The Accuracy of Three Impression Transfer Techniques for Implant Supported Prostheses

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SUMMARY

Cast framework for osseointegrated implant retained prostheses need to be passively fitting so as not to place undue forces and stress concentrations around the fixtures. Impression materials and techniques play a key role in the accuracy and fit of the metal framework. In this study, three impression procedures were investigated to establish which was the most accurate, reliable and predictable. This included using smooth sided tapered transfer copings and unsplinted and splinted square undercut transfer copings. A metal plated master model was fabricated and used as the standard against which models poured using the different impression techniques were compared. Readings were taken with a Reflex Microscope and used to calculate the mean, standard deviation and deviation index for each test model. The results of this study suggest that direct coping transfer techniques provide comparable or better results than indirect coping transfers in master cast fabrication. There was no significant difference in impression transfer accuracy between splinted and non-splinted square impression coping transfer techniques.

Keywords: Osseointegrated implants; impression techniques;

INTRODUCTION

Osseointegrated implants present a different clinical and biomechanical picture compared to natural teeth. They have limited movement of approximately 10 microns, while teeth can move up to 100 microns within their periodontal ligaments (Assif, Marshak & Schmidt, 1996). This micromovement of teeth may compensate for a certain degree of misfit in fixed bridgework, but necessitates the fit of a cast framework to be more accurate when prostheses are connected to "ankylotic" implants. Failure to fabricate a passively-fitting prosthesis may place undue forces and stress concentration around implants which could lead to excessive marginal bone loss and implant failure, loosening of screws, and fatigue fracture of the implant components (Adell, Eriksson, Lekholm *et al*., 1990; Jemt, Carlsson, Boss *et al*., 1991; Kallus and Bessing, 1994).

The cause of misfit of an implant supported framework is multifactorial. Implant prosthesis are fabricated making use of conventional crown and bridgework materials and techniques. Distortions of implant superstructures arise throughout the procedures involved in their fabrication. These include, machining tolerances, the impression materials, impression techniques, fabrication of the master cast, wax pattern fabrication, and dimensional changes inherent in the investing and casting process.

A passive fit is partially dependent on accurate registration of the supporting structures. The impression materials, different tray types and techniques used for master cast fabrication play a key role in the accuracy and fit of the cast metal framework (Henry, 1987; Burns, Palmer, Howe *et al*., 2003). Various transfer coping designs and impression procedures have evolved in the search for a reliable, predictable and efficient impression-taking procedure.
Implant impressions can be taken using an indirect or a direct technique. The former involves fastening a one-piece tapered transfer coping to each abutment prior to the impression procedure. Upon removal of the impression, these copings remain connected to the abutment. The copings are then removed from the abutment and together with their abutment analogues are replaced into their respective recesses within the impression. In the direct technique, two-piece square undercut transfer copings, which are retained in the impression following its removal, are used. These copings may be freestanding or splinted to each other with a resin matrix. The merits of all three techniques are not clearly defined with proponents and agonists for each (Brånemark, Albrektsson and Zarb, 1985; Humphries, Yaman and Bloem, 1990; Carr, 1991 and 1992; Assif, Fenton, Zarb *et al*., 1992; Chii-Chii, Milstein and Stein, 1993; Assif *et al*., 1996; Herbst, Nel, Driessen et al., 2000; Vigolo, Majzoub and Cordioli, 2003; Vigolo, Fonzi, Majzoub *et al*., 2004), and there is a consensus in the literature that further work is needed to identify the most reliable impression transfer procedure. The present study was designed to try and establish the most accurate implant transfer procedure which would enhance the success of an implant-supported prosthesis.

MATERIALS AND METHOD

The Master Model

A master model was fabricated using a metal plated mandibular stone cast with seven Brånemark System stainless steel abutment analogues (DCA 175)[1] (Figure. 1). Six of

Figure 1: The master model

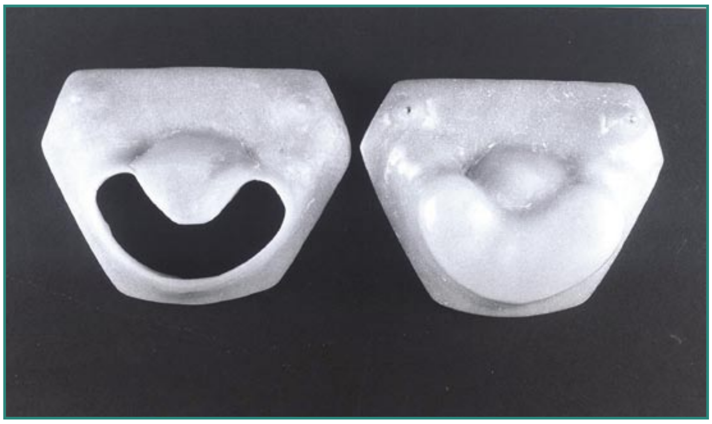

Figure 2: Open and closed custom trays

these analogues represented titanium abutments anchored in the mandibular stone cast. The seventh analogue was placed in the base of the model. The divergent angles between the abutment analogues did not exceed 15 degrees. The almost parallel abutment analogues facilitated the removal of the splinted square impression copings after polymerisation of the resin. Three pin-holes, one anteriorly and two posteriorly, on the base of the master model served as receptacles for three locating pins on the custom tray to facilitate consistent positioning during impression procedures. The master model served as the control against which all measurements were compared when the accuracy of casts made from different impression techniques were assessed.

Implant Impression Procedures

The master model was used as a template for the fabrication of non-perforated, autopolymerized resin custom impression trays. Rigid custom trays have been shown to produce more accurate impressions than stock trays (Burns *et al.*, 2003). Two layers of baseplate wax were used as a spacer to ensure uniform spacing of the trays thus allowing control of the thickness of the impression material. The impression trays were constructed as "closed" or with screw access windows (Figure 2) for use with tapered and square impression copings respectively. The trays were made at least 48 hours prior to use so that polymerization could take place before impression taking, thus eliminating the effect of setting distortion on the impression. A polyether impression material Impregum F2 was used for this investigation to exclude other variables inherent with the use of different materials. Fifteen minutes before the final impressions were taken, the trays were coated with adhesive to improve adherence of the impression materials. Three different transfer techniques were used and 10 different impressions were made with each technique:-

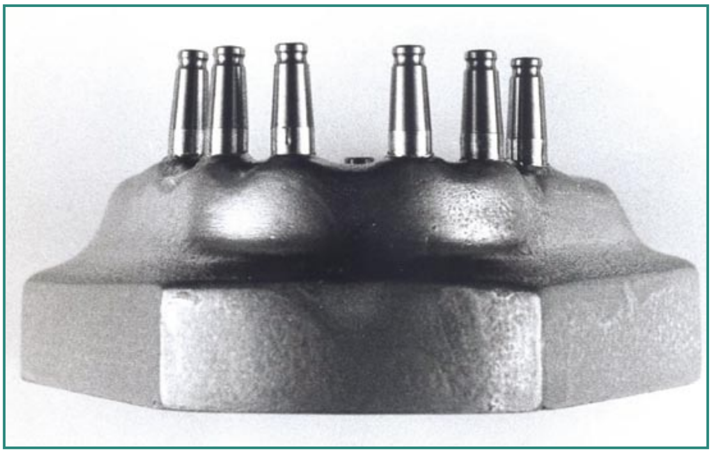

Figure 3: Tapered transfer copings on master model

Figure 4: Square undercut transfer copings on master model

Technique I – Seven unsplinted, one-piece, smooth sided tapered transfer copings (DCA 025)[1] with a small circular undercut were tightened by finger pressure with the prescribed holder onto the abutment analogues (Figure 3). Closed custom trays were used for the impression procedure.

Technique II – Seven unsplinted square undercut transfer copings (DCA 040)1 were secured onto the abutment analogues with 10mm guide pins (DCA 094)1 (Figure 4), and custom trays with a screw access window were used for the impression procedure.

Technique III – Seven square undercut transfer copings were secured onto the abutment analogues with 10mm guide pins. Twenty-four hours before the impression procedure, autopolymerizing resin (Duralay)[3] blocks were prefabricated around the six anterior square transfer copings until a small

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1. Nobelpharma AB, P.O. Box 5190, S-402-26, Goteborg, Sweden
2. ESPE. Fabrik Pharmazeutischer Praparate GMBH & Co. KG D-8031Seefeld/Oberay, Germany
3. Reliance Dental Manufacturing, Worth, Illinois, USA

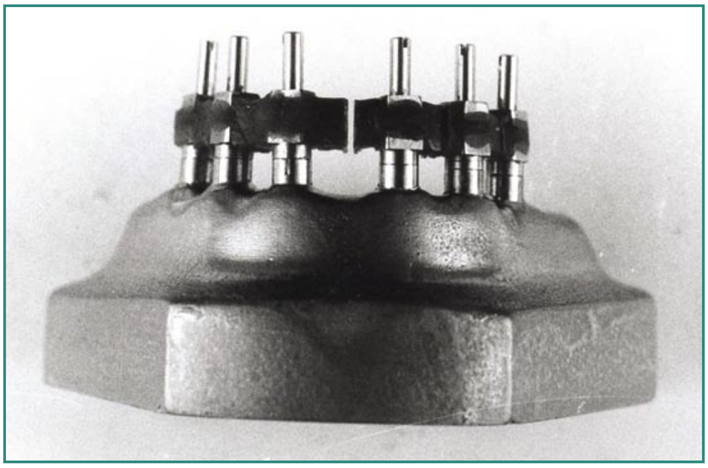

Figure 5: Partially splinted square undercut transfer copings on master model

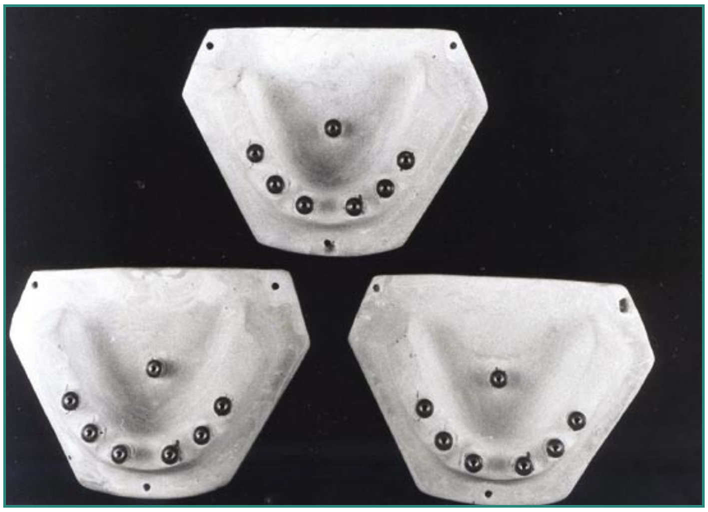

Figure 6: Stone casts poured after the impression procedure

space remained between them. (Figure 5). A polyether mould was used to standardise the dimensions of the acrylic splint (Golden,Wee,Danos *et al*., 2000). These six copings were rigidly connected by the addition of incremental amounts of resin between the resin blocks twenty minutes prior to the impression procedure (Assif, Marshak and Nissan, 1994; Caputi, Traini. Paciaffi *et al*., 2000). The seventh coping was not connected with the Duralay. Custom trays with screw access windows as for Technique II were used for the impressions.

All procedures and measurements were carried out by one operator in a temperature-controlled room at 21 degrees centigrade. The impression material was mixed according to the manufacturer's instructions and impressions were taken in random order. After six minutes of setting time, each impression was removed vertically along the axis of the pinholes to minimise lateral stresses.

For Technique I, the transfer copings were removed from the master die, attached to the stainless steel abutment analogues and replaced in their respective positions within the impression. For techniques II and III the 10mm guide pins were loosened to remove the impressions. The square transfer copings remained in the impression and stainless steel abutment analogues were attached using the same guide pins.

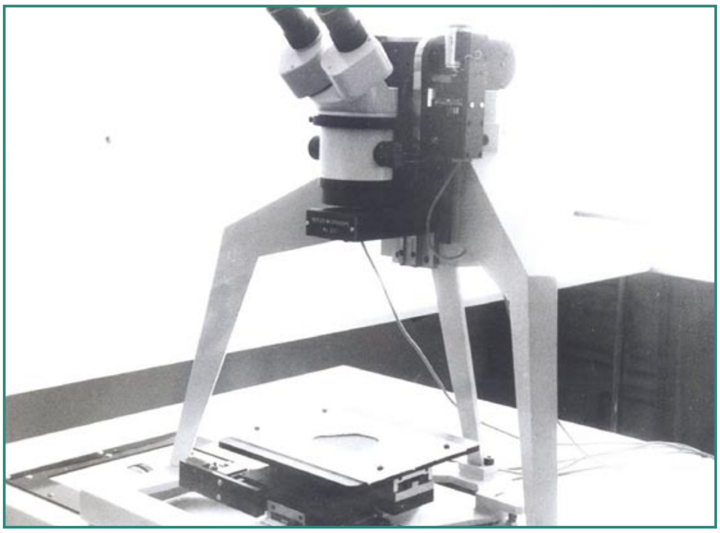

Figure 7: Measuring table of Reflex Microscope with secured perspex plate for consistent placement of casts

Consistent placement of the custom trays onto the master die during impression procedures was facilitated by the use of the locating pins on the custom trays.

Impressions were poured in a die stone (Vel-Mix)[4]. A total of 30 experimental stone casts were formed. All casts were allowed to set for 1 hour without inversion of the impression, thereafter they were inverted on a base of stone and allowed to set for 24 hours before separation and measurement procedures (Figure 6). The resulting casts were appropriately labelled for the technique that was used.

The Reflex Microscope

A motorised standard Reflex Microscope[5] with COMP 3D operating software linked to a microcomputer was used to measure the accuracy of the impression techniques according to the method described by Drage, Winzar and Killingback (1991). The microcomputer is programmed to perform analytical calculations to determine distances, angles, areas, and volumes by manipulation of co-ordinates within a menu driven software package (Speculand, 1988). To prevent errors from the placement of casts onto the moving stage of the microscope, a perspex plate was secured onto the measuring table to ensure consistent placement of casts during measurements (Figure 7).

The circles presented by the superior surfaces of the abutment analogue provided references for the measurement of linear distances between abutments. This allowed a work file to be created to utilize 12 arbitrary points on the outer circumference of the inner circle of each abutment analogue in a clockwise manner.

The centre of each abutment analogue (XA, XB, XC, XD, XE, XF AND XG) was determined by analytical calculations within

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4. Kerr Mfg Co. Romulus, M1 48174. USA
5. Reflex Measurement Ltd, Somerset, UK

Table 1: Computed Measurement Data for Master Die

Distances mm	Master Model
XA-XB	8.6901
XA-XC	16.3769
XA-XD	27.3821
XA-XE	32.468
XA-XF	36.3356
XA-XG	22.5134
XB-XC	8.7547
XB-XD	20.0044
XB-XE	27.3647
XB-XF	32.5568
XB-XG	23.5718
XB-XG	23.5718
XC-XD	12.4157
XC-XE	20.0085
XC-XF	27.4899
XC-XG	23.6702
XD-XE	8.7634
XD-XF	17.5053
XD-XG	23.6514
XE-XF	8.8124
XE-XG	23.5615
XF-XG	23.5856

Table 2: Descriptive Statistics for Technique I

Parameter	Mean mm	SD	Minimum mm	Median mm	Maximum mm
XA-XB	8.6842	0.007126	8.66.97	8.6836	8.6974
XA-XC	16.373	0.006223	16.359	16.372	16.381
XA-XD	27.393	0.007836	27.376	27.392	27.405
XA-XE	32.47	0.0132	32.449	32.467	32.5
XA-XF	36.34	0.008273	36.33	36.341	36.353
XA-XG	22.524	0.0317	22.497	22.516	22.61
XB-XC	8.7585	0.007606	8.7465	8.7578	8.7712
XB-XD	20.025	0.009129	20.015	20.022	20.047
XB-XE	27.376	0.0136	27.363	27.374	27.412
XB-XF	32.568	0.008296	32.556	32.568	32.58
XB-XG	23.575	0.0255	23.541	23.564	23.621
XC-XD	12.432	0.006686	12.422	12.432	12.44
XC-XE	20.017	0.008159	20.005	20.018	20.035
XC-XF	27.495	0.007509	27.478	27.495	27.503
XC-XG	23.683	0.0435	23.645	23.665	23.781
XD-XE	8.757.8	0.006747	8.7431	8.7581	8.7671
XD-XF	17.494	0.005963	17.48	17.494	17.504
XD-XG	23.692	0.0574	23.647	23.674	23.843
XE-XF	8.803	0.008528	8.7894	8.8006	8.8458
XE-XG	23.587	0.0667	23.538	23.567	23.771
XF-XG	23.563	0.0235	23.528	23.56	23.614
Deviation index	0.0395	0.002315	0.038	0.0388	0.046

the menu driven Comp 3D software. Measurements were then taken between XA-XB; XA-XC; XA-XD; XA-XE; XA-XF; XA-XG; XB-XC; XB-XD; XB-XE; XB-XF; XB-XG; XC-XD; XC-XE; XC-XF; XC- XG; XD-XE; XD-XF; XD-XG; XE-XF; XE-XG; XF-XG for the master model as well as for all the experiment dies.

Intra-operator variance and the accuracy of the measuring technique was continually assessed by measuring a known standard five times before and after each experimental session.

RESULTS

Measurement data was computed for the master model and the three experimental groups. The measurements reflect linear inter-abutment distances between the abutment analogues as calculated by means of the COMP 3D software programme. The centre point (mean of the x, y and z coordinates) for each of the abutment analogues were first determined and then a total of 21 distances were computed for the master model and each of the 30 experimental casts.

For each technique, mean, and standard deviation (SD), (Table 1) were calculated and used to establish the deviation index (DI). The deviation index is defined as the sum of the standardized deviations from the master model and is expressed as

$$DI = \Sigma \frac{(\text{Observed} - \text{Expected})^2}{\text{Expected}}$$

The three techniques were compared using the unrestricted t-test, after transforming the deviation indices to ranks. Pairwise t-tests were done between techniques using the standard deviation which was estimated from an analysis of variance of the ranks (Saville, 1990). Testing was done at the 0.05 level of significance.

Statistical analyses revealed that Technique I and Technique III differed significantly with respect to the deviation index ($P<0.05$). There was no significant difference between the deviation index of Technique II and Technique III.

DISCUSSION

A passively fitting implant-supported prosthesis is desirable so as to avoid imparting stress to the abutments and fixtures in an unloaded state, which could give rise to loosening, bending, fracture of implants and superstructure components or even loss of osseointegration. (Adell *et al.*, 1990; Jemt, 1991; Jemt *et al.*, 1991; Kallus and Bessing, 1994). To achieve a tension-free implant supported prosthesis the abutment analogues on the working casts must relate in the same manner as the implant abutments intra-orally. Thus accurate impression taking and cast forming, are primary factors in ensuring precise fitting of the final prosthesis. If the framework is not passively seated, it could be sectioned and reassembled, but this is time consuming and results in a weaker and metallurgically more complex prosthetic framework.

In this study, the square and square/resin impression transfer technique showed no significant difference, while the least

Table 3: Descriptive Statistics for Technique II

Parameter	Mean mm	SD	Minimum mm	Median mm	Maximum mm
XA-XB	8.6865	0.0039	8.6809	8.6864	8.6921
XA-XC	16.381	0.0298	16.365	16.371	16.464
XA-XD	27.397	0.0161	27.384	27.391	27.438
XA-XE	32.473	0.0122	32.458	32.469	32.497
XA-XF	36.341	9.083-03	36.33	36.341	36.361
XA-XG	22.518	0.0146	22.498	22.525	22.535
XB-XC	8.7596	0.0231	8.7427	8.7543	8.8224
XB-XD	20.017	0.009429	20.002	20.014	20.033
XB-XE	27.367	0.008498	27.354	27.366	27.38
XB-XF	32.556	0.014	32.525	32.559	32.572
XB-XG	23.563	0.022	23.523	23.561	23.603
XC-XD	12.427	0.008112	12.415	12.428	12.444
XC-XE	20.014	0.0102	20.003	20.012	20.03
XC-XF	27.492	0.0105	27.477	27.491	27.511
XC-XG	23.672	0.0407	23.623	23.665	23.777
XD-XE	8.7542	0.0201	8.7002	8.7591	8.7713
XD-XF	17.497	0.009229	17.476	17.498	17.507
XD-XG	23.687	0.0426	23.612	23.683	23.784
XE-XF	8.8026	0.008156	8.7914	8.805	8.8167
XE-XG	23.0293	0.0293	23.5	23.575	23.614
XF-XG	23.559	0.0298	23.481	23.564	23.596
DEVIATION INDEX	0.0387	0.001034	0.0372	0.0384	0.0402

Table 4: Descriptive Statistics for Technique III

Parameter	Mean mm	SD	Minimum mm	Median mm	Maximum mm
XA-XB	8.6871	0.00718	8.6745	8.6857	8.6987
XA-XC	16.373	0.005924	16.362	16.372	16.382
XA-XD	27.387	0.00778	27.374	27.389	27.395
XA-XE	32.463	0.007619	32.45	32.467	32.473
XA-XF	36.334	0.008062	36.322	36.335	36.349
XA-XG	22.542	0.0216	22.513	22.542	22.582
XB-XC	8.7527	0.008017	8.7396	8.7515	8.7652
XB-XD	20.01	0.009733	19.997	20.009	20.024
XB-XE	27.362	0.0102	27.35	27.361	27.379
XB-XF	32.555	0.0101	32.535	32.557	32.566
XB-XG	27.595	0.026	23.56	23.596	23.642
XC-XD	12.424	0.004646	12.418	12.424	12.433
XC-XE	20.013	0.005938	20.001	20.014	20.02
XC-XF	27.492	0.0111	27.478	27.494	27.506
XC-XG	23.694	0.0307	23.657	23.688	23.741
XD-XE	8.7648	0.00578	8.7582	8.7652	8.7748
XD-XF	17.502	0.007553	17.49	17.501	17.515
XD-XG	23.697	0.0219	23.674	23.691	23.741
XE-XF	8.8027	0.007801	8.7907	8.8034	8.8136
XE-XG	23.579	0.0191	23.554	23.57	23.611
XF-XG	23.56	23.524	23.557	23.614	23.614
DEVIATION INDEX	0.0382	0.0007763	0.037	0.038	0.0393

accurate was the tapered coping impression transfer technique. This confirms the results of previous studies by Assif *et al.*, (1992) and Assif *et al.*, (1996), who concluded that this inaccuracy may be attributed to a large enough circumferential gap present between the tapered coping and abutment which could be clearly recorded in the impression. Thus when a transfer coping and abutment analogue assembly are replaced into the impression, the entire assembly may be tilted by the binding of the ring of impression material in the region of the gap. They state that even though the indirect technique using the tapered coping is the easiest to apply clinically, least time-consuming and most comfortable to the patient, inaccuracies seen with this technique would limit its usefulness. However, Jemt, (1996) argues that prostheses connected to osseointegrated implants demonstrate distortion between the framework and individual implants of up to several hundred microns, and that this level of fit could be interpreted as clinically acceptable since few, complications relating to poor fit have been observed in patients with such prostheses.

In contrast to these findings, Humphries, Yaman & Bloem (1990) found no statistically significant differences between the three techniques, although their conclusions strongly suggested the indirect technique to be the most reliable. They theorized that softer finger pressure may have accounted for their results. The present investigation used harder stainless steel abutment analogues (as opposed to the brass analogues used in Humphries' investigation), which allowed more consistent positioning of the transfer coping on the analogues. A similar study by Spector, Donovan & Nicholls (1990), which used multiple variables of impression tray types and impression materials, demonstrated an overall inaccuracy for all techniques, with no statistically significant differences between them. They theorised that inaccuracies noted in the tapered impression coping techniques could be due to the difficulties in accurate orientation of the impression coping and abutment replica assembly in the impression, or that air entrapment and incomplete seating of the impression tray may have impeded accurate placement of the impression coping abutment analogue assembly. They argued that in the luted square coping technique the residual stresses in the autopolymerizing resin matrix may be released under impression-removal circumstances and affect the accuracy of abutment positions in the stone casts. Ogawa, Tanaka and Koyano (2000) have suggested polymerizing the resin in water between 60°C and 80°C to increase its mechanical strength. In the present study the bulk of the acrylic splint was made 24 hours prior to impression taking to allow sufficient time for polymerization shrinkage. The total shrinkage of acrylic resin is between 6.5% and 7.9% in the first 24 hours, with 80% of the shrinkage taking place in the first 17 minutes after mixing (Mojon, Oberholzer, Meyer *et al*., 1990). The larger the mass of acrylic resin used, the less accurate the relationship between the two splinted segments (Moon, Eshleman, Douglas *et al*., 1978). The practice of joining the square transfer coping with acrylic resin is an attempt to stabilize the copings against rotation during analogue fastening and to control the relationship between implants in a rigid manner. A simplified intraoral technique of splinting implant transfer copings with acrylic resin during impression procedures has been described (Dumbrigue, Gurun & Javid, 2000). Naconency, Teixeira, Shinkai *et al*. (2004) found the direct splinted technique was the most accurate transfer method for multiple abutments compared to direct non-splinted and indirect techniques. However, clinically implants placed in the maxillary arch are often placed nonparallel to each other. The removal of rigidly splinted impression copings may be impossible, thereby necessitating the use of nonsplinted impression copings. The present study showed no difference between the splinted and unsplinted techniques. It may well be that an impression material such as the Impregum polyether used in this study has properties ideally suited to coping transfer, and may therefore provide adequate rigidity to prevent rotation of the square transfer coping during analogue fastening and cast formation. For all practical purposes the extra time and complication involved in the fabrication of the resin splint may not be necessary and the non-splinted direct (square impression copings) technique can be recommended for use clinically. Future investigations could compare the accuracy when an adhesive is applied to the copings as this would be easier and faster to perform than luting with acrylic resin.

CONCLUSION

The three-dimensional accuracy of three impression techniques was investigated. These included tapered, square alone and square copings with an acrylic resin splint. Using a Reflex Microscope, the three different impression techniques were evaluated for their ability to reproduce abutment positions from a master model onto experimental stone casts. Under the conditions of this study the direct coping transfer techniques provided better results compared to indirect coping transfers in stone cast fabrication. The inaccuracies observed with the tapered coping technique may limit its usefulness.

Declaration: No conflict of interest was declared

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