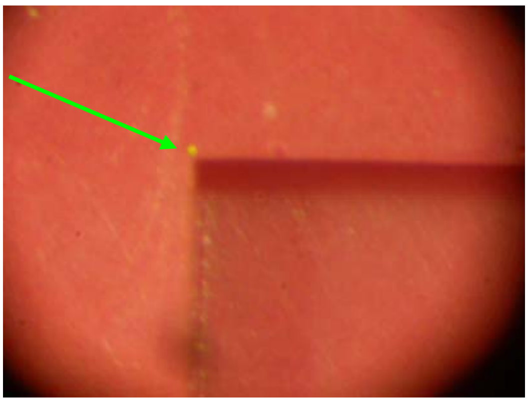

Figure 4.13 The Floating 10 µm Light Spot

Figure 4.14 Numbering of Copings on Impression

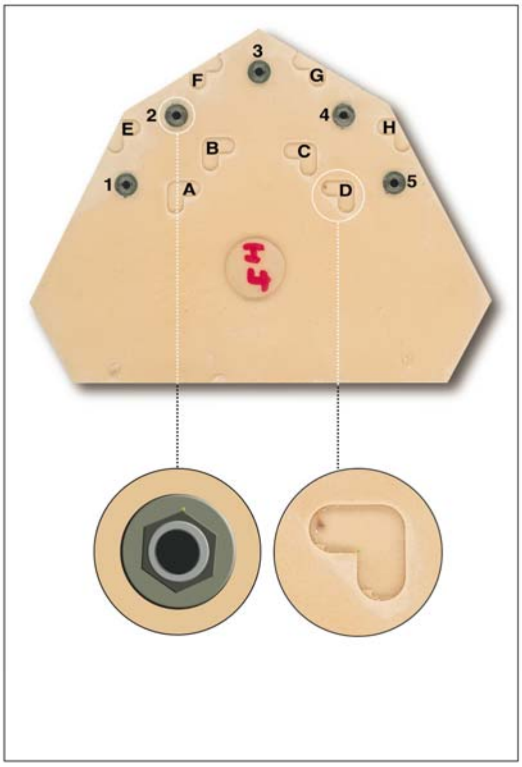

Figure 4.15 Numbering of Analogues on Cast from Polyether

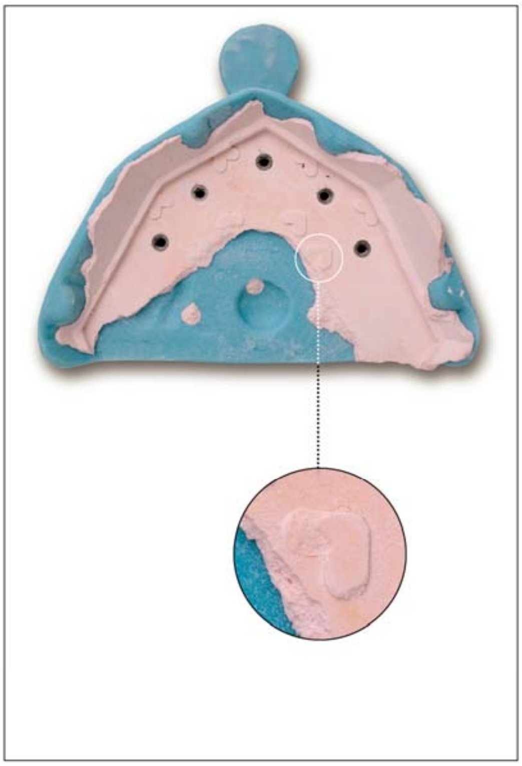

Figure 4.16 Detail of Plaster Impression

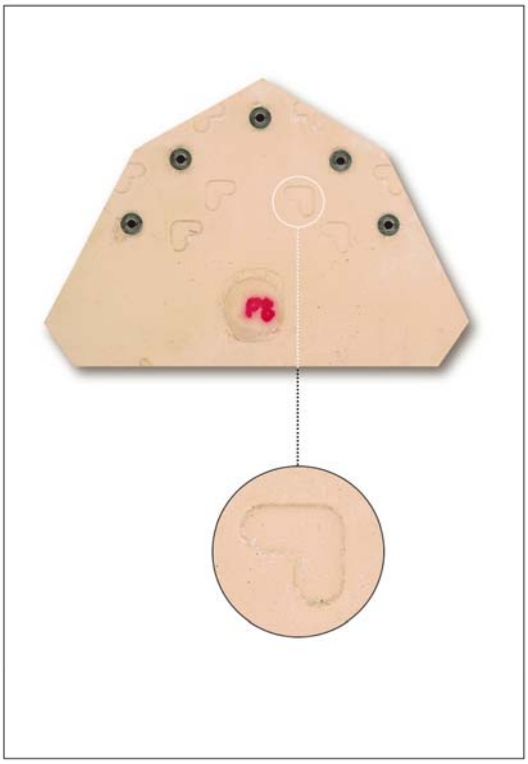

Figure 4.17 Detail of Cast from Plaster

Measuring Positions:

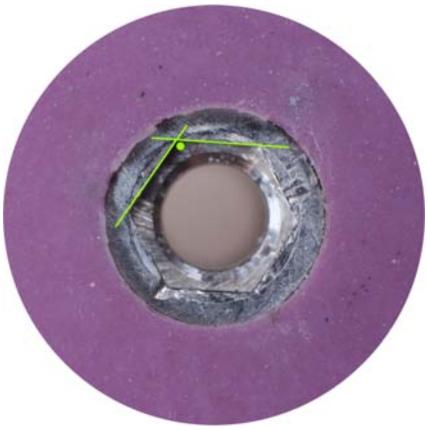

Figure 4.18 Position of Light Spot at Tangent to Inner Sides of Coping in Impression

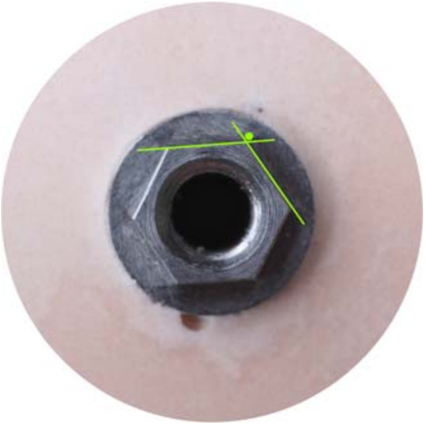

Figure 4.19 Light Spot at Tangent to Outside of Analogue in Cast

5. RESULTS

Methodology

The data was analyzed using descriptive statistics and the use of ANOVA (Analysis of Variance) to compare polyether, plaster and the stainless steel (SS) model, for both the impressions and their resultant casts.

Results

General

A two-way ANOVA was used to compare the casts from polyether impression material and the casts from plaster impression material with respect to the distances between the five implant analogues. The results indicate that there is a significant difference among the two impression materials and the SS model. Significant differences also exist among their resultant casts and the SS model for all but one of the interimplant distances. The only exception is the result for the casts of group 46 which relates to the distance between implants 2-4 ($p = 0.4836$) (Fig. 5.1). This is the only group where there is no significant difference among all three measured models, i.e. the two different casts and the stainless steel master. This group do, however, show a significant difference.

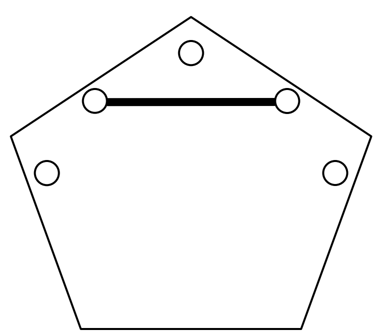

Fig 5.1 No significant difference for casts and SS master model

Variability

The results show considerable variability within and between the samples. The polyether impressions and casts show a greater consistency than the plaster impressions and casts, although significantly different from the stainless steel model.

Even though the measurements for plaster are more inconsistent than for polyether, generally the mean plaster values approximate the stainless steel values more closely than the polyether values do.

A. <u>Impressions:</u>

a) No significant difference ($p>0.05$) between:

Plaster/SS

Polyether/SS

Plaster/Polyether

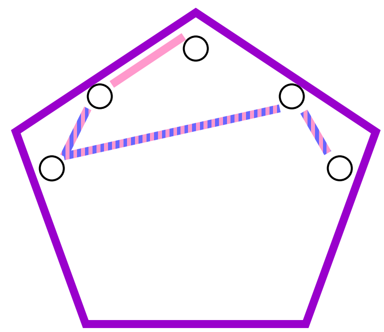

Fig. 5.2 No Significant diff: Impressions

b) Significant difference ($p<0.05$)

Significant differences were found in the following areas:

Plaster/SS

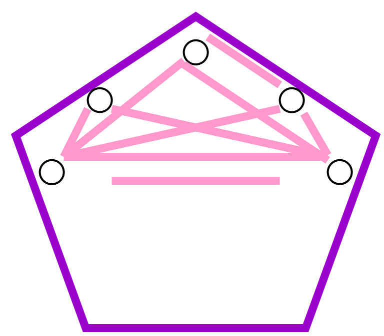

Fig. 5.3 Significant diff. Pl/SS

Polyether/SS

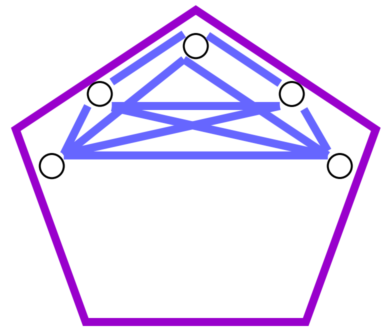

Fig. 5.4 Significant diff. Imp/SS

Plaster/Polyether

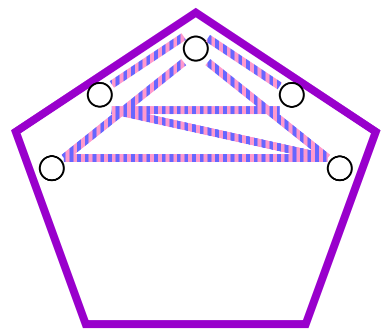

Fig. 5.5 Significant diff. Pl/Imp

i) Plaster/SS

Plaster and stainless steel differ significantly ($p<0.05$) in all but one area: i.e. group 45 (2-3). (Figs. 5.1, 5.2 & 5.3).

ii) Polyether/SS

Polyether and stainless steel differ significantly ($p<0.05$) in all cases. (Figs.5.2 & 5.4).

iii) Plaster/Polyether

Plaster and polyether differ significantly ($p<0.05$) in all but three areas: i.e. groups 41 (1-2), 43 (1-4) and 50 (4-5). (Figs. 5.2 & 5.5).

The largest P-value (0.972) is found in group 43 (1-4) between plaster and polyether. This indicates the least significant difference as can also be seen in the line graph in Figure 5.17 where the two lines are closely spaced.

In Figure 5.18 (group 44; 1-5) the plaster and polyether lines can be seen on either side of the stainless-steel line. Over this longest distance on the model it seems that the plaster impression has contracted and the polyether expanded relative to the SS model. Though there is still evidence of statistical significance observed in group 43, the one for Group 44 gives a more serious evidence of difference. Relatively therefore, observed difference in Group 43 is less than that for Group 44.

The chart below (Fig. 5.6) Discrepancy of Median Measurements of Impressions, indicates the discrepancy between the two impression materials compared to the stainless steel model.

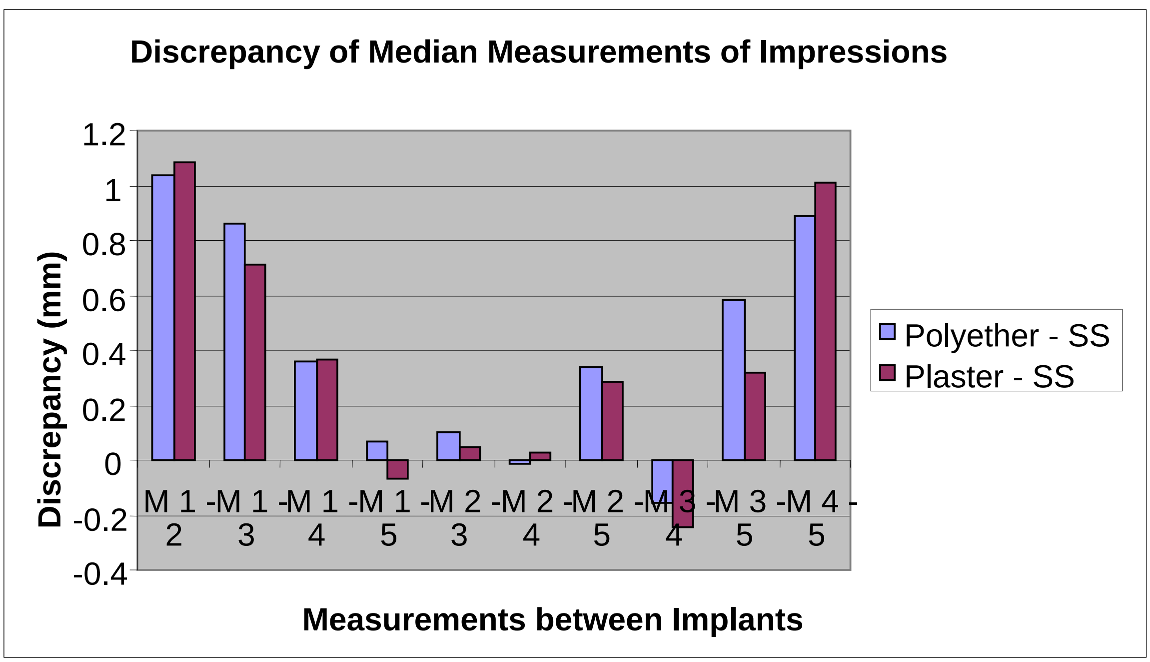

Fig. 5.6 Discrepancy of Median Measurements of Impressions

The width of the lines in Figure 5 .7 reflects the magnitude of the discrepancy in relation to its position on the model.

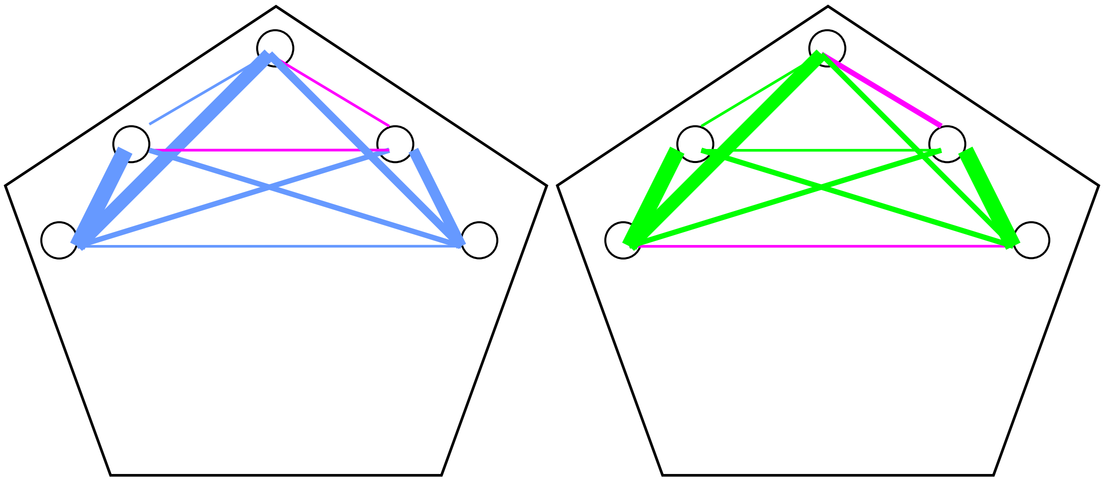

Fig 5.7 Magnitude of Discrepancy for Impressions

Polyether-SS expansion contraction

Plaster-SS expansion contraction

B. <u>Casts:</u>

a) No significant difference (p>0.05) between:

Plaster/SS

Polyether/SS

Plaster/Polyether

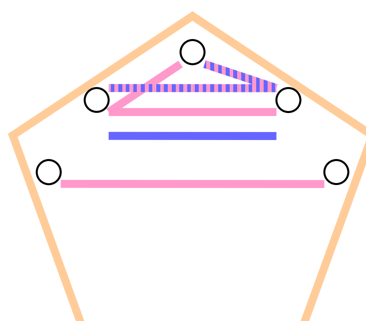

Fig. 5.8 No Significant diff: Casts

b) Significant difference ($p<0.05$)

Significant differences were found in the following areas:

Plaster/SS

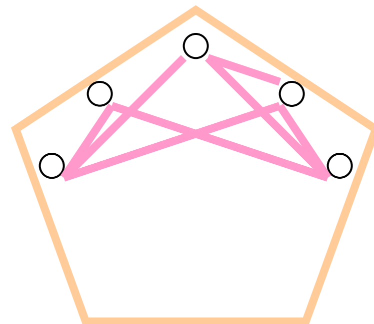

Fig. 5.9 Significant diff: Pl/SS

Polyether/SS

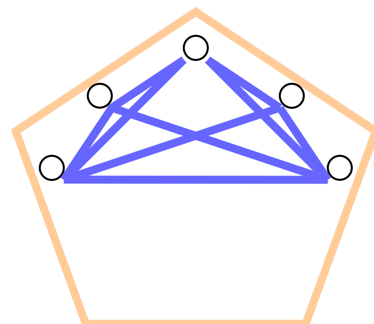

Fig. 5.10 Significant diff: Polyether/SS

Plaster/Polyether

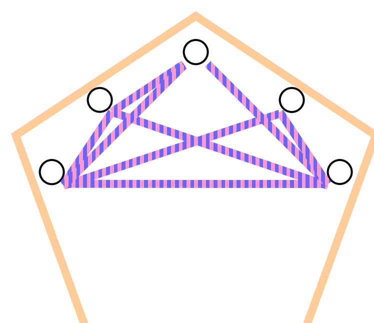

Fig. 5.11 Significant diff: Plaster/Polyether

i) Plaster/SS

Plaster and stainless steel differ significantly ($p<0.05$) in all but three areas: i.e. group 44 (1-5), 45 (2-3) and 46 (2-4). (Figs. 5.8 & 5.9).

ii) Polyether/SS

Polyether and stainless steel differ significantly ($p<0.05$) in all but one area: i.e. group 46 (2-4). (Figs. 5.8 & 5.10).

iii) Plaster/Polyether

Plaster and polyether differ significantly ($p<0.05$) in all but two areas: i.e. group 46 (2-4) and 48 (3-4). (Figs. 5.8 & 5.11.)

The line graphs for group 46 (2-4) (Fig. 5.30) and group 48 (3-4) (Fig. 5.32) are the only graphs where the values for the polyether casts are smaller than the stainless steel model (contractive distortion). In all the other graphs both the polyether and plaster lines lie above the stainless steel line, depicting expansive distortion, with polyether casts having a larger degree of expansive distortion than plaster casts.

This contraction for (2-4) and (3-4) is also depicted in Fig. 5.12 Discrepancy of Median Measurements of Casts. The discrepancy between the casts of the two impression materials compared to the stainless steel model is illustrated in the graph below (Fig. 5.12).

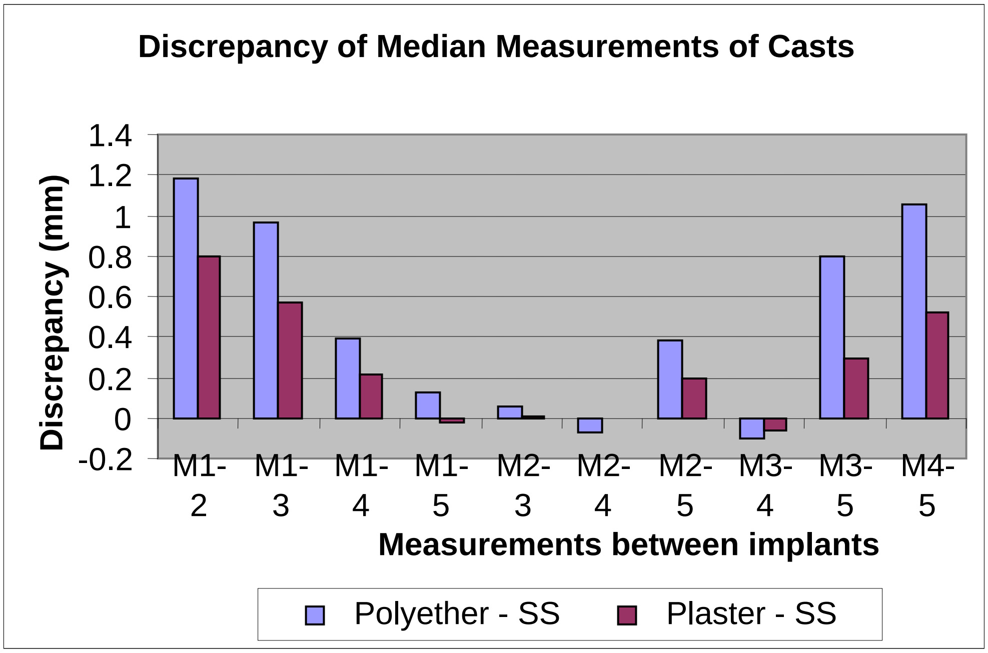

Fig. 5.12 Discrepancy of Median Measurements of Casts

The weight of the lines in Fig 5.13 reflect the magnitude of the discrepancy in relation to its position on the model.

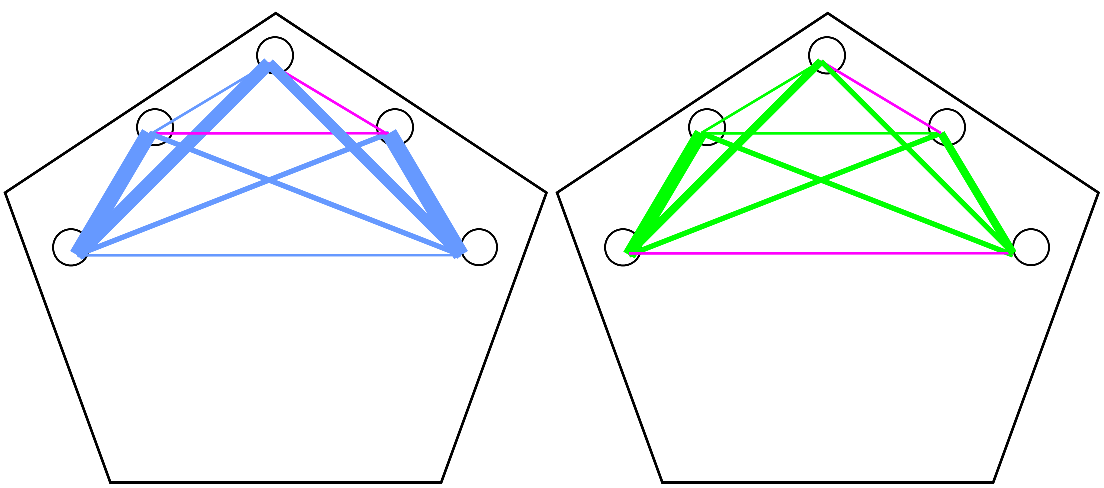

Fig. 5.13 Magnitude of Discrepancy for Casts

Polyether-SS expansion

contraction

Plaster-S expansion

contraction

F-value

The F-value it is another statistical test to determine significance.

Definition of F value: The ANOVA procedure employs the statistic (F) to test the statistical significance of the differences among the obtained means of two or more random samples from a given population. Using the Central Limit Theorem, one calculates two estimates of a population variance.

(1). An estimate in which the s square of the obtained means of the several samples is multiplied by n (the size of the samples).

(2). An estimate that is calculated as the average (mean) of the obtained s squares of the several samples.

The statistic value (F) is formed as the ratio of (1) over (2). If this ratio is sufficiently larger than 1.0, the observed differences among the obtained means are described as being statistically significant.

For the casts, all 10 groups have fairly high F values (ranging from 9.69 to 1282.07) except for group 46 which has a value of less than 1 (0.51). The large F values indicate that the plaster and polyether impression materials do provide significant differences in the casts that they produce. The exception is group 46. (Implant 2-4)

Total Inter-Implant Distances

The following table (5.1) depicts the Total Distances when the 10 various distances (mean values) are added together.

Table 5.1 Total of Mean Distances (mm)

	Polyether	Plaster	S-Steel
Impressions	282.90	282.10	278.74
Casts	284.04	281.31	278.74

From these values were calculated the differences and the percentage of expansion compared to the stainless-steel model as shown in table 5.2. It is noticeable that for the resultant casts the percentage expansion for polyether is double that of plaster.

Table 5.2 Expansion relative to Stainless-steel

	Polyether: mm	% exp Polyether	Plaster: mm	% exp Plaster
Impressions	4.17	1.49	3.37	1.21
Casts	5.30	1.90	2.57	0.92

The chart below of Total of Mean Inter-implant Distances (Fig. 5.14) reflects the sum of all the mean individual inter-implant measurements.

This shows over the total distances that casts from polyether showed more expansive distortion than casts from plaster. In fact, the casts from plaster underwent contraction in relation to their impressions.

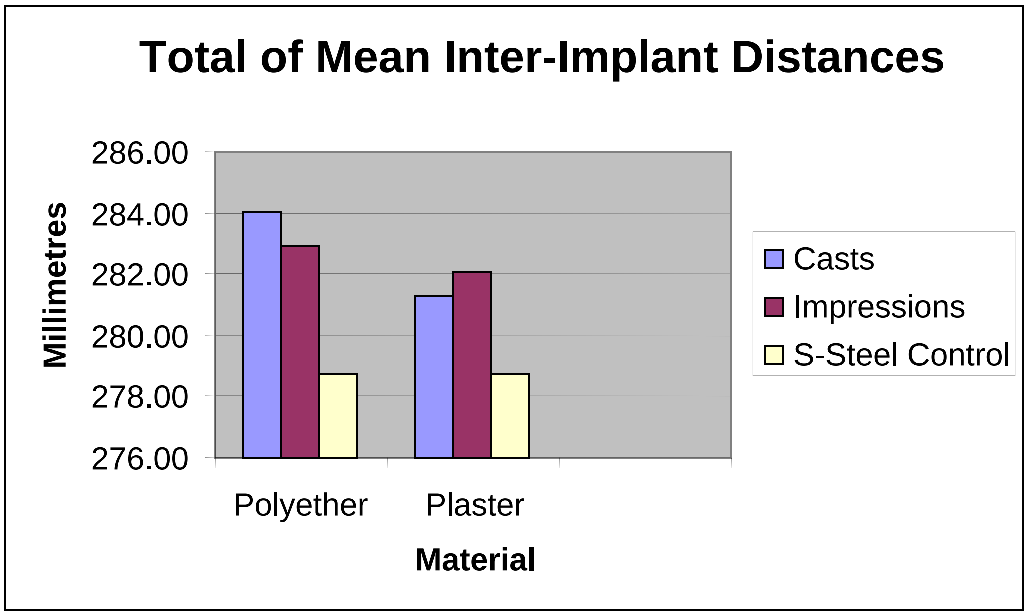

Fig 5.14 Total of Mean Inter-Implant Distances

CHARTS: COMPARISON OF IMPRESSIONS AND S-STEEL

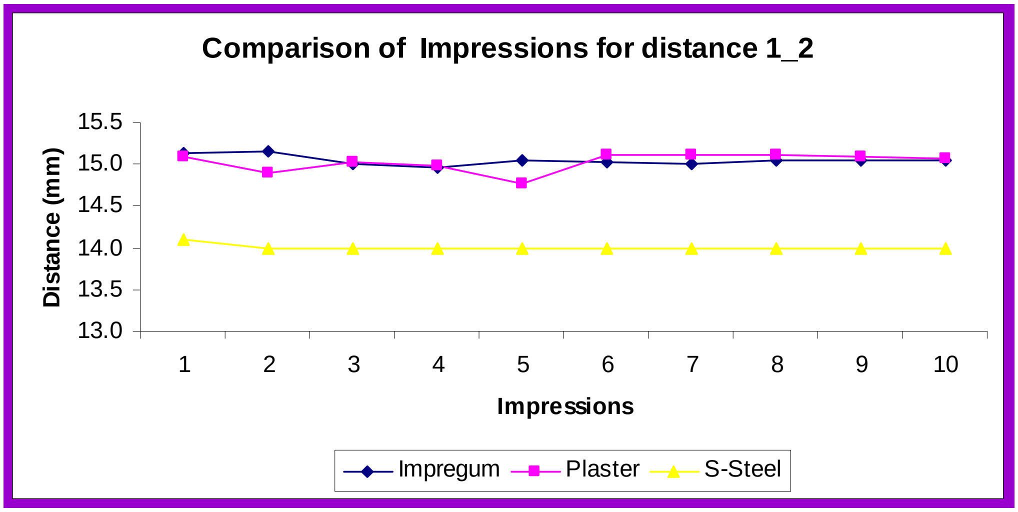

Fig.5.15 Group 41

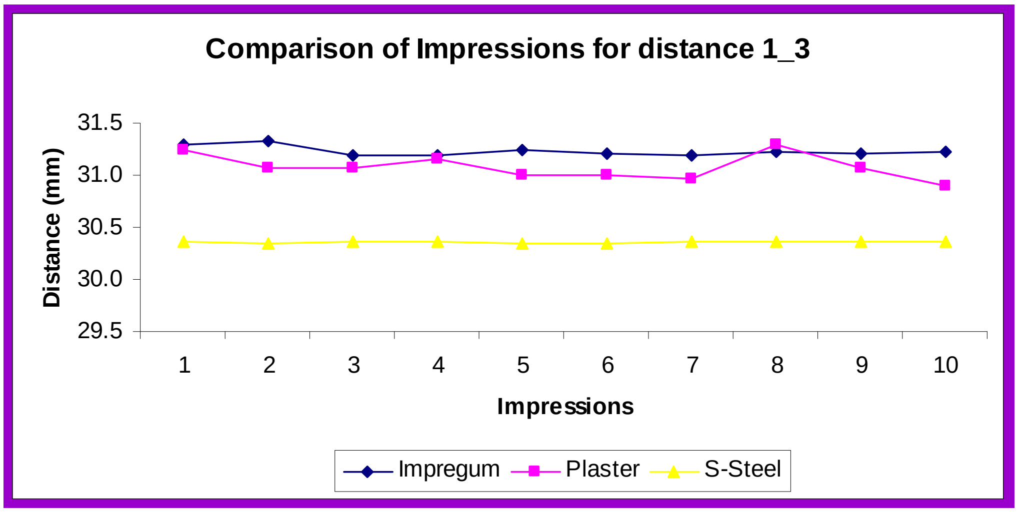

Fig.5.16 Group 42

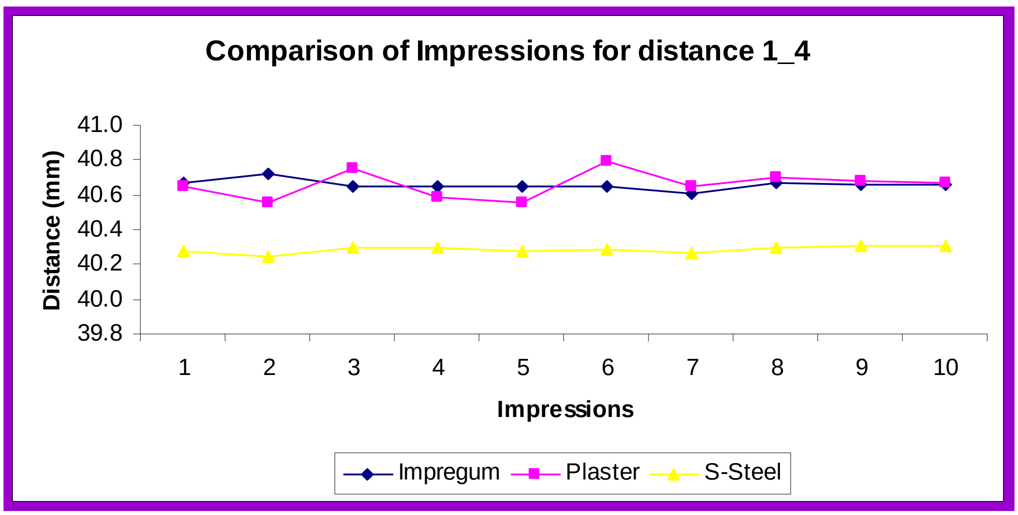

Fig.5.17 Group 43

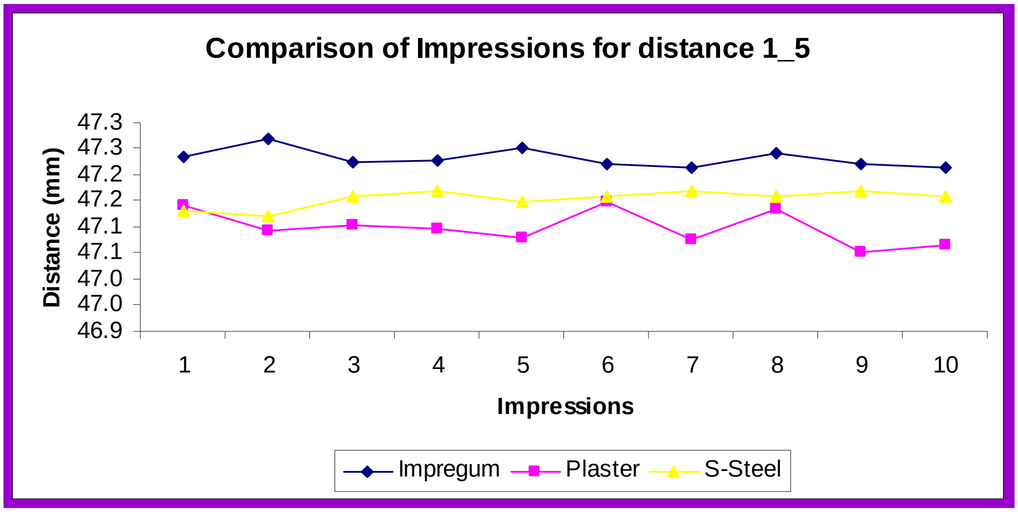

Fig.5.18 Group 44

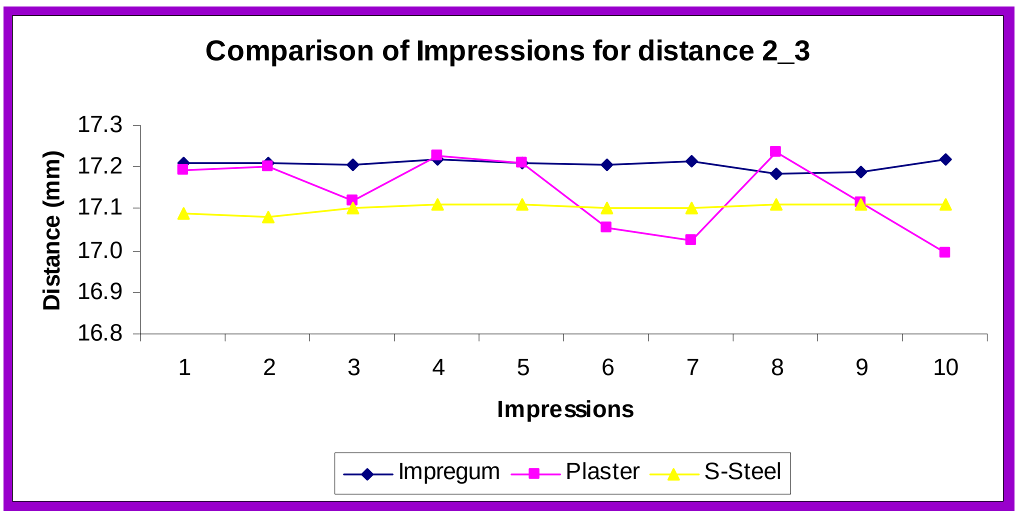

Fig.5.19 Group 45

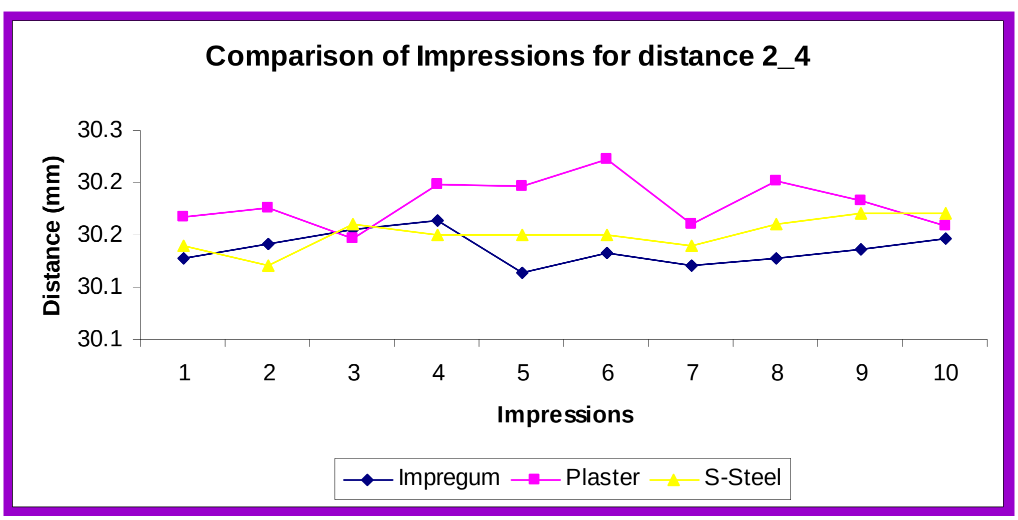

Fig.5.20 Group 46

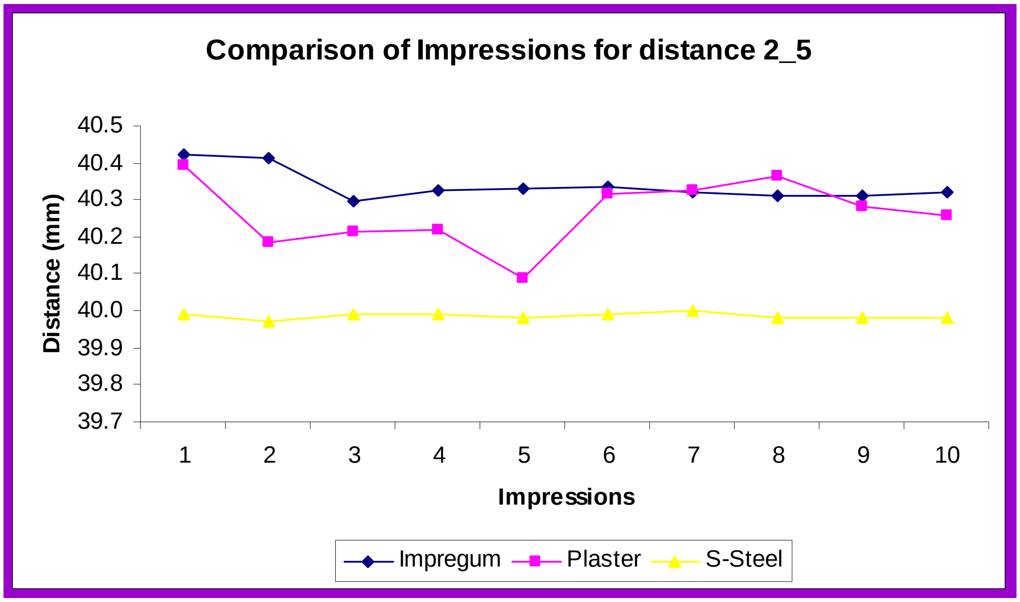

Fig.5.21 Group 47

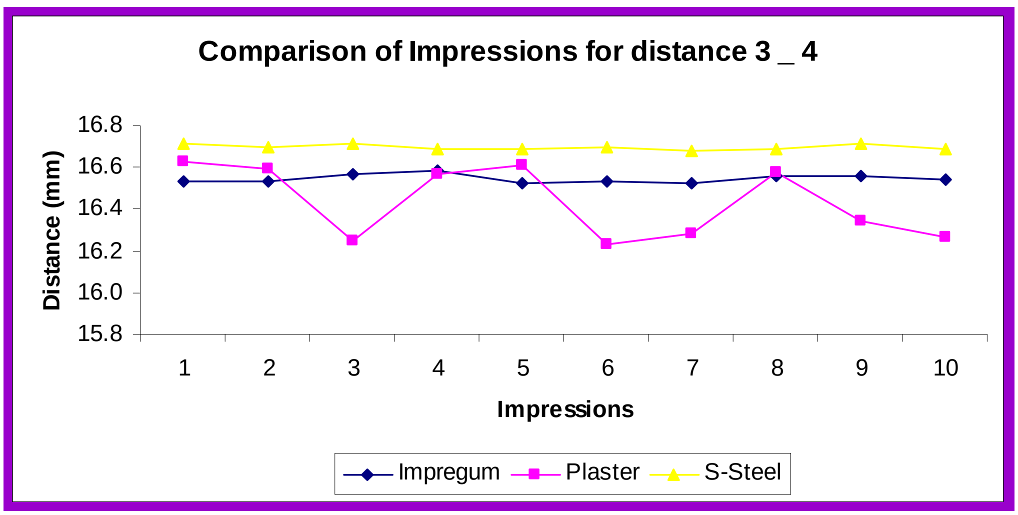

Fig.5.22 Group 48

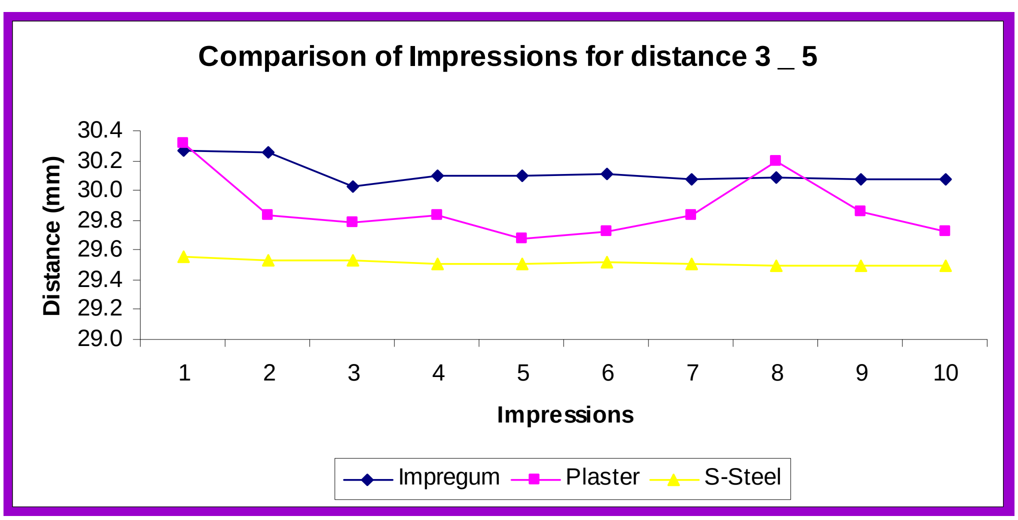

Fig.5.23 Group 49

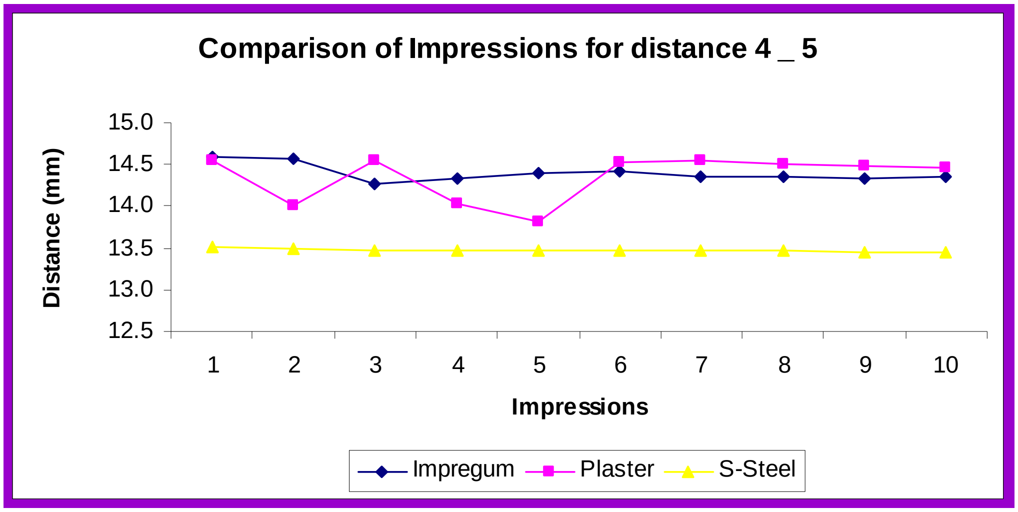

Fig.5.24 Group 50

CHARTS: COMPARISON OF CASTS AND S-STEEL

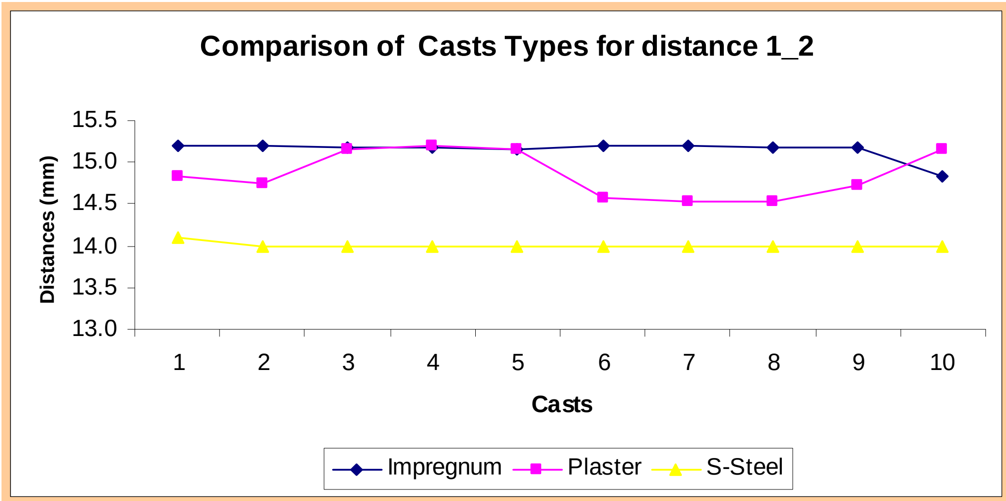

Fig.5.25 Group 41

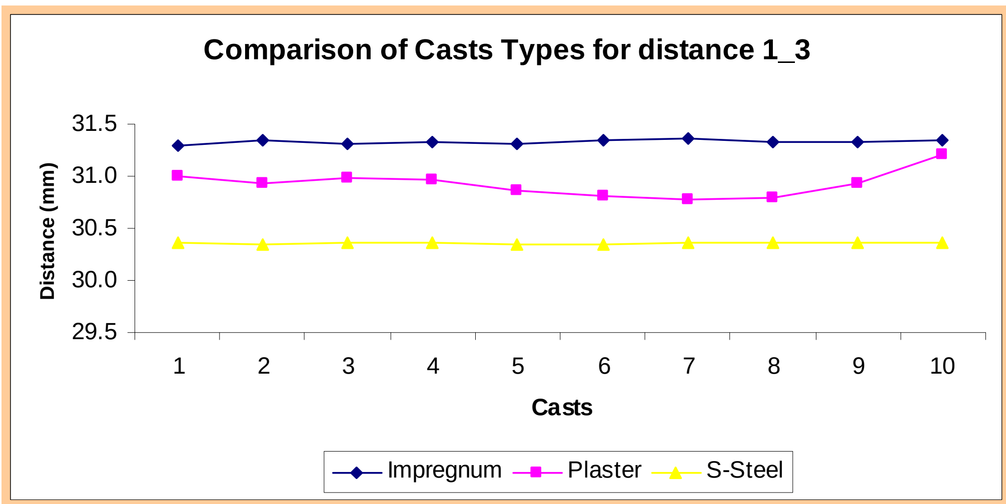

Fig.5.26 Group 42

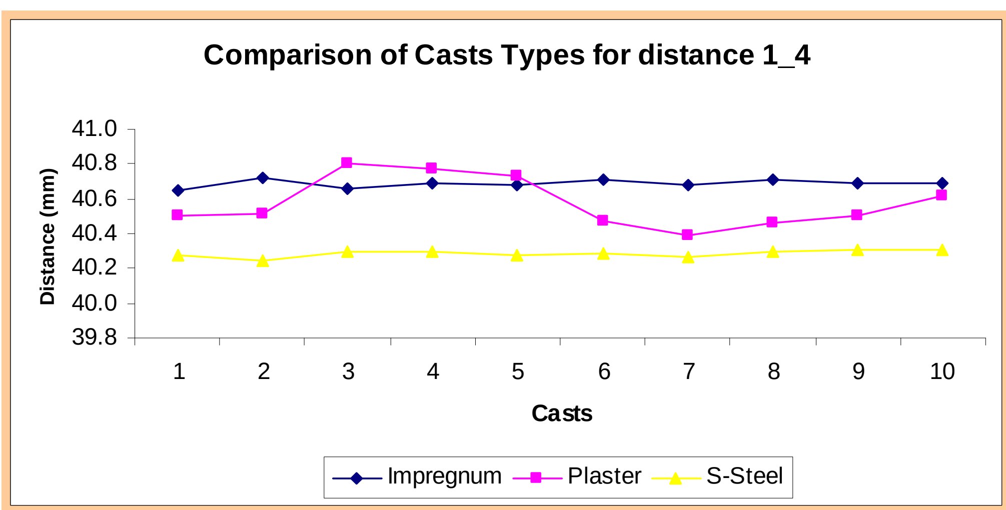

Fig.5.27 Group 43

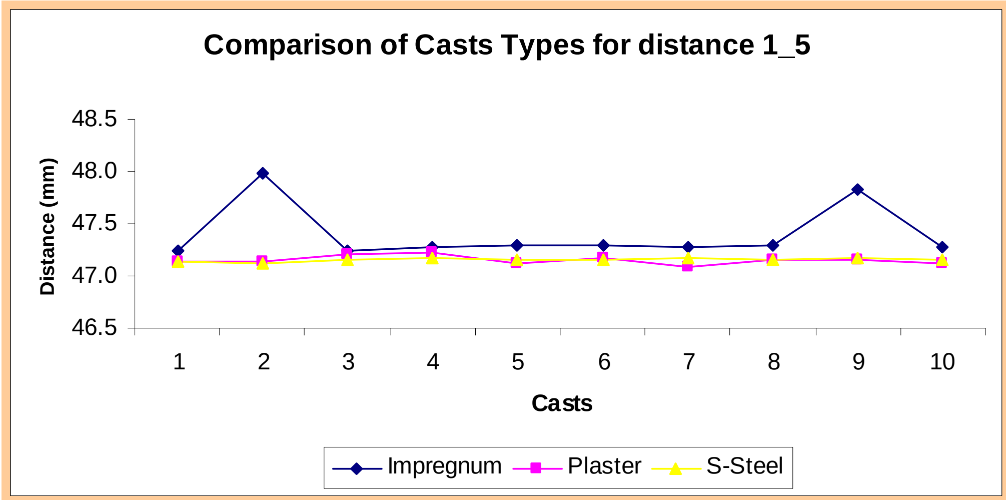

Fig.5.28 Group 44

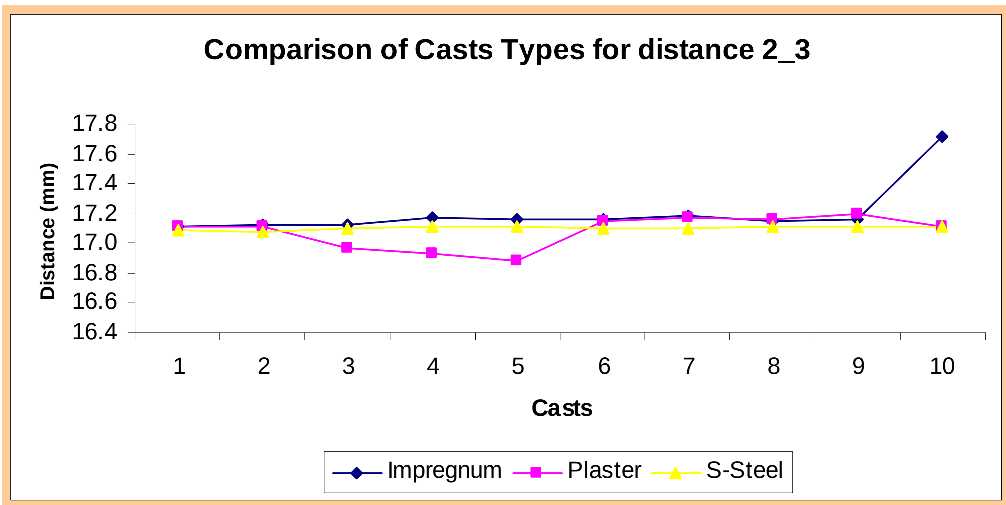

Fig.5.29 Group 45

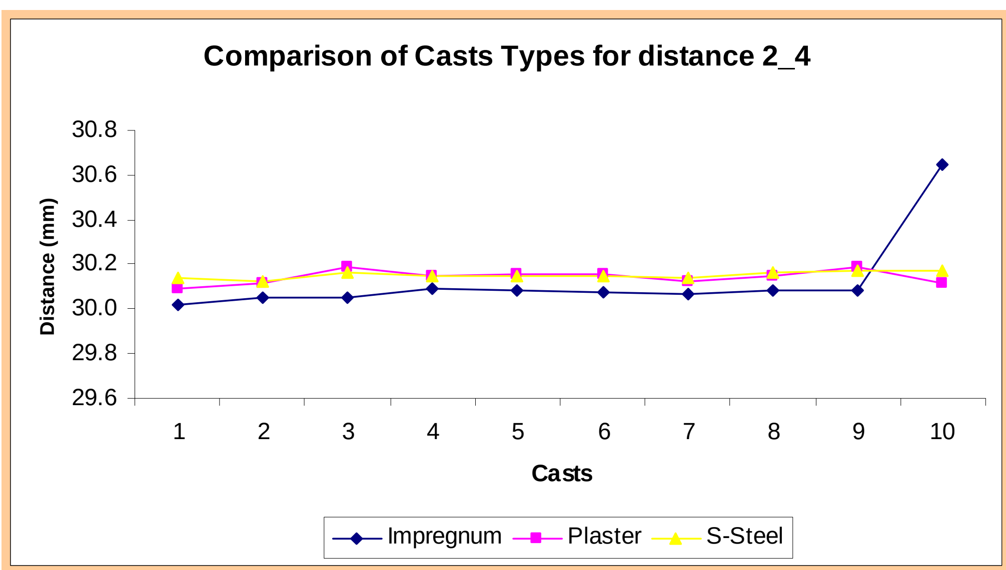

Fig.5.30 Group 46

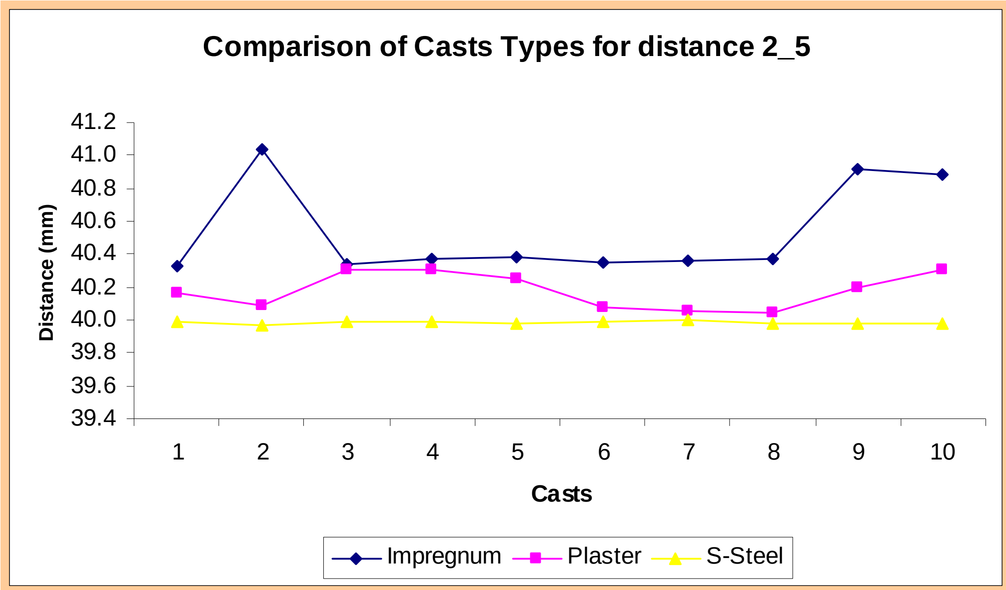

Fig.5.31 Group 47

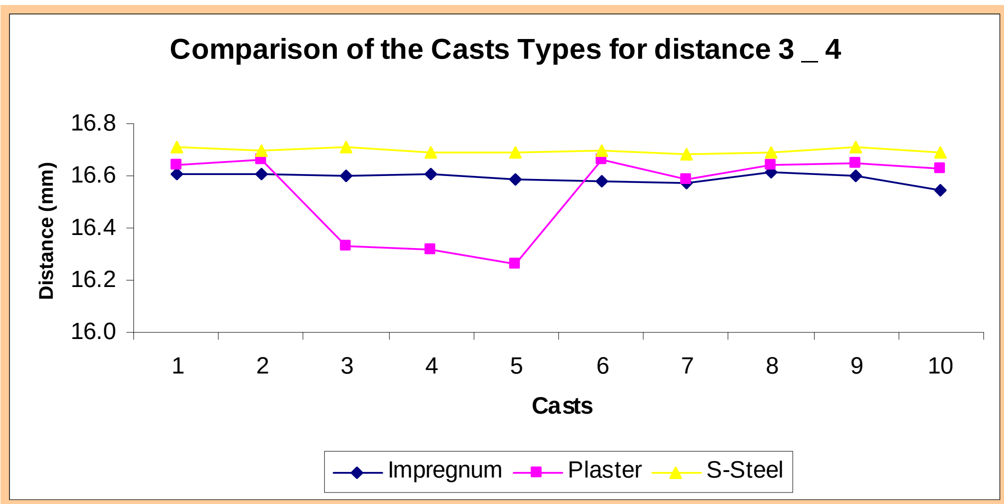

Fig.5.32 Group 48

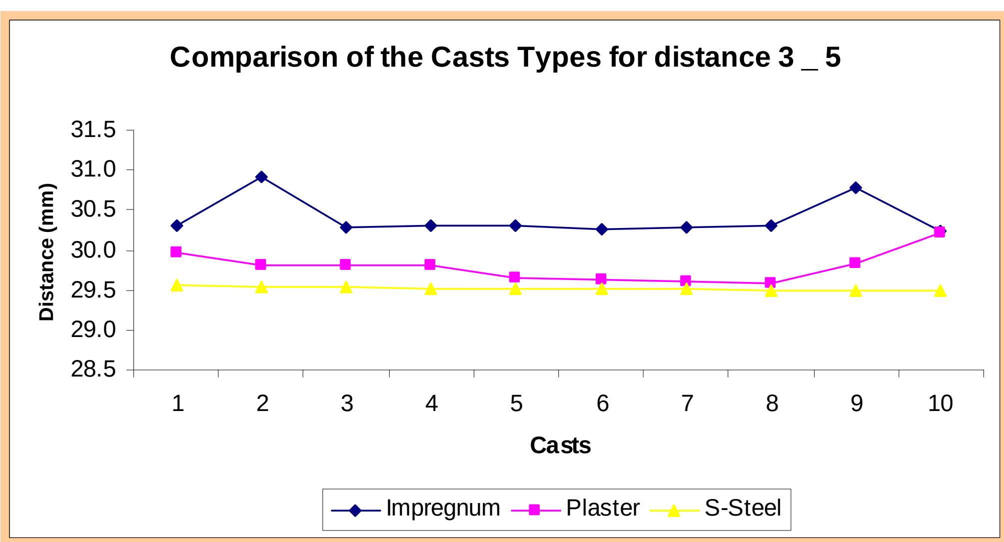

Fig.5.33 Group 49

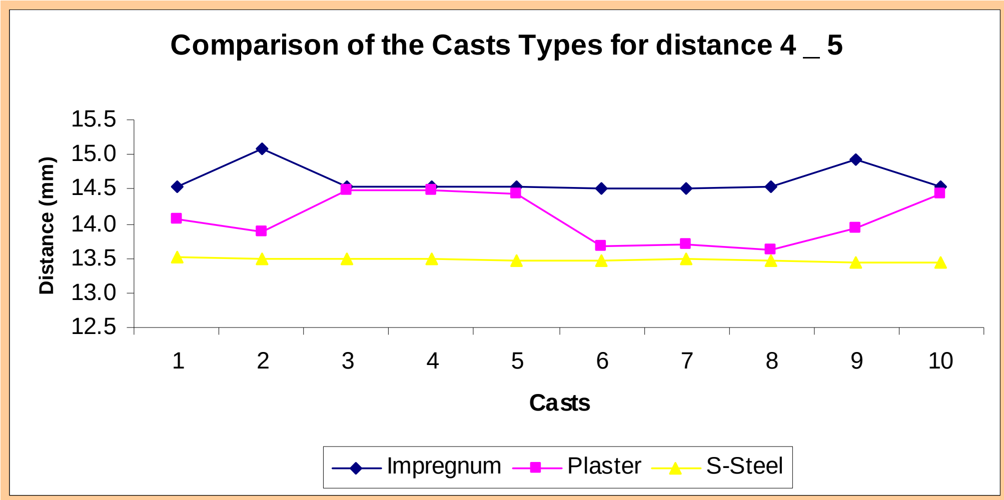

Fig.5.34 Group 50

COMBINED BOX PLOTS WITH SIGNIFICANCE INDICATION

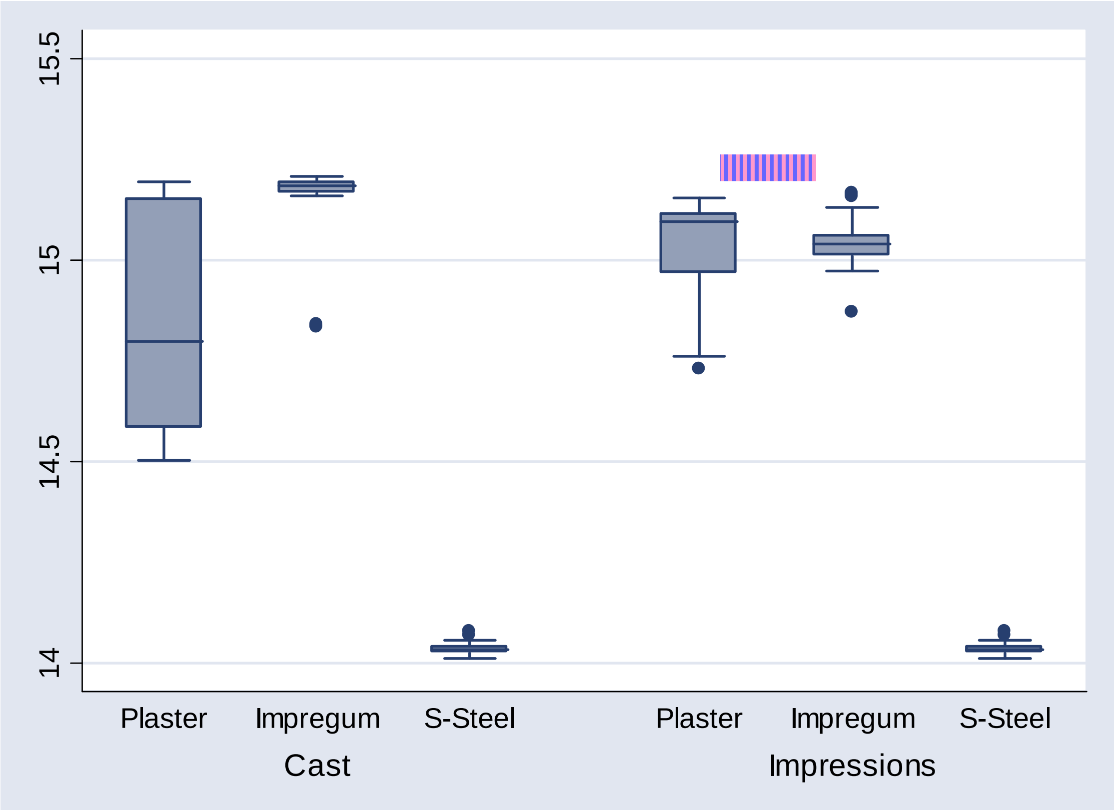

Fig. 5.35 Group 41 (1-2) in mm

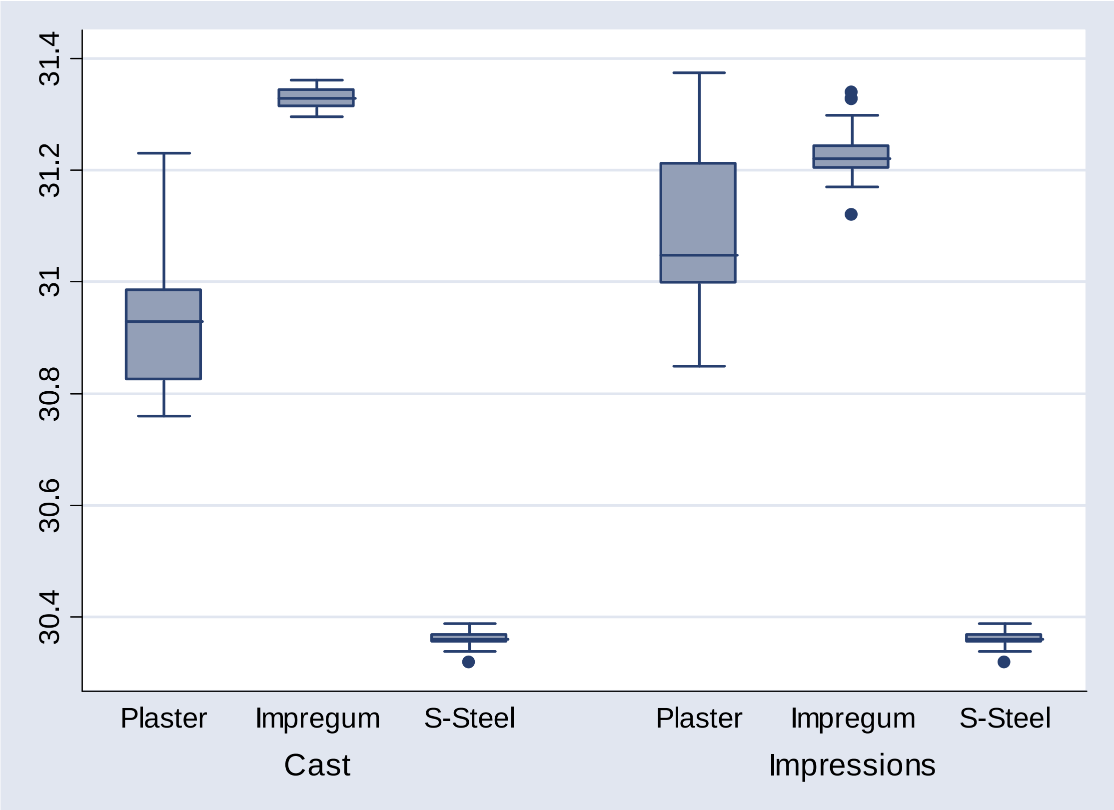

Fig. 5.36 Group 42 (1-3) in mm

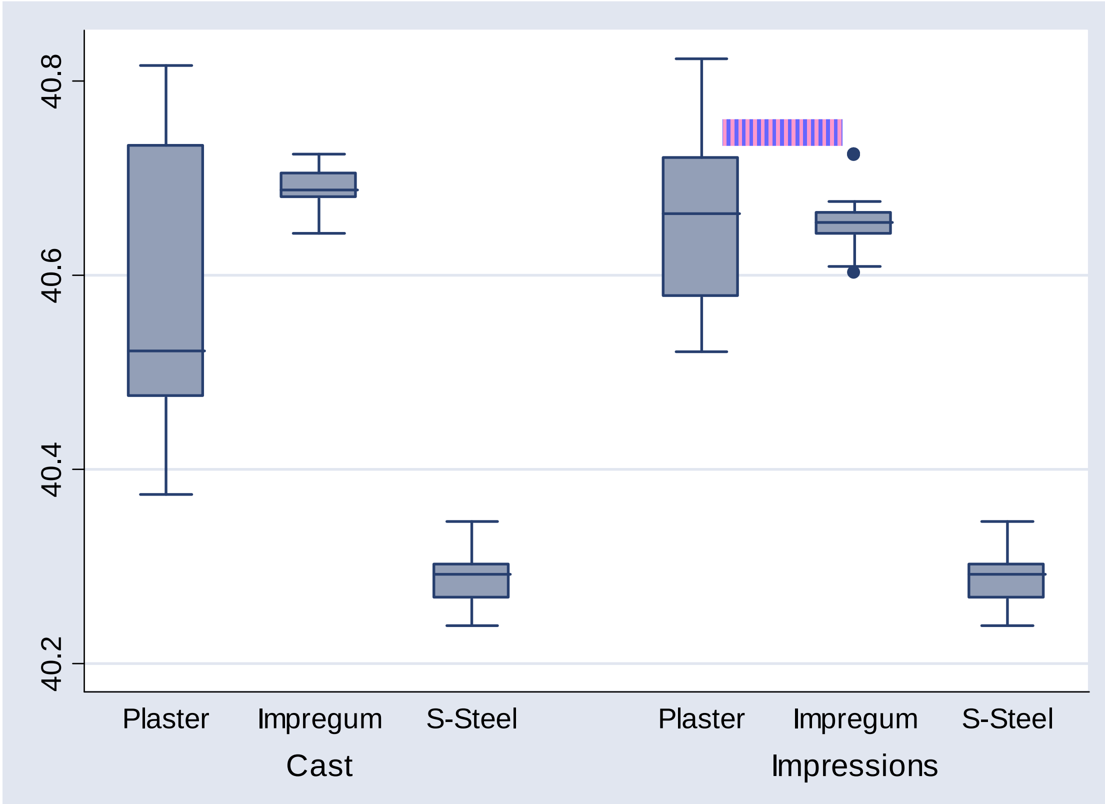

Fig. 5.37 Group 43 (1-4) in mm

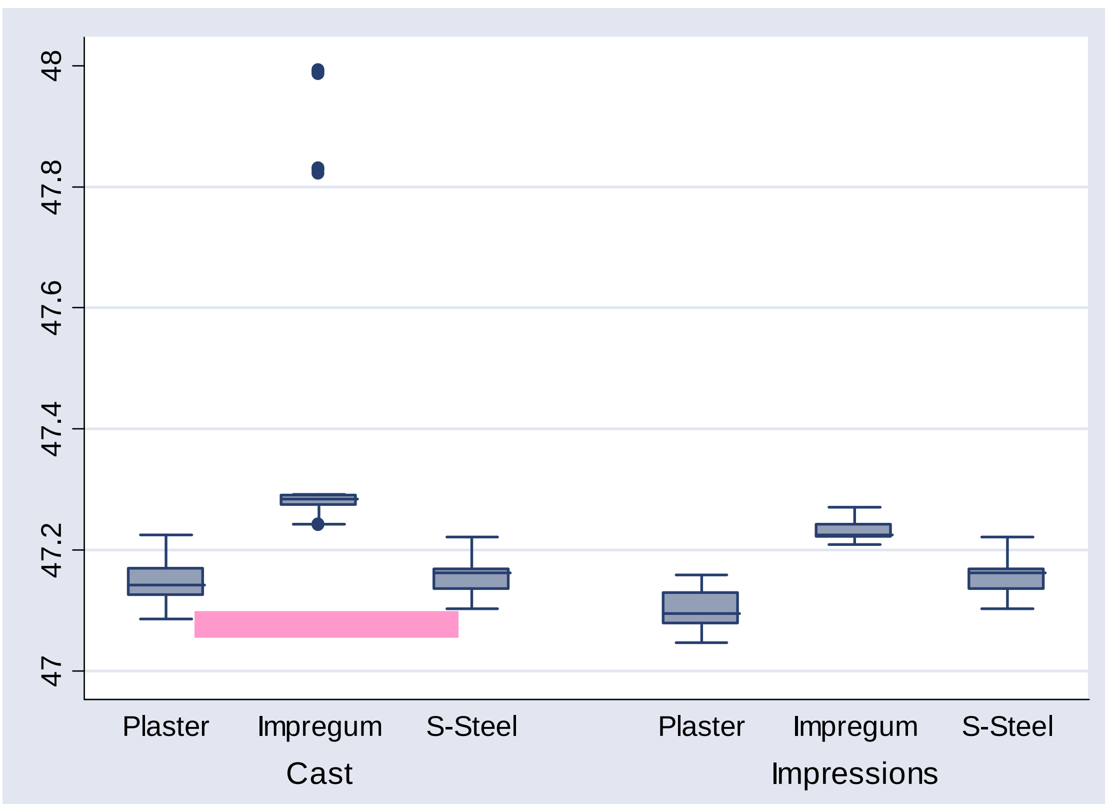

Fig. 5.38 Group 44 (1-5) in mm

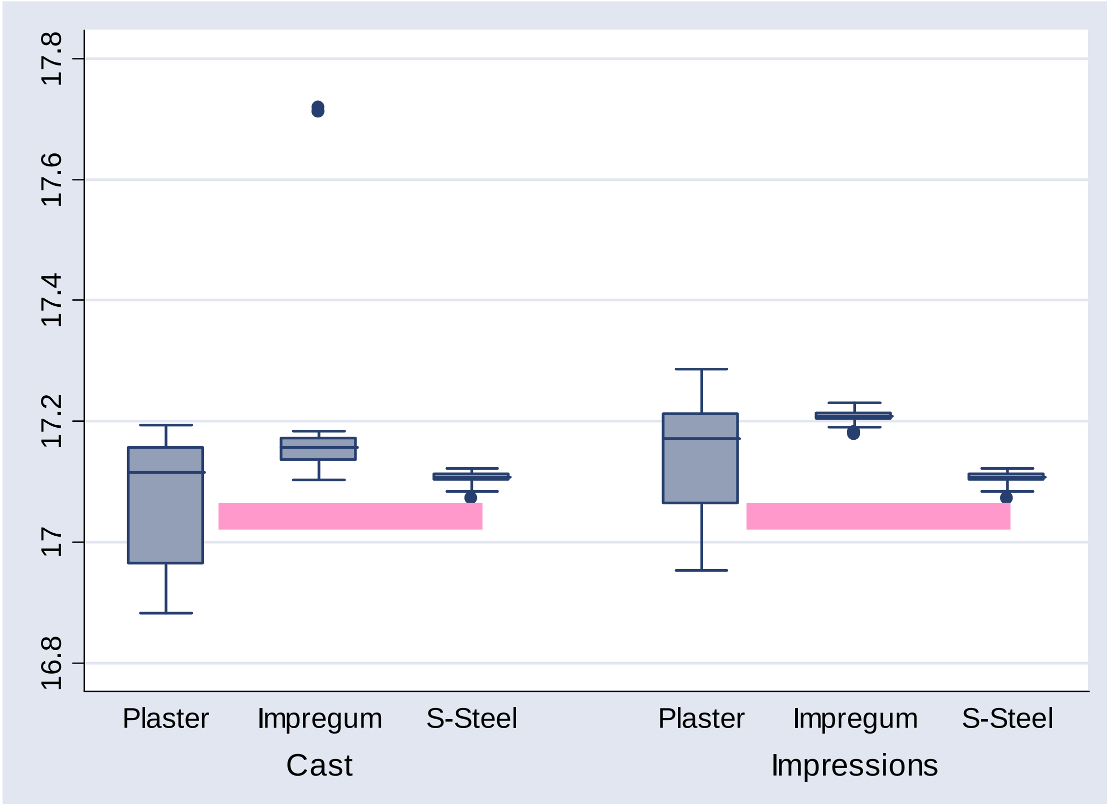

Fig. 5.39 Group 45 (2-3) in mm

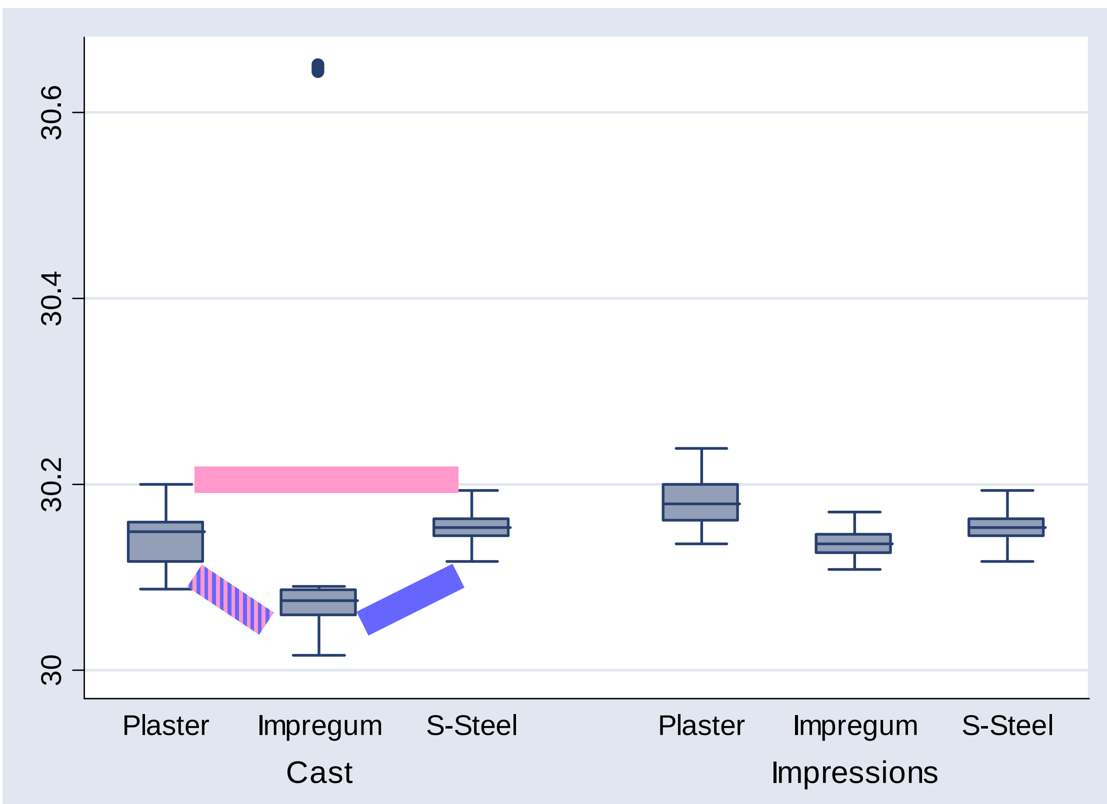

Fig. 5.40 Group 46 (2-4) in mm

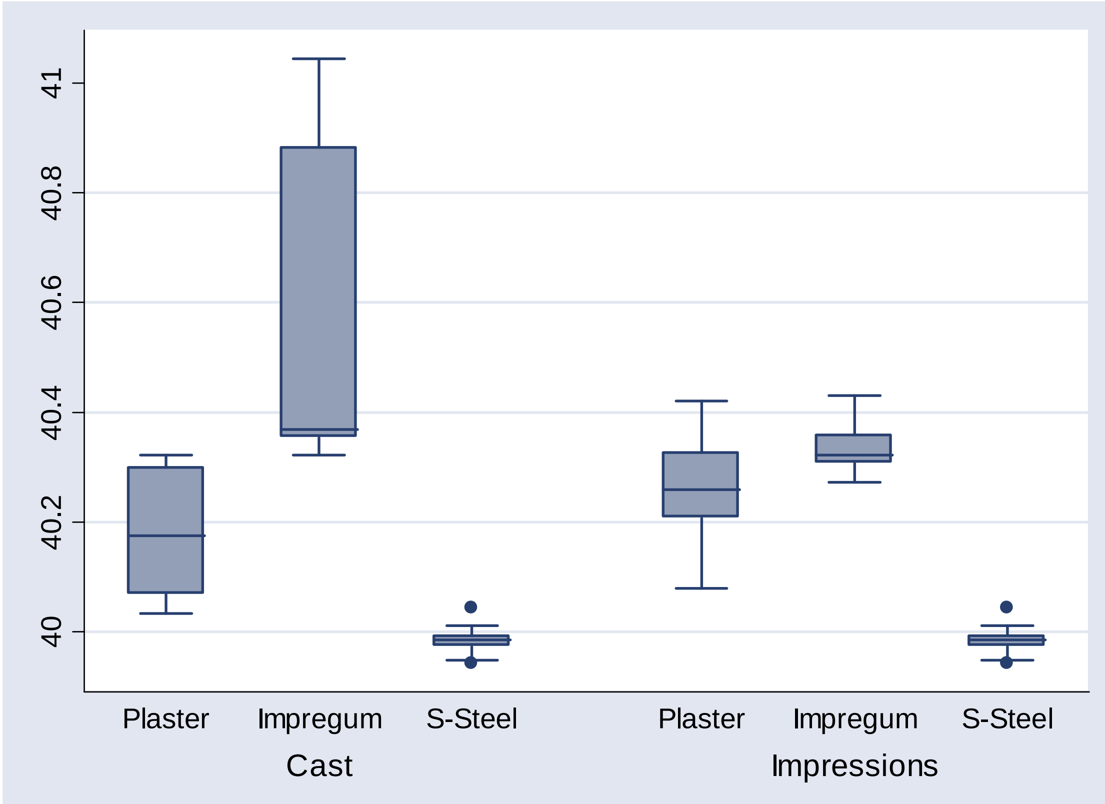

Fig. 5.41 Group 47 (2-5) in mm

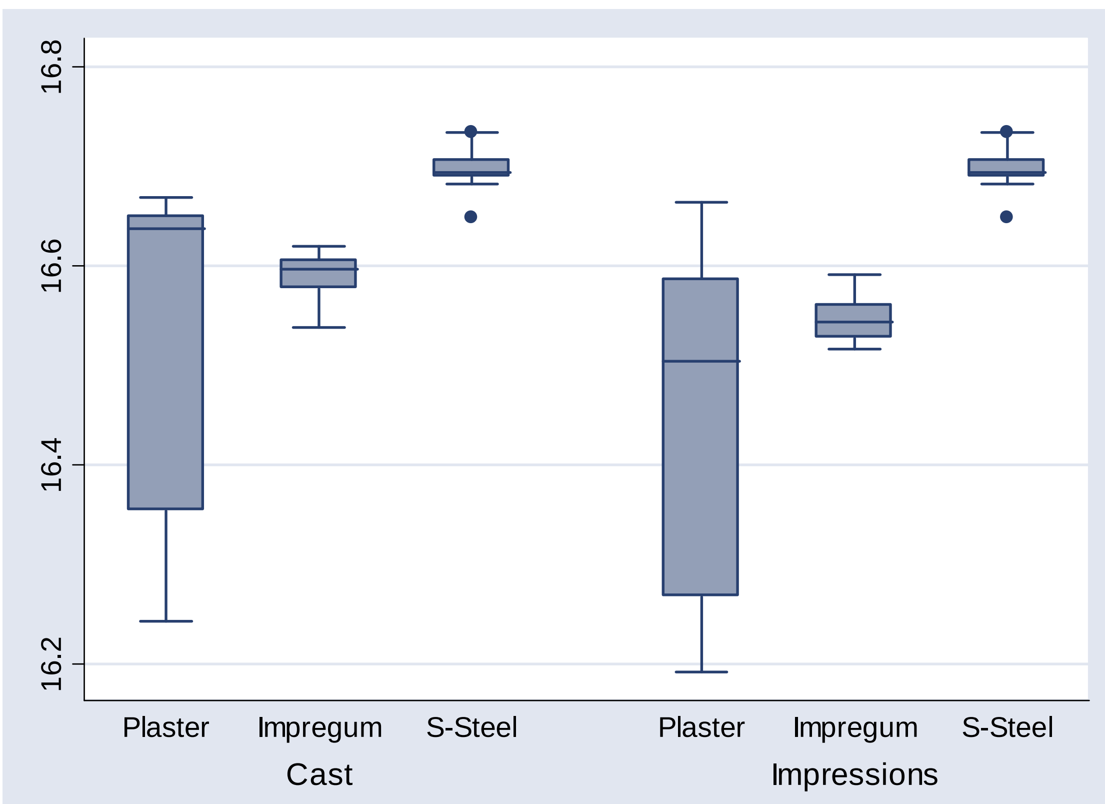

Fig. 5.42 Group 48 (3-4) in mm

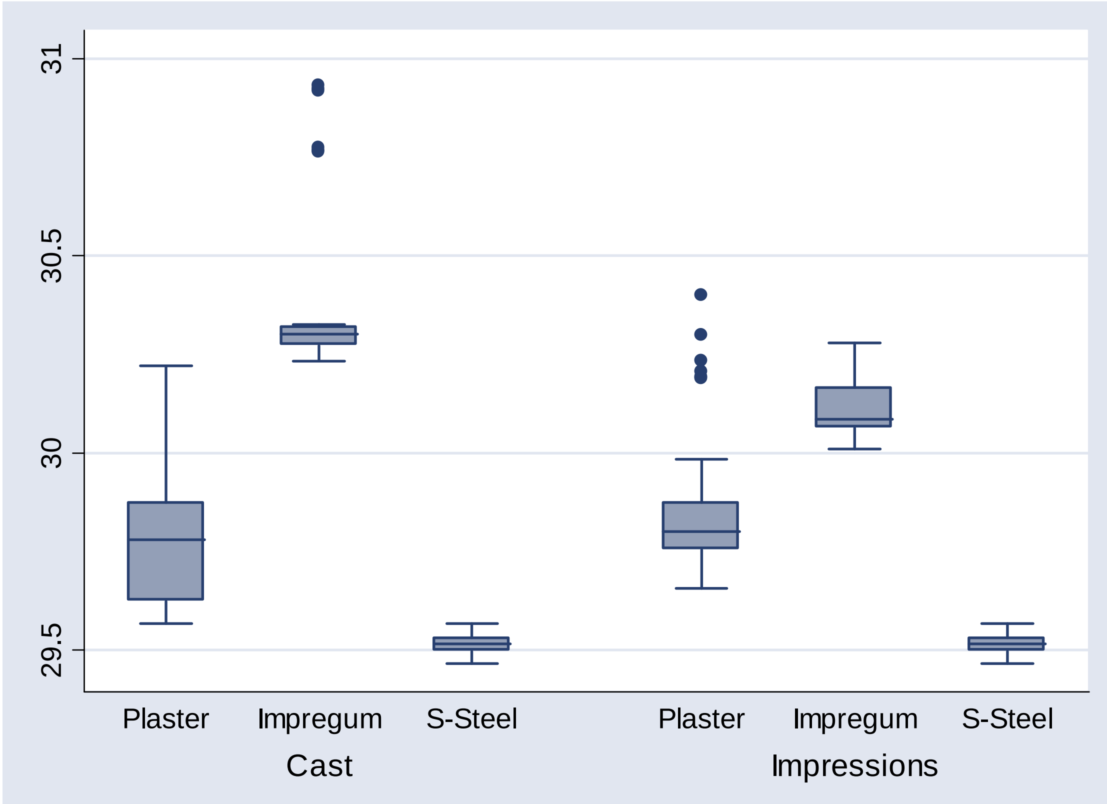

Fig. 5.43 Group 49 (3-5) in mm

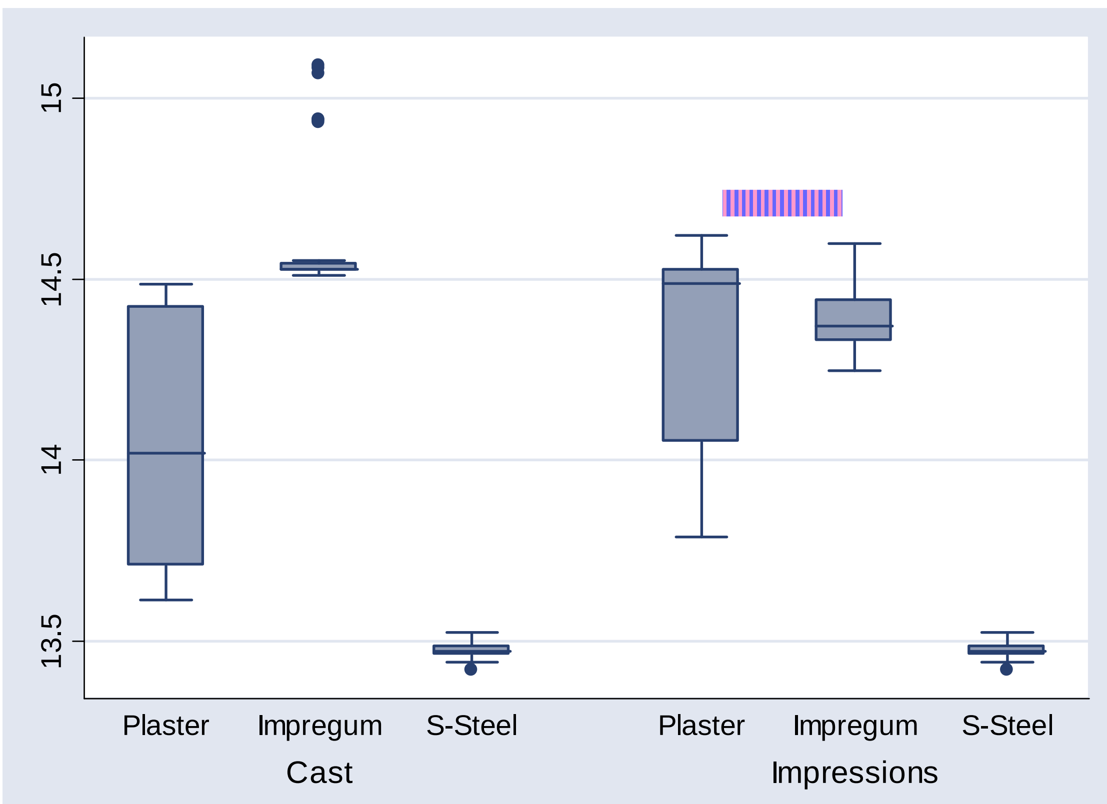

Fig. 5.44 Group 50 (4-5) in mm

6. DISCUSSION

The three-dimensional accuracy of two impression materials was investigated with the use of a Reflex Microscope. By studying the results a few observations were made.

It is not possible to make an undistorted impression or cast. These measurements and the review of the literature shows that it is almost impossible to duplicate the three dimensions from the jaw onto a cast on which a precisely fitting and passive superstructure can be manufactured. It appears from this set of results that horizontal dimensions between implant analogues tend to increase with both impression materials. This supports the findings of Linke et al. [32]. The rationale for using plaster impression material is the limitation of expansive distortion that takes place compared to polyether impressions. The general conclusion from these findings is that plaster creates less distortion, but that the reproduction of consistent dimensions is less predictable. The polyether measurements produced a straighter line graph, showing a better consistency over the ten models, but greater distortion.

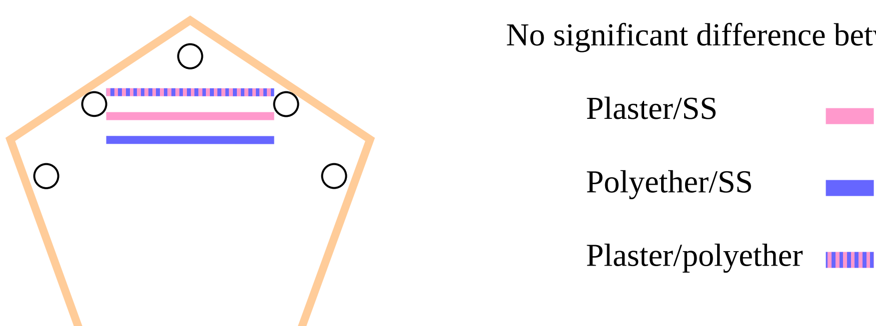

Fig. 6.1 Casts vs S-Steel

Distance 2-4 is the only distance where there is no significant difference for both casts and the master model (Fig. 6.1).

It is essential to have meticulous inspection of laboratory and clinical components during their connection, to prevent avoidable errors in fit which are not inherent to the impression, or laboratory techniques. When looking at the impressions under the Reflex Microscope, the author noticed several fibre or dust-like particles on the impression copings in the plaster impressions. These had to be removed with high pressure air spray before the implant analogues could be connected to the copings. These particles might have flaked off from the plaster and could make a meaningful difference in the vertical position of the analogue when secured over the debris. Distortion is unpredictable and is determined by the site (Figs 5.12 & 5.13). It is likely to be expansive and more so in the anterior-posterior dimension than in a lateral dimension. From Fig. 5.12 it is noticeable that the differences in measurements across the model are negligible. The differences in measurements anterior-posteriorly are much bigger; almost 1 .2 mm for polyether casts from distance 1-2. This may possibly result in a framework that is wide enough but too long in the anterior-posterior dimension. Contraction distortion during the process was found to be less than the expansive distortion resulting in net expansion.

The least distortion appears generally to be across the cast. In this case it included the tilted implants. Group 46 (2-4) recorded a P-value of 0.955 which indicates a non-significant difference between the casts from plaster and the S-Steel model. This was the second highest P-value recorded for casts. The highest was 0.996 also for casts from plaster vs. S-S for group 44 (1-5), indicating the least significance of all measurements. Both measurements were across the cast.

The casts from polyether were generally bigger than their impressions (Fig 5.15) by a magnitude of 1.14mm over the total distance measured (284.04mm for the casts vs. 282.90mm for their impressions)(Table 5.1). That is an expansion of 0.4%. Over the same distance measured the casts from polyether were 5.3mm bigger than the stainless steel model. That is a 1.9% expansion (Table5.2).

The casts from plaster, however, were smaller than their impressions by 0.79mm over the total distance (281.31mm for the casts vs. 282.10mm for their impressions). That is shrinkage of 0.28%. The casts from plaster were still larger than the stainless steel model by 2.57mm which is expansion of 0.92%. From this it appears that the amount of expansion for polyether casts is double that of plaster casts which may be significant in the passive fit of the framework.

As a result of the discrepancies that occur using stone casts, current research and development is being directed towards techniques that eliminated them from the fabrication of the prosthesis. The importance of that is to eliminate the sectioning and luting of the metal framework and thereby having to alter the working model. Sectioning and reassembling the framework is time-consuming and results in a weaker and metallurgically more complex prosthetic framework. The CAD/CAM technique may full-fill this requirement. Images are scanned intraorally or extra orally and frameworks are manufactured from this information. The Procera implant bridge works on this technique. The problem here is that a distorted model is scanned which defeats the object. Ideally the implants should be scanned intraorally, but currently that is a technique which is not yet available.

Passive abutments are components which may be used in cases where a passive fit cannot be established (Fig. 6.2). With an ill-fitting framework passive abutments can be secured over the implants with a small screw. The framework is subsequently cemented onto the passive abutments. Due to the tolerances that exist, the leeway is taken up by cement. Once the cement has set the small screws are removed and the passive abutments will be picked up by the framework. The whole framework can now be secured onto the implants with the bigger screws. This allows the framework to be screw-retained while discrepancies are absorbed in the cement (Fig.6.3).

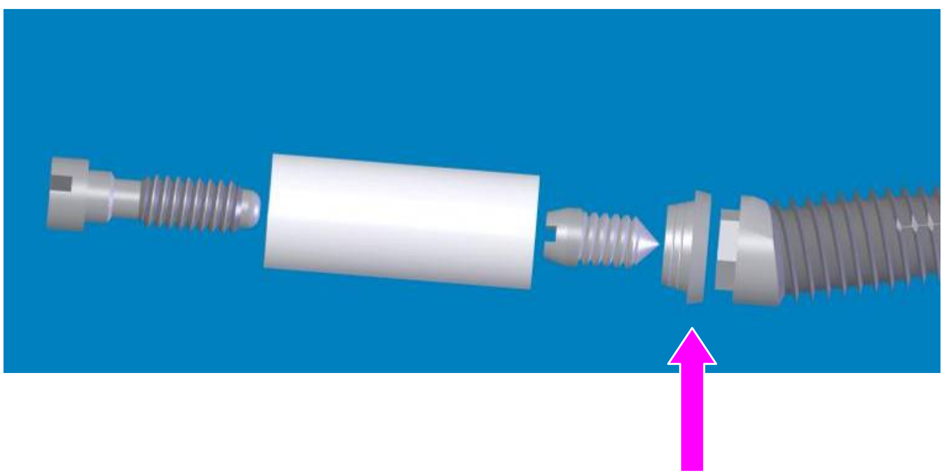

Fig. 6.2 the Passive abutment

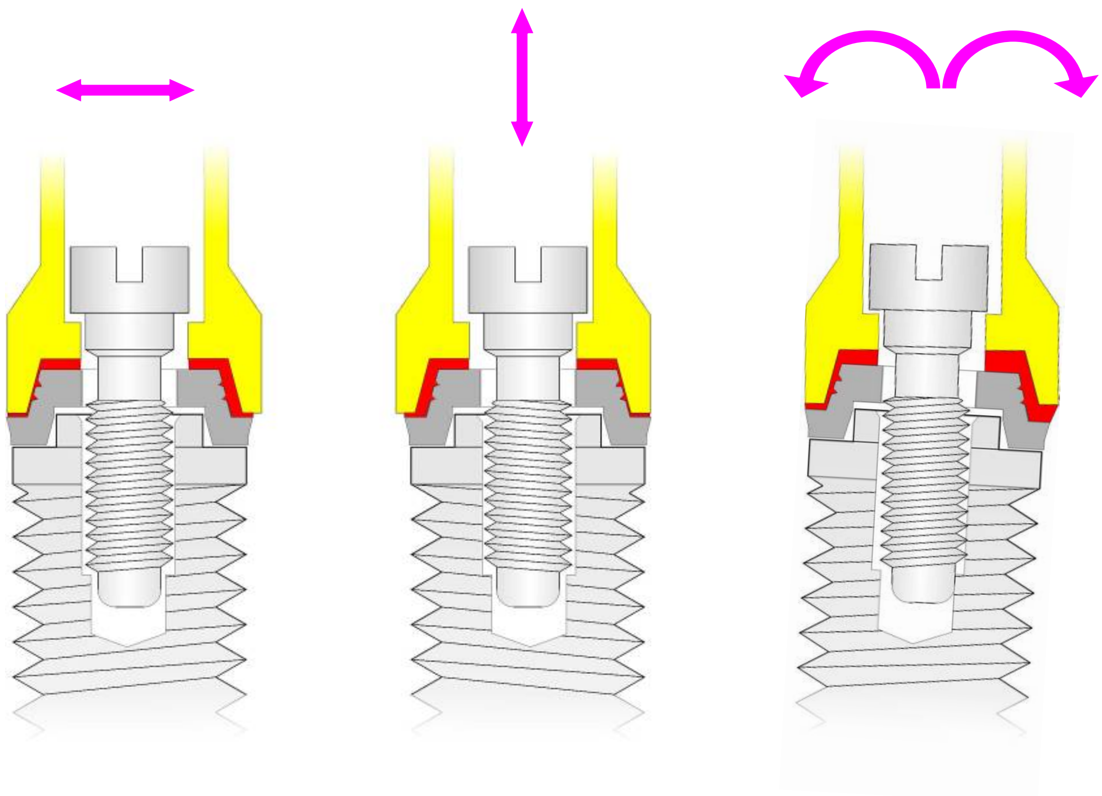

Fig. 6.3 Diagram of passive abutment illustrating its capacity to allow ill-fitting frameworks to be adapted to the implants.

Gallucci et al. [56] immediately loaded implants with a provisional restoration in order to minimise "micromotion". In this way, fibrous encapsulation is prevented, and osseointegration results. When the provisional restoration was removed on a fortnightly basis, screw loosening was found in all patients after the first removal of the prosthesis, but no screw loosening was found 15 days later. It appears that, if the implants are splinted with no tension on them, the normal complications with ill-fitting prostheses are prevented. However, Jemt and Book [5] disagree, and state that no orthodontic adjustment takes place around osseointegrated implants with stress introduced on them. Hoshaw, Brunski and Cochran [57] concluded that there was an increased bone modelling response at the periosteal surface near loaded implants.

Further study in this field is necessary.

7. CONCLUSION

Under the conditions of this study the following conclusions can be drawn with respect to distortion of implant analogue positions on the master cast:

1. The null hypothesis is rejected as there is a significant difference between models made using polyether impression material compared to those made with plaster impression material.

2. Plaster impression material results in less expansion of the cast, but in more variance with less predictability.

3. As a result of this finding, plaster impression material should be considered for full arch implant supported prostheses.

4. Digital intraoral scanning of the implants may be the future solution for more accurate reproduction of implant positions.

5. A plaster free technique may be considered where a passive cementation matrix is used. The cementation matrix is screwed onto the implants, luted together and taken off. Implant analogues are connected to the cementation matrix and attached to each other without using plaster. Theoretically no distortion takes place.

8. APPENDIX A TABLE OF MEANS IMPRESSIONS

```
. anova  distance  type model type* model if group==41

                           Number of obs =      90     R-squared     =  0.9938
                           Root MSE      = .046197     Adj R-squared =  0.9908

                  Source |  Partial SS    df       MS           F     Prob > F
              -----------+----------------------------------------------------
                   Model |  20.5522996    29  .708699986     332.08     0.0000
                         |
                    type |   20.104063     2  10.0520315    4710.10     0.0000
                   model |  .145838885     9  .016204321       7.59     0.0000
              type*model |  .302397676    18  .016799871       7.87     0.0000
                         |
                Residual |  .128048584    60  .002134143
              -----------+----------------------------------------------------
                   Total |  20.6803482    89  .232363463

. table  type  model if group==41, c(mean  distance n distance sd  distance) format(%7.2f)

--------------------------------------------------------------------------------
          |                               model
  typelbl |     1      2      3      4      5      6      7      8      9     10
----------+---------------------------------------------------------------------
 Impregum | 15.12  15.16  15.00  14.96  15.04  15.03  15.00  15.05  15.05  15.04
          |     3      3      3      3      3      3      3      3      3      3
          |  0.01   0.00   0.02   0.08   0.02   0.02   0.02   0.01   0.05   0.01
          |
 Plaster  | 15.10  14.90  15.04  14.99  14.77  15.12  15.11  15.12  15.10  15.07
          |     3      3      3      3      3      3      3      3      3      3
          |  0.01   0.14   0.09   0.14   0.05   0.00   0.01   0.01   0.00   0.00
          |
  S-Steel | 14.07  14.04  14.05  14.03  14.02  14.03  14.03  14.03  14.03  14.03
          |     3      3      3      3      3      3      3      3      3      3
          |  0.01   0.02   0.01   0.01   0.01   0.00   0.01   0.00   0.01   0.01
--------------------------------------------------------------------------------

. anova  distance  type model type* model if group==42

                           Number of obs =      90     R-squared     =  0.9903
                           Root MSE      = .046811     Adj R-squared =  0.9856

                  Source |  Partial SS    df       MS           F     Prob > F
              -----------+----------------------------------------------------
                   Model |  13.4156254    29  .462607771     211.11     0.0000
                         |
                    type |  12.9399282     2  6.46996408    2952.61     0.0000
                   model |  .185396713     9  .020599635       9.40     0.0000
              type*model |   .29030049    18  .016127805       7.36     0.0000
                         |
                Residual |  .131475971    60  .002191266
              -----------+----------------------------------------------------
                   Total |  13.5471013    89  .152214622

. table  type  model if group==42, c(mean  distance n distance sd  distance) format(%7.2f)

--------------------------------------------------------------------------------
          |                               model
  typelbl |     1      2      3      4      5      6      7      8      9     10
----------+---------------------------------------------------------------------
 Impregum | 31.29  31.33  31.19  31.18  31.23  31.21  31.19  31.23  31.21  31.23
          |     3      3      3      3      3      3      3      3      3      3
          |  0.01   0.01   0.02   0.06   0.02   0.01   0.02   0.01   0.03   0.01
          |
 Plaster  | 31.25  31.08  31.07  31.16  31.00  31.00  30.96  31.29  31.07  30.90
          |     3      3      3      3      3      3      3      3      3      3
          |  0.01   0.12   0.07   0.11   0.04   0.02   0.12   0.07   0.07   0.03
          |
  S-Steel | 30.37  30.34  30.37  30.36  30.35  30.35  30.36  30.37  30.36  30.36
          |     3      3      3      3      3      3      3      3      3      3
          |  0.01   0.02   0.03   0.01   0.02   0.01   0.02   0.00   0.01   0.01
--------------------------------------------------------------------------------
```

```
. anova  distance  type model type* model if group==43

                           Number of obs =      90     R-squared     =  0.9851
                           Root MSE      = .027246     Adj R-squared =  0.9779

                  Source |  Partial SS    df       MS           F     Prob > F
              -----------+----------------------------------------------------
                   Model |  2.94475649    29  .101543327     136.79     0.0000
                         |
                    type |  2.75075177     2  1.37537588    1852.74     0.0000
                   model |  .061889896     9  .006876655       9.26     0.0000
              type*model |  .132114826    18  .007339713       9.89     0.0000
                         |
                Residual |  .044540725    60  .000742345
              -----------+----------------------------------------------------
                   Total |  2.98929722    89  .033587609

. table  type  model if group==43, c(mean  distance n distance sd  distance) format(%7.2f)

--------------------------------------------------------------------------------
          |                                model
  typelbl |     1      2      3      4      5      6      7      8      9     10
----------+---------------------------------------------------------------------
 Impregum | 40.66  40.72  40.65  40.64  40.64  40.65  40.61  40.66  40.65  40.65
          |     3      3      3      3      3      3      3      3      3      3
          |  0.01   0.00   0.01   0.03   0.01   0.01   0.01   0.00   0.01   0.01
          |
 Plaster  | 40.65  40.55  40.75  40.59  40.55  40.79  40.65  40.70  40.68  40.67
          |     3      3      3      3      3      3      3      3      3      3
          |  0.01   0.05   0.02   0.05   0.02   0.04   0.08   0.04   0.01   0.01
          |
  S-Steel | 40.28  40.25  40.30  40.30  40.28  40.29  40.27  40.30  40.31  40.31
          |     3      3      3      3      3      3      3      3      3      3
          |  0.02   0.01   0.05   0.01   0.02   0.01   0.03   0.01   0.01   0.02
--------------------------------------------------------------------------------

. anova  distance  type model type* model if group==44

                           Number of obs =      90     R-squared     =  0.9548
                           Root MSE      = .015648     Adj R-squared =  0.9330

                  Source |  Partial SS    df       MS           F     Prob > F
              -----------+----------------------------------------------------
                   Model |  .310683858    29  .010713236      43.75     0.0000
                         |
                    type |  .263743248     2  .131871624     538.57     0.0000
                   model |  .010595793     9   .00117731       4.81     0.0001
              type*model |  .036344817    18  .002019156       8.25     0.0000
                         |
                Residual |  .014691357    60  .000244856
              -----------+----------------------------------------------------
                   Total |  .325375215    89  .003655901

. table  type  model if group==44, c(mean  distance n distance sd  distance) format(%7.2f)

--------------------------------------------------------------------------------
          |                                model
  typelbl |     1      2      3      4      5      6      7      8      9     10
----------+---------------------------------------------------------------------
 Impregum | 47.23  47.27  47.22  47.23  47.25  47.22  47.21  47.24  47.22  47.21
          |     3      3      3      3      3      3      3      3      3      3
          |  0.01   0.00   0.00   0.00   0.01   0.00   0.00   0.01   0.00   0.00
          |
 Plaster  | 47.14  47.09  47.10  47.10  47.08  47.15  47.08  47.14  47.05  47.06
          |     3      3      3      3      3      3      3      3      3      3
          |  0.02   0.01   0.01   0.01   0.01   0.01   0.00   0.01   0.01   0.00
          |
  S-Steel | 47.13  47.12  47.16  47.17  47.15  47.16  47.17  47.16  47.17  47.16
          |     3      3      3      3      3      3      3      3      3      3
          |  0.02   0.01   0.05   0.01   0.04   0.01   0.05   0.00   0.00   0.00
--------------------------------------------------------------------------------
```

```
. anova  distance  type model type* model if group==45

                           Number of obs =      90     R-squared     =  0.9395
                           Root MSE      = .020263     Adj R-squared =  0.9103

                  Source |  Partial SS    df       MS           F     Prob > F
              -----------+----------------------------------------------------
                   Model |  .382535143    29  .013190867      32.13     0.0000
                         |
                    type |   .16015753     2  .080078765     195.03     0.0000
                   model |  .065652762     9  .007294751      17.77     0.0000
              type*model |  .156724851    18  .008706936      21.21     0.0000
                         |
                Residual |  .024635493    60  .000410592
              -----------+----------------------------------------------------
                   Total |  .407170636    89  .004574951

. table  type  model if group==45, c(mean  distance n distance sd  distance) format(%7.2f)

--------------------------------------------------------------------------------
          |                                model
  typelbl |     1      2      3      4      5      6      7      8      9     10
----------+---------------------------------------------------------------------
 Impregum | 17.21  17.21  17.20  17.22  17.21  17.20  17.21  17.18  17.19  17.22
          |     3      3      3      3      3      3      3      3      3      3
          |  0.00   0.01   0.01   0.01   0.01   0.00   0.01   0.01   0.01   0.01
          |
 Plaster  | 17.19  17.20  17.12  17.23  17.21  17.05  17.02  17.24  17.11  16.99
          |     3      3      3      3      3      3      3      3      3      3
          |  0.02   0.00   0.01   0.01   0.00   0.01   0.07   0.04   0.05   0.02
          |
  S-Steel | 17.09  17.08  17.10  17.11  17.11  17.10  17.11  17.11  17.11  17.11
          |     3      3      3      3      3      3      3      3      3      3
          |  0.02   0.00   0.02   0.00   0.01   0.00   0.01   0.00   0.00   0.00
--------------------------------------------------------------------------------

. anova  distance  type model type* model if group==46

                           Number of obs =      90     R-squared     =  0.8669
                           Root MSE      = .012059     Adj R-squared =  0.8025

                  Source |  Partial SS    df       MS           F     Prob > F
              -----------+----------------------------------------------------
                   Model |  .056806257    29  .001958836      13.47     0.0000
                         |
                    type |  .030587536     2  .015293768     105.18     0.0000
                   model |  .008526503     9  .000947389       6.52     0.0000
              type*model |  .017692218    18  .000982901       6.76     0.0000
                         |
                Residual |  .008724747    60  .000145412
              -----------+----------------------------------------------------
                   Total |  .065531004    89  .000736303
```

```
. table  type  model if group==46, c(mean  distance n distance sd  distance) format(%7.2f)

--------------------------------------------------------------------------------
          |                                model
  typelbl |     1      2      3      4      5      6      7      8      9     10
----------+---------------------------------------------------------------------
 Impregum | 30.13  30.14  30.16  30.16  30.11  30.13  30.12  30.13  30.14  30.15
          |     3      3      3      3      3      3      3      3      3      3
          |  0.01   0.00   0.01   0.01   0.01   0.01   0.01   0.01   0.00   0.01
          |
 Plaster  | 30.17  30.18  30.15  30.20  30.20  30.22  30.16  30.20  30.18  30.16
          |     3      3      3      3      3      3      3      3      3      3
          |  0.02   0.00   0.01   0.01   0.01   0.01   0.01   0.01   0.02   0.00
          |
  S-Steel | 30.14  30.12  30.16  30.15  30.15  30.15  30.14  30.16  30.17  30.17
          |     3      3      3      3      3      3      3      3      3      3
          |  0.01   0.00   0.04   0.00   0.01   0.01   0.02   0.00   0.01   0.00
--------------------------------------------------------------------------------
```

```
. anova  distance  type model type* model if group==47

                          Number of obs =      90     R-squared     =  0.9820
                          Root MSE      = .026877     Adj R-squared =  0.9734

                 Source |  Partial SS    df       MS           F     Prob > F
             -----------+----------------------------------------------------
                  Model |  2.36953211    29  .081708004     113.11     0.0000
                        |
                   type |  2.09572743     2  1.04786371    1450.54     0.0000
                  model |  .103635824     9  .011515092      15.94     0.0000
             type*model |  .170168861    18  .009453826      13.09     0.0000
                        |
               Residual |  .043343738    60  .000722396
             -----------+----------------------------------------------------
                  Total |  2.41287585    89  .027110965

. table  type  model if group==47, c(mean  distance n distance sd  distance) format(%7.2f)

--------------------------------------------------------------------------------
          |                                 model
  typelbl |     1      2      3      4      5      6      7      8      9     10
----------+---------------------------------------------------------------------
 Impregum | 40.42  40.41  40.30  40.32  40.33  40.33  40.32  40.31  40.31  40.32
          |     3      3      3      3      3      3      3      3      3      3
          |  0.01   0.01   0.00   0.03   0.01   0.03   0.00   0.04   0.01   0.03
          |
 Plaster  | 40.39  40.19  40.21  40.22  40.09  40.32  40.33  40.36  40.28  40.26
          |     3      3      3      3      3      3      3      3      3      3
          |  0.03   0.03   0.03   0.02   0.01   0.03   0.08   0.04   0.02   0.01
          |
  S-Steel | 39.99  39.97  39.99  39.99  39.98  39.99  40.00  39.98  39.98  39.98
          |     3      3      3      3      3      3      3      3      3      3
          |  0.01   0.01   0.03   0.00   0.03   0.00   0.04   0.00   0.02   0.01
--------------------------------------------------------------------------------

. anova  distance  type model type* model if group==48

                          Number of obs =      90     R-squared     =  0.9809
                          Root MSE      =  .02456     Adj R-squared =  0.9717

                 Source |  Partial SS    df       MS           F     Prob > F
             -----------+----------------------------------------------------
                  Model |  1.85772709    29  .064059555     106.20     0.0000
                        |
                   type |  1.04091444     2  .520457222     862.86     0.0000
                  model |  .272464132     9  .030273792      50.19     0.0000
             type*model |  .544348516    18  .030241584      50.14     0.0000
                        |
               Residual |   .03619075    60  .000603179
             -----------+----------------------------------------------------
                  Total |  1.89391784    89  .021279976

. table  type  model if group==48, c(mean  distance n distance sd  distance) format(%7.2f)

--------------------------------------------------------------------------------
          |                                 model
  typelbl |     1      2      3      4      5      6      7      8      9     10
----------+---------------------------------------------------------------------
 Impregum | 16.54  16.54  16.56  16.58  16.52  16.53  16.53  16.56  16.56  16.54
          |     3      3      3      3      3      3      3      3      3      3
          |  0.01   0.01   0.01   0.01   0.00   0.01   0.00   0.00   0.00   0.01
          |
 Plaster  | 16.63  16.60  16.25  16.57  16.61  16.23  16.29  16.58  16.34  16.26
          |     3      3      3      3      3      3      3      3      3      3
          |  0.04   0.01   0.04   0.01   0.01   0.04   0.04   0.01   0.09   0.03
          |
  S-Steel | 16.71  16.70  16.71  16.69  16.69  16.70  16.68  16.69  16.71  16.69
          |     3      3      3      3      3      3      3      3      3      3
          |  0.00   0.01   0.02   0.00   0.01   0.01   0.02   0.01   0.01   0.01
--------------------------------------------------------------------------------
```

```
. anova  distance  type model type* model if group==49

                           Number of obs =      90     R-squared     =  0.9846
                           Root MSE      =  .04232     Adj R-squared =  0.9772

                  Source |  Partial SS    df       MS           F     Prob > F
              -----------+----------------------------------------------------
                   Model |   6.8733753    29  .237012942     132.33     0.0000
                         |
                    type |   5.5081407     2  2.75407035    1537.72     0.0000
                   model |  .651615976     9  .072401775      40.43     0.0000
              type*model |  .713618633    18   .03964548      22.14     0.0000
                         |
                Residual |  .107460864    60  .001791014
              -----------+----------------------------------------------------
                   Total |  6.98083617    89  .078436361

. table  type  model if group==49, c(mean  distance n distance sd  distance) format(%7.2f)

--------------------------------------------------------------------------------
          |                                 model
  typelbl |     1      2      3      4      5      6      7      8      9     10
----------+---------------------------------------------------------------------
 Impregum | 30.27  30.25  30.03  30.10  30.09  30.11  30.07  30.09  30.08  30.08
          |     3      3      3      3      3      3      3      3      3      3
          |  0.01   0.01   0.02   0.06   0.02   0.06   0.02   0.08   0.01   0.04
          |
 Plaster  | 30.31  29.83  29.79  29.83  29.67  29.72  29.84  30.20  29.85  29.72
          |     3      3      3      3      3      3      3      3      3      3
          |  0.08   0.04   0.05   0.04   0.02   0.06   0.04   0.01   0.12   0.04
          |
  S-Steel | 29.55  29.53  29.53  29.51  29.51  29.52  29.51  29.50  29.50  29.49
          |     3      3      3      3      3      3      3      3      3      3
          |  0.01   0.01   0.02   0.01   0.02   0.02   0.02   0.02   0.03   0.03
--------------------------------------------------------------------------------

. anova  distance  type model type* model if group==50

                           Number of obs =      90     R-squared     =  0.9961
                           Root MSE      =  .03498     Adj R-squared =  0.9942

                  Source |  Partial SS    df       MS           F     Prob > F
              -----------+----------------------------------------------------
                   Model |  18.5597263    29  .639990561     523.04     0.0000
                         |
                    type |  16.1627583     2  8.08137914    6604.55     0.0000
                   model |  .717910126     9  .079767792      65.19     0.0000
              type*model |  1.67905788    18  .093280993      76.23     0.0000
                         |
                Residual |  .073416491    60  .001223608
              -----------+----------------------------------------------------
                   Total |  18.6331428    89  .209361155

. table  type  model if group==50, c(mean  distance n distance sd  distance) format(%7.2f)

--------------------------------------------------------------------------------
          |                                 model
  typelbl |     1      2      3      4      5      6      7      8      9     10
----------+---------------------------------------------------------------------
 Impregum | 14.59  14.58  14.28  14.33  14.39  14.42  14.36  14.35  14.34  14.36
          |     3      3      3      3      3      3      3      3      3      3
          |  0.01   0.01   0.02   0.07   0.03   0.08   0.03   0.09   0.01   0.05
          |
 Plaster  | 14.56  14.01  14.55  14.04  13.82  14.53  14.54  14.50  14.48  14.46
          |     3      3      3      3      3      3      3      3      3      3
          |  0.05   0.05   0.01   0.04   0.03   0.00   0.01   0.01   0.01   0.00
          |
  S-Steel | 13.51  13.50  13.48  13.48  13.47  13.47  13.48  13.46  13.45  13.45
          |     3      3      3      3      3      3      3      3      3      3
          |  0.01   0.03   0.01   0.01   0.02   0.01   0.02   0.01   0.02   0.01
--------------------------------------------------------------------------------
. log off
       log:  C:\Dudu\Von Berg\Data2m23.log
  log type:  text
```

Comparison of the means

```
      log:  C:\Dudu\Von Berg\Data2m23.log
 log type:  text
resumed on:  22 Mar 2006, 07:53:15

.  oneway  distance  type if   group==41,tabulate scheffe

            |         Summary of distance
    typelbl |        Mean   Std. Dev.       Freq.
------------+------------------------------------
   Impregum |       15.04        0.06          30
   Plaster  |       15.03        0.12          30
    S-Steel |       14.03        0.02          30
------------+------------------------------------
      Total |       14.70        0.48          90

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups       20.104063      2   10.0520315   1517.52     0.0000
 Within groups      .576285145     87   .006623967
------------------------------------------------------------------------
    Total           20.6803482     89   .232363463

Bartlett's test for equal variances:  chi2(2) =  81.8621  Prob>chi2 = 0.000

                      Comparison of distance by typelbl
                                  (Scheffe)
Row Mean-|
Col Mean |   Impregum   Plaster
---------+----------------------
Plaster  |      -0.01
         |      0.782
         |
 S-Steel |      -1.01      -1.00
         |      0.000      0.000
```

```
.  oneway  distance  type if   group==42,tabulate scheffe

            |         Summary of distance
    typelbl |        Mean   Std. Dev.       Freq.
------------+------------------------------------
   Impregum |       31.23        0.05          30
   Plaster  |       31.08        0.14          30
    S-Steel |       30.36        0.01          30
------------+------------------------------------
      Total |       30.89        0.39          90

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      12.9399282      2   6.46996408    927.06     0.0000
 Within groups      .607173174     87   .006979002
------------------------------------------------------------------------
    Total           13.5471013     89   .152214622

Bartlett's test for equal variances:  chi2(2) = 101.1718  Prob>chi2 = 0.000

                      Comparison of distance by typelbl
                                  (Scheffe)
Row Mean-|
Col Mean |   Impregum   Plaster
---------+----------------------
Plaster  |      -0.15
         |      0.000
         |
 S-Steel |      -0.87      -0.72
         |      0.000      0.000
```

```
.  oneway  distance  type if   group==43,tabulate scheffe

            |         Summary of distance
    typelbl |        Mean   Std. Dev.       Freq.
------------+------------------------------------
   Impregum |       40.66        0.03          30
   Plaster  |       40.66        0.08          30
    S-Steel |       40.29        0.03          30
------------+------------------------------------
      Total |       40.53        0.18          90

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      2.75075177      2   1.37537588    501.61     0.0000
 Within groups      .238545447     87   .002741902
------------------------------------------------------------------------
    Total           2.98929722     89   .033587609

Bartlett's test for equal variances:  chi2(2) =  49.1541  Prob>chi2 = 0.000

                      Comparison of distance by typelbl
                                  (Scheffe)
Row Mean-|
Col Mean |   Impregum   Plaster
---------+----------------------
Plaster  |       0.00
         |      0.972
         |
 S-Steel |      -0.37      -0.37
         |      0.000      0.000



.  oneway  distance  type if   group==44,tabulate scheffe

            |         Summary of distance
    typelbl |        Mean   Std. Dev.       Freq.
------------+------------------------------------
   Impregum |       47.23        0.02          30
   Plaster  |       47.10        0.03          30
    S-Steel |       47.15        0.03          30
------------+------------------------------------
      Total |       47.16        0.06          90

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      .263743248      2   .131871624    186.15     0.0000
 Within groups      .061631967     87   .000708413
------------------------------------------------------------------------
    Total           .325375215     89   .003655901

Bartlett's test for equal variances:  chi2(2) =  10.2315  Prob>chi2 = 0.006

                      Comparison of distance by typelbl
                                  (Scheffe)
Row Mean-|
Col Mean |   Impregum   Plaster
---------+----------------------
Plaster  |      -0.13
         |      0.000
         |
 S-Steel |      -0.08       0.05
         |      0.000      0.000
```

```
.  oneway  distance  type if   group==45,tabulate scheffe

            |         Summary of distance
    typelbl |        Mean   Std. Dev.       Freq.
------------+------------------------------------
   Impregum |       17.21        0.01          30
   Plaster  |       17.14        0.09          30
    S-Steel |       17.10        0.01          30
------------+------------------------------------
      Total |       17.15        0.07          90

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups       .16015753      2   .080078765     28.20     0.0000
 Within groups      .247013106     87   .002839231
------------------------------------------------------------------------
    Total           .407170636     89   .004574951

Bartlett's test for equal variances:  chi2(2) = 136.3753  Prob>chi2 = 0.000

                      Comparison of distance by typelbl
                                  (Scheffe)
Row Mean-|
Col Mean |   Impregum   Plaster
---------+----------------------
Plaster  |      -0.07
         |      0.000
         |
 S-Steel |      -0.10      -0.03
         |      0.000      0.068
```

```
.  oneway  distance  type if   group==46,tabulate scheffe

            |         Summary of distance
    typelbl |        Mean   Std. Dev.       Freq.
------------+------------------------------------
   Impregum |       30.14        0.02          30
   Plaster  |       30.18        0.02          30
    S-Steel |       30.15        0.02          30
------------+------------------------------------
      Total |       30.16        0.03          90

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      .030587536      2   .015293768     38.08     0.0000
 Within groups      .034943468     87   .000401649
------------------------------------------------------------------------
    Total           .065531004     89   .000736303

Bartlett's test for equal variances:  chi2(2) =   5.6806  Prob>chi2 = 0.058

                      Comparison of distance by typelbl
                                  (Scheffe)
Row Mean-|
Col Mean |   Impregum   Plaster
---------+----------------------
Plaster  |       0.04
         |      0.000
         |
 S-Steel |       0.01      -0.03
         |      0.023      0.000
```

```
.  oneway  distance  type if   group==47,tabulate scheffe

            |         Summary of distance
    typelbl |        Mean   Std. Dev.       Freq.
------------+------------------------------------
   Impregum |       40.34       0.05          30
   Plaster  |       40.26       0.09          30
    S-Steel |       39.98       0.02          30
------------+------------------------------------
      Total |       40.20       0.16          90

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      2.09572743      2   1.04786371    287.45     0.0000
 Within groups      .317148423     87   .003645384
------------------------------------------------------------------------
    Total           2.41287585     89   .027110965

Bartlett's test for equal variances:  chi2(2) =  58.5537  Prob>chi2 = 0.000

                      Comparison of distance by typelbl
                                  (Scheffe)
Row Mean-|
Col Mean |   Impregum   Plaster
---------+----------------------
Plaster  |      -0.07
         |      0.000
         |
 S-Steel |      -0.35      -0.28
         |      0.000      0.000
```

```
.  oneway  distance  type if   group==48,tabulate scheffe

            |         Summary of distance
    typelbl |        Mean   Std. Dev.       Freq.
------------+------------------------------------
   Impregum |       16.55       0.02          30
   Plaster  |       16.43       0.17          30
    S-Steel |       16.70       0.01          30
------------+------------------------------------
      Total |       16.56       0.15          90

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      1.04091444      2   .520457222     53.08     0.0000
 Within groups      .853003399     87   .009804637
------------------------------------------------------------------------
    Total           1.89391784     89   .021279976

Bartlett's test for equal variances:  chi2(2) = 168.2924  Prob>chi2 = 0.000

                      Comparison of distance by typelbl
                                  (Scheffe)
Row Mean-|
Col Mean |   Impregum   Plaster
---------+----------------------
Plaster  |      -0.11
         |      0.000
         |
 S-Steel |       0.15       0.26
         |      0.000      0.000
```

```
.  oneway  distance  type if   group==49,tabulate scheffe

            |         Summary of distance
    typelbl |        Mean   Std. Dev.       Freq.
------------+------------------------------------
   Impregum |       30.12        0.08          30
   Plaster  |       29.88        0.21          30
    S-Steel |       29.51        0.03          30
------------+------------------------------------
      Total |       29.84        0.28          90

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups       5.5081407      2   2.75407035    162.70     0.0000
 Within groups      1.47269547     87   .016927534
------------------------------------------------------------------------
    Total           6.98083617     89   .078436361

Bartlett's test for equal variances:  chi2(2) =  92.3283  Prob>chi2 = 0.000

                      Comparison of distance by typelbl
                                  (Scheffe)
Row Mean-|
Col Mean |   Impregum   Plaster
---------+----------------------
Plaster  |      -0.24
         |      0.000
         |
 S-Steel |      -0.60      -0.36
         |      0.000      0.000



.  oneway  distance  type if   group==50,tabulate scheffe

            |         Summary of distance
    typelbl |        Mean   Std. Dev.       Freq.
------------+------------------------------------
   Impregum |       14.40        0.11          30
   Plaster  |       14.35        0.27          30
    S-Steel |       13.47        0.02          30
------------+------------------------------------
      Total |       14.07        0.46          90

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      16.1627583      2   8.08137914    284.60     0.0000
 Within groups       2.4703845     87   .028395224
------------------------------------------------------------------------
    Total           18.6331428     89   .209361155

Bartlett's test for equal variances:  chi2(2) = 109.0900  Prob>chi2 = 0.000

                      Comparison of distance by typelbl
                                  (Scheffe)
Row Mean-|
Col Mean |   Impregum   Plaster
---------+----------------------
Plaster  |      -0.05
         |      0.492
         |
 S-Steel |      -0.92      -0.87
         |      0.000      0.000

. log off
       log:  C:\Dudu\Von Berg\Data2m23.log
  log type:  text
 paused on:  22 Mar 2006, 07:54:36
```

9. APPENDIX B
CAST DATA ANALYSIS OF VARIANCE AND TABLE OF MEANS

```
      log:  C:\Dudu\Von Berg\Casts output.log
 log type:  text
opened on:  28 Apr 2006, 09:18:37
```

```
. anova  distance type model if group==41
```

Number of obs =	90	R-squared =	0.9170
Root MSE =	.154756	Adj R-squared =	0.9053

Source	Partial SS	df	MS	F	Prob > F
Model	20.6326876	11	1.87569887	78.32	0.0000
type	20.0656184	2	10.0328092	418.92	0.0000
model	.567069167	9	.063007685	2.63	0.0103
Residual	1.86805093	78	.023949371		
Total	22.5007385	89	.252817287		

```
. table  type model if group==41, c(mean  distance sd distance n distance) col row f(%7.2f)
```

type	model 1	2	3	4	5	6	7	8	9	10	Total
Plaster	14.84	14.75	15.16	15.19	15.15	14.58	14.53	14.53	14.72	15.15	14.86
	0.05	0.06	0.01	0.00	0.00	0.01	0.03	0.03	0.07	0.02	0.27
	3	3	3	3	3	3	3	3	3	3	30
Impregum	15.19	15.20	15.18	15.17	15.16	15.20	15.19	15.19	15.17	14.84	15.15
	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.11
	3	3	3	3	3	3	3	3	3	3	30
S-Steel	14.07	14.04	14.05	14.03	14.02	14.03	14.03	14.03	14.03	14.03	14.03
	0.01	0.02	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.02
	3	3	3	3	3	3	3	3	3	3	30
Total	14.70	14.66	14.80	14.80	14.78	14.60	14.59	14.58	14.64	14.67	14.68
	0.50	0.51	0.56	0.58	0.57	0.51	0.50	0.50	0.50	0.50	0.50
	9	9	9	9	9	9	9	9	9	9	90

```
. anova  distance type model if group==42
```

Number of obs =	90	R-squared =	0.9772
Root MSE =	.065483	Adj R-squared =	0.9740

Source	Partial SS	df	MS	F	Prob > F
Model	14.3542234	11	1.3049294	304.32	0.0000
type	14.2066691	2	7.10333454	1656.53	0.0000
model	.147554322	9	.016394925	3.82	0.0005
Residual	.334470244	78	.00428808		
Total	14.6886937	89	.165041502		

```
. table  type model if group==42, c(mean  distance sd distance n distance) col row f(%7.2f)
```

	model

```
      type |     1       2       3       4       5       6       7       8       9      10   Total
----------+------------------------------------------------------------------------------------
  Plaster | 30.99   30.93   30.98   30.97   30.86   30.82   30.78   30.79   30.94   31.21   30.93
          |  0.04    0.05    0.03    0.02    0.01    0.01    0.02    0.02    0.06    0.02    0.13
          |     3       3       3       3       3       3       3       3       3       3      30
          |
 Impregum | 31.30   31.34   31.30   31.33   31.32   31.34   31.36   31.32   31.32   31.34   31.33
          |  0.01    0.00    0.01    0.00    0.01    0.00    0.00    0.01    0.01    0.01    0.02
          |     3       3       3       3       3       3       3       3       3       3      30
          |
  S-Steel | 30.37   30.34   30.37   30.36   30.35   30.35   30.36   30.37   30.36   30.36   30.36
          |  0.01    0.02    0.03    0.01    0.02    0.01    0.02    0.00    0.01    0.01    0.01
          |     3       3       3       3       3       3       3       3       3       3      30
          |
    Total | 30.89   30.87   30.89   30.89   30.84   30.84   30.83   30.83   30.87   30.97   30.87
          |  0.41    0.44    0.41    0.43    0.42    0.43    0.43    0.41    0.42    0.46    0.41
          |     9       9       9       9       9       9       9       9       9       9      90
-----------------------------------------------------------------------------------------------
```

```
. anova  distance type model if group==43

                           Number of obs =      90     R-squared     =  0.8701
                           Root MSE      = .072848     Adj R-squared =  0.8518

                  Source |  Partial SS    df       MS           F     Prob > F
              -----------+----------------------------------------------------
                   Model |  2.77257971    11  .252052701      47.50     0.0000
                         |
                    type |  2.57531727     2  1.28765863     242.64     0.0000
                   model |  .197262444     9  .021918049       4.13     0.0002
                         |
                Residual |  .413930289    78  .005306799
              -----------+----------------------------------------------------
                   Total |     3.18651    89  .035803483

. table  type model if group==43, c(mean  distance sd distance n distance) col row f(%7.2f)
```

```
-----------------------------------------------------------------------------------------------
          |                                    model
      type |     1       2       3       4       5       6       7       8       9      10   Total
----------+------------------------------------------------------------------------------------
  Plaster | 40.51   40.52   40.80   40.77   40.73   40.47   40.38   40.46   40.51   40.62   40.58
          |  0.01    0.03    0.02    0.03    0.01    0.01    0.01    0.01    0.02    0.00    0.14
          |     3       3       3       3       3       3       3       3       3       3      30
          |
 Impregum | 40.65   40.72   40.66   40.68   40.68   40.71   40.68   40.71   40.69   40.69   40.69
          |  0.00    0.00    0.01    0.00    0.01    0.00    0.00    0.01    0.00    0.01    0.02
          |     3       3       3       3       3       3       3       3       3       3      30
          |
  S-Steel | 40.28   40.25   40.30   40.30   40.28   40.29   40.27   40.30   40.31   40.31   40.29
          |  0.02    0.01    0.05    0.01    0.02    0.01    0.03    0.01    0.01    0.02    0.03
          |     3       3       3       3       3       3       3       3       3       3      30
          |
    Total | 40.48   40.50   40.59   40.58   40.57   40.49   40.44   40.49   40.50   40.54   40.52
          |  0.16    0.21    0.23    0.22    0.22    0.18    0.18    0.18    0.17    0.18    0.19
          |     9       9       9       9       9       9       9       9       9       9      90
-----------------------------------------------------------------------------------------------
```

```
. anova  distance type model if group==44

                           Number of obs =      90     R-squared     =  0.5611
                           Root MSE      = .135611     Adj R-squared =  0.4992
```

```
                Source |  Partial SS    df       MS           F     Prob > F
           -----------+----------------------------------------------------
                 Model |  1.83406097    11  .166732815       9.07     0.0000
                       |
                  type |  1.21725869     2  .608629344      33.10     0.0000
                 model |  .616802278     9  .068533586       3.73     0.0006
                       |
              Residual |  1.43444042    78  .018390262
           -----------+----------------------------------------------------
                 Total |  3.26850139    89  .036724735

. table  type model if group==44, c(mean  distance sd distance n distance) col row f(%7.2f)

----------------------------------------------------------------------------------------
          |                                   model
     type |      1       2       3       4       5       6       7       8       9      10   Total
----------+-----------------------------------------------------------------------------
  Plaster |  47.13   47.13   47.21   47.22   47.12   47.17   47.09   47.16   47.15   47.12   47.15
          |   0.01    0.00    0.01    0.00    0.00    0.00    0.00    0.01    0.00    0.01    0.04
          |      3       3       3       3       3       3       3       3       3       3      30
          |
 Impregum |  47.24   47.99   47.25   47.27   47.29   47.29   47.28   47.29   47.83   47.28   47.40
          |   0.00    0.00    0.01    0.01    0.00    0.00    0.00    0.00    0.00    0.00    0.26
          |      3       3       3       3       3       3       3       3       3       3      30
          |
  S-Steel |  47.13   47.12   47.16   47.17   47.15   47.16   47.17   47.16   47.17   47.16   47.15
          |   0.02    0.01    0.05    0.01    0.04    0.01    0.05    0.00    0.00    0.00    0.03
          |      3       3       3       3       3       3       3       3       3       3      30
          |
    Total |  47.17   47.41   47.20   47.22   47.19   47.21   47.18   47.20   47.38   47.19   47.23
          |   0.06    0.43    0.04    0.04    0.08    0.06    0.08    0.06    0.33    0.07    0.19
          |      9       9       9       9       9       9       9       9       9       9      90
----------------------------------------------------------------------------------------

. anova  distance type model if group==45

                           Number of obs =      90     R-squared     =  0.4835
                           Root MSE      = .098545     Adj R-squared =  0.4106

                Source |  Partial SS    df       MS           F     Prob > F
           -----------+----------------------------------------------------
                 Model |  .708999156    11  .064454469       6.64     0.0000
                       |
                  type |  .267121422     2  .133560711      13.75     0.0000
                 model |  .441877733     9  .049097526       5.06     0.0000
                       |
              Residual |  .757473467    78  .009711198
           -----------+----------------------------------------------------
                 Total |  1.46647262    89   .01647722

. table  type model if group==45, c(mean  distance sd distance n distance) col row f(%7.2f)

----------------------------------------------------------------------------------------
          |                                   model
     type |      1       2       3       4       5       6       7       8       9      10   Total
----------+-----------------------------------------------------------------------------
  Plaster |  17.11   17.11   16.97   16.93   16.89   17.15   17.18   17.16   17.19   17.11   17.08
          |   0.01    0.01    0.01    0.01    0.01    0.00    0.01    0.00    0.00    0.00    0.11
          |      3       3       3       3       3       3       3       3       3       3      30
          |
 Impregum |  17.11   17.13   17.13   17.17   17.16   17.16   17.18   17.14   17.16   17.71   17.21
          |   0.01    0.00    0.01    0.00    0.01    0.01    0.00    0.00    0.01    0.00    0.17
          |      3       3       3       3       3       3       3       3       3       3      30
          |
  S-Steel |  17.09   17.08   17.10   17.11   17.11   17.10   17.11   17.11   17.11   17.11   17.10
          |   0.02    0.00    0.02    0.00    0.01    0.00    0.01    0.00    0.00    0.00    0.01
          |      3       3       3       3       3       3       3       3       3       3      30
          |
    Total |  17.11   17.11   17.07   17.07   17.06   17.14   17.16   17.14   17.15   17.31   17.13
          |   0.02    0.02    0.08    0.11    0.13    0.03    0.03    0.02    0.04    0.30    0.13
          |      9       9       9       9       9       9       9       9       9       9      90
----------------------------------------------------------------------------------------

. anova  distance type model if group==46

                           Number of obs =      90     R-squared     =  0.3329
```

```
                          Root MSE      = .091087     Adj R-squared =  0.2389

                 Source |  Partial SS    df       MS           F     Prob > F
              -----------+----------------------------------------------------
                  Model |  .323017089    11   .02936519       3.54     0.0005
                         |
                   type |  .011156822     2  .005578411       0.67     0.5134
                  model |  .311860267     9  .034651141       4.18     0.0002
                         |
               Residual |  .647156067    78  .008296873
              -----------+----------------------------------------------------
                  Total |  .970173156    89  .010900822

. table  type model if group==46, c(mean  distance sd distance n distance) col row f(%7.2f)

--------------------------------------------------------------------------------------
          |                                  model
     type |     1       2       3       4       5       6       7       8       9      10   Total
----------+---------------------------------------------------------------------------
  Plaster | 30.09   30.11   30.19   30.14   30.16   30.16   30.12   30.15   30.19   30.11   30.14
          |  0.00    0.01    0.01    0.01    0.00    0.00    0.01    0.00    0.01    0.00    0.03
          |     3       3       3       3       3       3       3       3       3       3      30
          |
 Impregum | 30.02   30.05   30.05   30.09   30.08   30.07   30.06   30.08   30.08   30.65   30.12
          |  0.01    0.01    0.01    0.00    0.00    0.00    0.01    0.01    0.01    0.00    0.18
          |     3       3       3       3       3       3       3       3       3       3      30
          |
  S-Steel | 30.14   30.12   30.16   30.15   30.15   30.15   30.14   30.16   30.17   30.17   30.15
          |  0.01    0.00    0.04    0.00    0.01    0.01    0.02    0.00    0.01    0.00    0.02
          |     3       3       3       3       3       3       3       3       3       3      30
          |
    Total | 30.08   30.10   30.13   30.13   30.13   30.13   30.11   30.13   30.15   30.31   30.14
          |  0.05    0.03    0.06    0.03    0.04    0.04    0.04    0.04    0.05    0.25    0.10
          |     9       9       9       9       9       9       9       9       9       9      90
--------------------------------------------------------------------------------------

. anova  distance type model if group==47

                          Number of obs =      90     R-squared     =  0.7625
                          Root MSE      = .148426     Adj R-squared =  0.7291

                 Source |  Partial SS    df       MS           F     Prob > F
              -----------+----------------------------------------------------
                  Model |  5.51804239    11  .501640217      22.77     0.0000
                         |
                   type |  4.67168096     2  2.33584048     106.03     0.0000
                  model |  .846361433     9  .094040159       4.27     0.0002
                         |
               Residual |  1.71835193    78  .022030153
              -----------+----------------------------------------------------
                  Total |  7.23639432    89  .081307801

. table  type model if group==47, c(mean  distance sd distance n distance) col row f(%7.2f)

--------------------------------------------------------------------------------------
          |                                  model
     type |     1       2       3       4       5       6       7       8       9      10   Total
----------+---------------------------------------------------------------------------
  Plaster | 40.17   40.08   40.31   40.31   40.25   40.07   40.06   40.04   40.20   40.31   40.18
          |  0.03    0.01    0.00    0.02    0.01    0.01    0.01    0.01    0.04    0.01    0.11
          |     3       3       3       3       3       3       3       3       3       3      30
          |
 Impregum | 40.33   41.03   40.34   40.37   40.38   40.35   40.36   40.37   40.92   40.88   40.53
          |  0.01    0.01    0.00    0.01    0.01    0.00    0.00    0.00    0.00    0.01    0.28
          |     3       3       3       3       3       3       3       3       3       3      30
          |
  S-Steel | 39.99   39.97   39.99   39.99   39.98   39.99   40.00   39.98   39.98   39.98   39.98
          |  0.01    0.01    0.03    0.00    0.03    0.00    0.04    0.00    0.02    0.01    0.02
          |     3       3       3       3       3       3       3       3       3       3      30
          |
    Total | 40.16   40.36   40.21   40.22   40.20   40.14   40.14   40.13   40.37   40.39   40.23
          |  0.15    0.51    0.17    0.18    0.18    0.17    0.17    0.18    0.42    0.40    0.29
          |     9       9       9       9       9       9       9       9       9       9      90
--------------------------------------------------------------------------------------
```

```
. anova  distance type model if group==48

                           Number of obs =      90     R-squared     =  0.5501
                           Root MSE      = .081434     Adj R-squared =  0.4867

                  Source |  Partial SS    df       MS           F     Prob > F
              -----------+----------------------------------------------------
                   Model |  .632477278    11  .057497934       8.67     0.0000
                         |
                    type |  .390016289     2  .195008144      29.41     0.0000
                   model |  .242460989     9   .02694011       4.06     0.0003
                         |
                Residual |  .517253711    78  .006631458
              -----------+----------------------------------------------------
                   Total |  1.14973099    89  .012918326

. table  type model if group==48, c(mean  distance sd distance n distance) col row f(%7.2f)

----------------------------------------------------------------------------------------
          |                                    model
     type |      1       2       3       4       5       6       7       8       9      10   Total
----------+-----------------------------------------------------------------------------
  Plaster |  16.64   16.66   16.33   16.32   16.26   16.66   16.59   16.64   16.65   16.63   16.54
          |   0.00    0.00    0.02    0.05    0.01    0.00    0.00    0.00    0.01    0.01    0.16
          |      3       3       3       3       3       3       3       3       3       3      30
          |
 Impregum |  16.60   16.60   16.60   16.61   16.59   16.58   16.57   16.61   16.60   16.55   16.59
          |   0.01    0.01    0.00    0.00    0.02    0.00    0.01    0.01    0.00    0.01    0.02
          |      3       3       3       3       3       3       3       3       3       3      30
          |
  S-Steel |  16.71   16.70   16.71   16.69   16.69   16.70   16.68   16.69   16.71   16.69   16.70
          |   0.00    0.01    0.02    0.00    0.01    0.01    0.02    0.01    0.01    0.01    0.01
          |      3       3       3       3       3       3       3       3       3       3      30
          |
    Total |  16.65   16.66   16.55   16.54   16.51   16.65   16.61   16.65   16.65   16.62   16.61
          |   0.04    0.04    0.17    0.17    0.20    0.05    0.05    0.03    0.05    0.06    0.11
          |      9       9       9       9       9       9       9       9       9       9      90
----------------------------------------------------------------------------------------

. anova  distance type model if group==49

                           Number of obs =      90     R-squared     =  0.8850
                           Root MSE      = .148125     Adj R-squared =  0.8688

                  Source |  Partial SS    df       MS           F     Prob > F
              -----------+----------------------------------------------------
                   Model |   13.167992    11  1.19709018      54.56     0.0000
                         |
                    type |   12.285059     2  6.14252948     279.96     0.0000
                   model |  .882933067     9  .098103674       4.47     0.0001
                         |
                Residual |   1.7113886    78  .021940879
              -----------+----------------------------------------------------
                   Total |  14.8793806    89  .167184052

. table  type model if group==49, c(mean  distance sd distance n distance) col row f(%7.2f)

----------------------------------------------------------------------------------------
          |                                    model
     type |      1       2       3       4       5       6       7       8       9      10   Total
----------+-----------------------------------------------------------------------------
  Plaster |  29.96   29.80   29.81   29.81   29.65   29.64   29.61   29.58   29.83   30.21   29.79
          |   0.07    0.02    0.03    0.07    0.03    0.02    0.02    0.02    0.09    0.01    0.19
          |      3       3       3       3       3       3       3       3       3       3      30
          |
 Impregum |  30.31   30.92   30.29   30.30   30.30   30.27   30.27   30.31   30.77   30.24   30.40
          |   0.01    0.01    0.00    0.01    0.02    0.00    0.00    0.01    0.00    0.00    0.23
          |      3       3       3       3       3       3       3       3       3       3      30
          |
  S-Steel |  29.55   29.53   29.53   29.51   29.51   29.52   29.51   29.50   29.50   29.49   29.51
          |   0.01    0.01    0.02    0.01    0.02    0.02    0.02    0.02    0.03    0.03    0.03
          |      3       3       3       3       3       3       3       3       3       3      30
          |
    Total |  29.94   30.09   29.88   29.88   29.82   29.81   29.80   29.79   30.03   29.98   29.90
          |   0.33    0.64    0.33    0.35    0.37    0.35    0.36    0.39    0.57    0.37    0.41
          |      9       9       9       9       9       9       9       9       9       9      90
----------------------------------------------------------------------------------------
```

```
. anova  distance type model if group==50

                           Number of obs =      90     R-squared     =  0.8607
                           Root MSE      = .208728     Adj R-squared =  0.8410

                  Source |  Partial SS    df       MS           F     Prob > F
              -----------+----------------------------------------------------
                   Model |  20.9891267    11  1.90810242      43.80     0.0000
                         |
                    type |  19.7671652     2  9.88358258     226.86     0.0000
                   model |  1.22196151     9  .135773501       3.12     0.0030
                         |
                Residual |  3.39825596    78  .043567384
              -----------+----------------------------------------------------
                   Total |  24.3873826    89  .274015535

. table  type model if group==50, c(mean  distance sd distance n distance) col row f(%7.2f)

-------------------------------------------------------------------------------------
          |                                   model
     type |     1      2      3      4      5      6      7      8      9     10  Total
----------+--------------------------------------------------------------------------
  Plaster | 14.07  13.88  14.48  14.48  14.42  13.66  13.71  13.63  13.92  14.43  14.07
          |  0.09   0.02   0.00   0.01   0.01   0.03   0.02   0.02   0.13   0.01   0.35
          |     3      3      3      3      3      3      3      3      3      3     30
          |
 Impregum | 14.53  15.08  14.52  14.52  14.54  14.52  14.52  14.53  14.94  14.52  14.62
          |  0.01   0.01   0.00   0.00   0.01   0.00   0.01   0.00   0.00   0.00   0.20
          |     3      3      3      3      3      3      3      3      3      3     30
          |
  S-Steel | 13.51  13.50  13.48  13.48  13.47  13.47  13.48  13.46  13.45  13.45  13.47
          |  0.01   0.03   0.01   0.01   0.02   0.01   0.02   0.01   0.02   0.01   0.02
          |     3      3      3      3      3      3      3      3      3      3     30
          |
    Total | 14.04  14.15  14.16  14.16  14.15  13.88  13.90  13.87  14.10  14.13  14.06
          |  0.45   0.71   0.51   0.51   0.51   0.48   0.47   0.50   0.66   0.51   0.52
          |     9      9      9      9      9      9      9      9      9      9     90
-------------------------------------------------------------------------------------
```

COMPARISON OF THE TYPES

```
. oneway  distance  type if   group==41,tabulate scheffe

            |         Summary of distance
       type |        Mean   Std. Dev.       Freq.
------------+------------------------------------
    Plaster |   14.860633   .26884177          30
   Impregum |   15.149033   .10691004          30
    S-Steel |   14.034833   .01624825          30
------------+------------------------------------
      Total |     14.6815   .50280939          90

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      20.0656184      2   10.0328092    358.44     0.0000
 Within groups       2.4351201     87   .027989886
------------------------------------------------------------------------
    Total           22.5007385     89   .252817287

Bartlett's test for equal variances:  chi2(2) = 131.6893  Prob>chi2 = 0.000

                        Comparison of distance by type
                                  (Scheffe)
Row Mean-|
Col Mean |    Plaster   Impregum
---------+----------------------
Impregum |      .2884
         |      0.000
         |
 S-Steel |     -.8258    -1.1142
         |      0.000      0.000
```

```
. oneway  distance  type if   group==42,tabulate scheffe

            |         Summary of distance
       type |        Mean   Std. Dev.       Freq.
------------+------------------------------------
    Plaster |     30.9274   .12665827          30
   Impregum |   31.328333   .01891238          30
    S-Steel |     30.3599   .01488427          30
------------+------------------------------------
      Total |   30.871878     .406253          90

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      14.2066691      2   7.10333454   1282.07     0.0000
 Within groups      .482024567     87   .005540512
------------------------------------------------------------------------
    Total           14.6886937     89   .165041502

Bartlett's test for equal variances:  chi2(2) = 139.8494  Prob>chi2 = 0.000

                        Comparison of distance by type
                                  (Scheffe)
Row Mean-|
Col Mean |    Plaster   Impregum
---------+----------------------
Impregum |    .400933
         |      0.000
         |
 S-Steel |     -.5675   -.968433
         |      0.000      0.000
```

```
. oneway  distance  type if   group==43,tabulate scheffe

            |         Summary of distance
       type |        Mean   Std. Dev.       Freq.
------------+------------------------------------
    Plaster |     40.5775   .14124148          30
   Impregum |   40.687767   .02217436          30
    S-Steel |   40.286733   .02519433          30
------------+------------------------------------
      Total |   40.517333   .18921808          90

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      2.57531727      2   1.28765863    183.29     0.0000
 Within groups      .611192733     87   .007025204
------------------------------------------------------------------------
    Total              3.18651     89   .035803483

Bartlett's test for equal variances:  chi2(2) = 114.8125  Prob>chi2 = 0.000

                        Comparison of distance by type
                                  (Scheffe)
Row Mean-|
Col Mean |    Plaster   Impregum
---------+----------------------
Impregum |    .110267
         |      0.000
         |
 S-Steel |   -.290767   -.401033
         |      0.000      0.000
```

```
. oneway  distance  type if   group==44,tabulate scheffe

            |         Summary of distance
       type |        Mean   Std. Dev.       Freq.
------------+------------------------------------
    Plaster |   47.150533   .03985468          30
   Impregum |   47.399067   .26154395          30
    S-Steel |   47.154233   .02718225          30
------------+------------------------------------
      Total |   47.234611   .19163699          90

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      1.21725869      2   .608629344     25.81     0.0000
 Within groups       2.0512427     87   .023577502
------------------------------------------------------------------------
    Total           3.26850139     89   .036724735

Bartlett's test for equal variances:  chi2(2) = 145.5342  Prob>chi2 = 0.000

                        Comparison of distance by type
                                  (Scheffe)
Row Mean-|
Col Mean |    Plaster   Impregum
---------+----------------------
Impregum |    .248533
         |      0.000
         |
 S-Steel |      .0037   -.244833
         |      0.996      0.000
```

```
. oneway  distance  type if   group==45,tabulate scheffe

            |         Summary of distance
       type |        Mean   Std. Dev.       Freq.
------------+------------------------------------
    Plaster |   17.079933   .10544289          30
   Impregum |   17.205933   .17346925          30
    S-Steel |   17.104867   .01213071          30
------------+------------------------------------
      Total |   17.130244   .12836363          90

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      .267121422      2   .133560711      9.69     0.0002
 Within groups       1.1993512     87   .013785646
------------------------------------------------------------------------
    Total           1.46647262     89    .01647722

Bartlett's test for equal variances:  chi2(2) = 113.5159  Prob>chi2 = 0.000

                        Comparison of distance by type
                                  (Scheffe)
Row Mean-|
Col Mean |    Plaster   Impregum
---------+----------------------
Impregum |       .126
         |      0.000
         |
 S-Steel |    .024933   -.101067
         |      0.714      0.005
```

```
. oneway  distance  type if   group==46,tabulate scheffe

            |         Summary of distance
       type |        Mean   Std. Dev.       Freq.
------------+------------------------------------
    Plaster |   30.142767   .03245122          30
   Impregum |   30.124367   .17803728          30
    S-Steel |      30.151    .0178654          30
------------+------------------------------------
      Total |   30.139378     .104407          90

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      .011156822      2   .005578411      0.51     0.6046
 Within groups      .959016333     87   .011023176
------------------------------------------------------------------------
    Total           .970173156     89   .010900822

Bartlett's test for equal variances:  chi2(2) = 138.0721  Prob>chi2 = 0.000

                        Comparison of distance by type
                                  (Scheffe)
Row Mean-|
Col Mean |    Plaster   Impregum
---------+----------------------
Impregum |     -.0184
         |      0.795
         |
 S-Steel |    .008233    .026633
         |      0.955      0.619
```

```
. oneway  distance  type if   group==47,tabulate scheffe

            |         Summary of distance
       type |        Mean   Std. Dev.       Freq.
------------+------------------------------------
    Plaster |   40.178867   .10848637          30
   Impregum |     40.5344   .27624459          30
    S-Steel |     39.9841   .01892153          30
------------+------------------------------------
      Total |   40.232456   .28514523          90

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      4.67168096      2   2.33584048     79.24     0.0000
 Within groups      2.56471337     87   .029479464
------------------------------------------------------------------------
    Total           7.23639432     89   .081307801

Bartlett's test for equal variances:  chi2(2) = 125.0434  Prob>chi2 = 0.000

                        Comparison of distance by type
                                  (Scheffe)
Row Mean-|
Col Mean |    Plaster   Impregum
---------+----------------------
Impregum |    .355533
         |      0.000
         |
 S-Steel |   -.194767     -.5503
         |      0.000      0.000
```

```
. oneway  distance  type if   group==48,tabulate scheffe

            |         Summary of distance
       type |        Mean   Std. Dev.       Freq.
------------+------------------------------------
    Plaster |   16.538567   .15983713          30
   Impregum |   16.591467   .02066437          30
    S-Steel |   16.696933   .01490414          30
------------+------------------------------------
      Total |   16.608989   .11365881          90

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      .390016289      2   .195008144     22.33     0.0000
 Within groups        .7597147     87   .008732353
------------------------------------------------------------------------
    Total           1.14973099     89   .012918326

Bartlett's test for equal variances:  chi2(2) = 160.4045  Prob>chi2 = 0.000

                        Comparison of distance by type
                                  (Scheffe)
Row Mean-|
Col Mean |    Plaster   Impregum
---------+----------------------
Impregum |      .0529
         |      0.096
         |
 S-Steel |    .158367    .105467
         |      0.000      0.000
```

```
. oneway  distance  type if   group==49,tabulate scheffe

            |         Summary of distance
       type |        Mean   Std. Dev.       Freq.
------------+------------------------------------
    Plaster |   29.789033   .18768471          30
   Impregum |     30.3985   .23151491          30
    S-Steel |     29.5144    .0251925          30
------------+------------------------------------
      Total |   29.900644   .40888146          90

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups       12.285059      2   6.14252948    205.99     0.0000
 Within groups      2.59432167     87   .029819789
------------------------------------------------------------------------
    Total           14.8793806     89   .167184052

Bartlett's test for equal variances:  chi2(2) =  88.4537  Prob>chi2 = 0.000


                    Comparison of distance by type
                                  (Scheffe)
Row Mean-|
Col Mean |    Plaster   Impregum
---------+----------------------
Impregum |    .609467
         |      0.000
         |
 S-Steel |   -.274633     -.8841
         |      0.000      0.000




. oneway  distance  type if   group==50,tabulate scheffe

            |         Summary of distance
       type |        Mean   Std. Dev.       Freq.
------------+------------------------------------
    Plaster |     14.0684   .34530552          30
   Impregum |   14.622533   .19874429          30
    S-Steel |     13.4748   .02413811          30
------------+------------------------------------
      Total |   14.055244   .52346493          90

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      19.7671652      2   9.88358258    186.11     0.0000
 Within groups      4.62021747     87   .053105948
------------------------------------------------------------------------
    Total           24.3873826     89   .274015535

Bartlett's test for equal variances:  chi2(2) = 114.2391  Prob>chi2 = 0.000

                        Comparison of distance by type
                                  (Scheffe)
Row Mean-|
Col Mean |    Plaster   Impregum
---------+----------------------
Impregum |    .554133
         |      0.000
         |
 S-Steel |     -.5936   -1.14773
         |      0.000      0.000

. log close
       log:  C:\Dudu\Von Berg\Casts output.log
  log type:  text
 closed on:  28 Apr 2006, 09:33:43

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